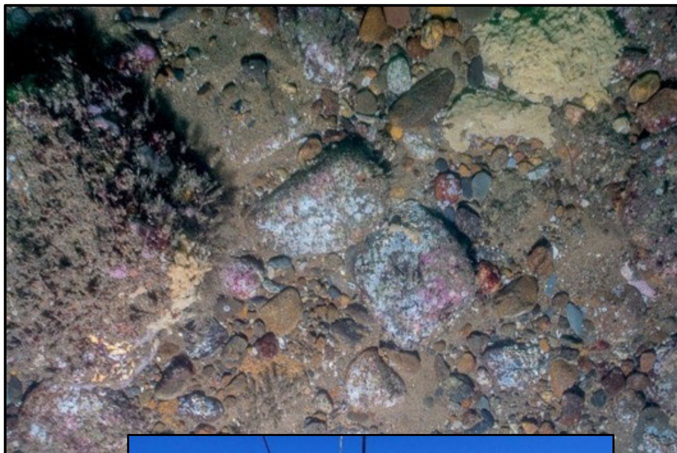
Revolution Wind
Fisheries Research and Monitoring Plan

May 2023



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ACCOL	Anderson Cabot Center for Ocean Life
AIC	Akaike Information Criteria
AIS	Automatic Identification System
AC	Alternating current
ANOSIM	Analysis of Similarities
ANOVA	Analysis of Variance
aRPD	apparent redox potential discontinuity
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
CFR	Code of Federal Regulations
CI	Confidence Interval
CPUE	Catch per Unit Effort
cm	centimeter
CMECS	Coastal and Marine Ecological Classification Standard
CPUE	Catch per unit effort
CTD	Conductivity Temperature Depth
CV	Coefficient of Variation
DMF	Division of Marine Fisheries
DSLR	Digital single-lens reflex
DVR	Digital video recorder
ECDF	Empirical Cumulative Distribution Function
EFH	Essential Fish Habitat
EFP	Exempted Fishing Permit
EMF	electromagnetic fields
ESA	Endangered Species Act
FAB	Fisheries Advisory Board
FGDC	Federal Geographic Data Committee
FMP	Fisheries Monitoring Plan
ft	feet

GLM	Generalized Linear Model
GAM	Generalized Additive Model
GPS	Global Positioning System
HD	High definition
HMS	Highly migratory species
HVTC	High voltage direct current
IAC	Inter-Array Cable
ICF	Interconnection Facility
INSPIRE	INSPIRE Environmental, LLC
IT IS	Integrated Taxonomy Information System
kg	kilogram
km	kilometer
kV	kilovolt
LED	Light-emitting diode
LOA	Letter of Acknowledgement
LPIL	Lowest possible identification level
MADMF	Massachusetts Division of Marine Fisheries
MA/RI WEA	Massachusetts/Rhode Island Wind Energy Area
MATOS	Mid-Atlantic Telemetry Observation System
MBES	Multibeam Echosounder
m	meter
mi	mile
mm	millimeter
MMPA	Marine Mammal Protection Act
NEAMAP	Northeast Area Monitoring and Assessment Program
NEFOP	Northeast Fisheries Observer Program
NEFSC	Northeast Fisheries Science Center
nMDS	Non-metric Multidimensional Scaling
NMFS	National Marine Fisheries Service
NMFS-PRD	National Marine Fisheries Service Protected Resources Division
NOAA	National Oceanic and Atmospheric Administration
NYSERDA	The New York State Energy Research and Development Authority
Ocean SAMP	Ocean Special Area Management Plan

OCS	Outer Continental Shelf
OnSS	Onshore Substation
OSS	Offshore Substation
OSW	Offshore Wind
PERMANOVA	Permutational Analysis of Variance
PV	Plan View
QA/QC	Quality Assurance/Quality Control
REFE	Reference Area East
REFS	Reference Area South
RI CRMC	Rhode Island Coastal Resources Management Council
RIDEM	Rhode Island Department of Environmental Management
RIVTS	RIDEM DMF Ventless Trap Survey
ROSA	Responsible Offshore Science Alliance
ROV	Remotely Operated Vehicle
RPD	Redox potential discontinuity
R/V	Research Vessel
RWEC	Revolution Wind Export Cable
RWEC–OCS	Revolution Wind Export Cable – Outer Continental Shelf
RWEC–RI	Revolution Wind Export Cable – Rhode Island State Waters
RWF	Revolution Wind Farm
SFW	South Fork Wind
SIMPER	Similarity Percentages
SNECVTS	Southern New England Cooperative Ventless Trap Survey
SOD	Sediment oxygen demand
SPI	Sediment Profile Imaging
SS	Systematic (random) sampling
SSS	Side-Scan Sonar
UHD	Ultra-High Definition
USBL	Ultra Short Baseline
VMS	Vessel Monitoring System
VTR	Vessel Trip Report
VTS	Ventless Trap Survey
WTG	Wind Turbine Generators

1.0 Introduction

Revolution Wind, LLC (Revolution Wind), a 50/50 joint venture between Orsted North America Inc. (Orsted)1 and Eversource Investment, LLC (Eversource), proposes to construct and operate the Revolution Wind Farm Project (hereinafter referred to as the Project). The wind farm portion of the Project will be located in federal waters on the Outer Continental Shelf (OCS) in the designated Bureau of Ocean Energy Management (BOEM) Renewable Energy Lease Area OCS-A 0486 (Lease Area) (Figure 1)2. The Lease Area was awarded through the BOEM competitive renewable energy lease auction of the Wind Energy Area off the shores of Rhode Island and Massachusetts (MA/RI WEA). Other components of the Project will be located in state waters of Rhode Island and onshore in North Kingstown, Rhode Island. The Project will specifically include the following offshore and onshore components:

Offshore:

- up to 100 Wind Turbine Generators (WTGs) connected by a network of Inter-Array Cables (IAC);
- up to two Offshore Substations (OSSs) connected by an OSS-Link Cable; and
- up to two submarine export cables (referred to as the Revolution Wind Export Cable [RWEC]), generally co-located within a single corridor.

Onshore:

- a landfall location located at Quonset Point in North Kingstown, Rhode Island;
- up to two underground transmission circuits (referred to as the Onshore Transmission Cable), co-located within a single corridor; and
- a new Onshore Substation (OnSS), Interconnection Facility (ICF) and associated interconnection circuits located adjacent, and connecting to, the existing Davisville Substation in North Kingstown, Rhode Island.

The Project's components are grouped into four general categories: the Revolution Wind Farm (RWF), inclusive of the WTGs, OSSs, IAC, and OSS-Link Cable; the RWEC–OCS, inclusive of up to 25 miles (mi) (40 kiometers [km]) of the RWEC in federal waters; the RWEC–RI State Waters, inclusive of up to 23 mi (37 km) of the RWEC in state waters; and Onshore Facilities, inclusive of a Landfall Work Area, the Onshore Transmission Cable, and new OnSS and ICF (including associated interconnection circuits). Also, Figure 1 depicts the RWF Envelope and RWEC Envelope areas, which are based on the extent of geophysical data collection and indicate the area within which offshore Project infrastructure will be sited; seafloor impacts (including from vessel anchoring) will not extend beyond these areas. Revolution Wind assumes that all state and federal permits will be issued between Q1 and Q3 2023. Construction will begin as early as Q1 2023, beginning with the installation of the onshore components and initiation of seabed preparation activities (clearing of debris and obstructions).

This Fisheries Monitoring Plan (FMP) has been developed in accordance with recommendations set forth in "Guidelines for Providing Information on Fisheries for Renewable Energy Development

[1] Note that in October 2018, Deepwater Wind LLC was acquired by Orsted North America Inc.

[2] On January 10, 2020, a request was made to BOEM to segregate Lease Area OCS-A 0486 to accommodate both the Revolution Wind Farm Project and South Fork Wind Farm Project. The Revolution Wind Farm Project retained lease number OCS-A 0486 while a new lease number was assigned for the SFWF Project (OCS-A 0517).

on the Atlantic Outer Continental Shelf" (BOEM 2019a), which state that a fishery survey plan should aim to:

- Identify and confirm which dominant benthic, demersal, and pelagic species are using the project site, and when these species may be present where development is proposed;
- Establish a pre-construction baseline which may be used to assess whether detectable changes associated with proposed operations occurred in post-construction abundance and distribution of fisheries;
- Collect additional information aimed at reducing uncertainty associated with baseline estimates and/or to inform the interpretation of research results; and
- Develop an approach to quantify any substantial changes in the distribution and abundance of fisheries associated with proposed operations.

Further, BOEM provides guidance related to specific survey gears that may be used to complete the fisheries monitoring including otter trawl, beam trawl, gillnet/trammel net, and ventless traps. BOEM guidelines stipulate that two years of pre-construction monitoring data are recommended, and that data should be collected across all four seasons. Consultations with BOEM and other agencies are encouraged during the development of fisheries monitoring plans. BOEM also encourages developers to review the existing data, and to seek input from the local fishing industry to select survey equipment and sampling protocols that are appropriate for the area of interest.

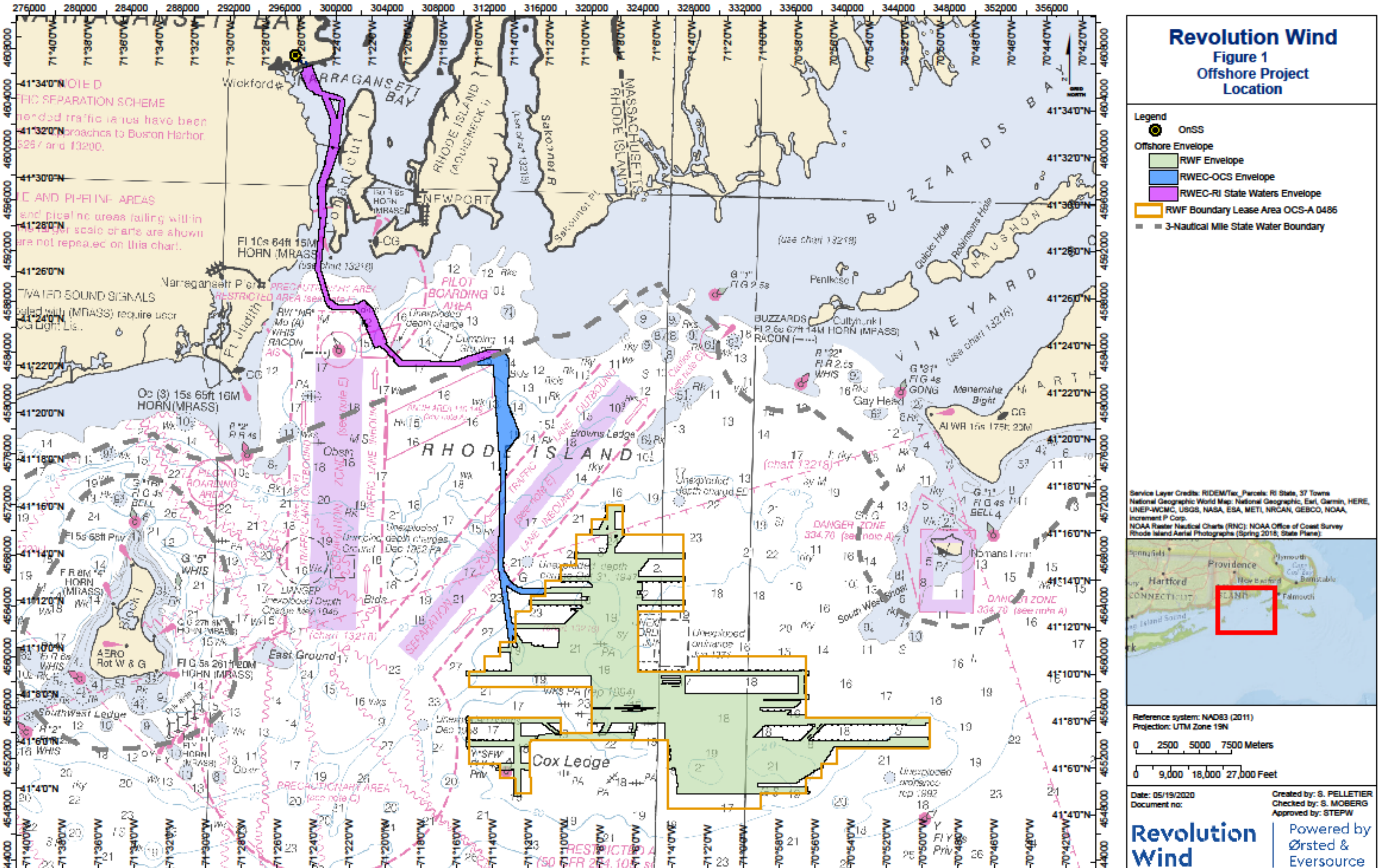


Figure 1. Map of the Project Area, including the Export Cable route

The Rhode Island Coastal Resources Management Council (RI CRMC) also set out monitoring guidelines as part of the Rhode Island Ocean Special Area Management Plan (Ocean SAMP; RICRMC 2010) which stipulate that RI CRMC shall work in conjunction with the Joint Agency Working Group to "determine requirements for monitoring prior to, during, and post construction. Specific monitoring requirements shall be determined on a project-by-project basis and may include but are not limited to the monitoring of: coastal processes and physical oceanography, underwater noise, benthic ecology, avian species, marine mammals, sea turtles, fish and fish habitat, commercial and recreational fishing, recreation and tourism, marine transportation, navigation and existing infrastructure, and cultural and historic resources." Further guidance from the RI CRMC (McCann et al. 2013) dictates that "[t]his assessment shall examine the relative abundance, distribution, and different life stages of these species at all four seasons of the year. This assessment shall comprise a series of surveys, employing survey equipment and methods that are appropriate for sampling finfish, shellfish, and crustacean species at the project's proposed location. Such an assessment shall be performed at least four times: pre-construction (to assess baseline conditions); during construction; and at two different intervals during operation. At each time this assessment must capture all four seasons of the year. This assessment may include evaluation of survey data collected through an existing survey program, if data are available for the proposed site."

This FMP was developed through an iterative process, and the survey protocols and methodologies were refined and updated based on feedback received from stakeholder groups. Revolution Wind met with numerous regulatory agencies and stakeholders during the development of this plan including; National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Bureau of Ocean Energy Management, Rhode Island Coastal Resources Management Council, Rhode Island Department of Environmental Management Division of Marine Fisheries, Massachusetts Division of Marine Fisheries, Massachusetts Office of Coastal Zone Management, and representatives from the Responsible Offshore Science Alliance and the Responsible Offshore Development Alliance.

Several revisions to the FMP were made based on the feedback received during meetings with agency staff. Power analyses were developed for both the trawl survey (Appendix 2) and the ventless trap survey (Appendix 3), and the power analyses were informed by an examination of contemporary fisheries independent data collected in proximity to the RWF. Cumulative prey curves were derived from the Block Island Wind Farm trawl survey data and used to determine the target sample sizes for stomach content analyses for the trawl survey. A distance-based sampling element was added to the plan for lobsters and Jonah crabs during the post-construction phase of the project, and additional protocols were added to better delineate the habitats at the RWF and reference areas. The proposed biological sampling protocols for lobsters and crabs were also modified to be consistent with the sampling protocols used by state agencies during their ventless trap surveys. The acoustic telemetry monitoring was also added to the monitoring plan in response to agency feedback, and the acoustic telemetry monitoring will allow for the examination of cause-effect relationships for Highly Migratory Species at the RWF and elsewhere in the MA/RI WEA. Following consultation with staff at the National Marine Fisheries Service (NMFS) Protected Resources Division several measures were added to the FMP to minimize the potential for interactions with protected species. Distance based sampling elements were incorporated into the sampling protocols for the benthic monitoring plan. Finally, at the request of agency scientists we have proposed to host annual workshops to better disseminate the monitoring results to local stakeholders, particularly members of the fishing industry.

Revolution Wind is committed to conducting sound, credible science using the following guiding principles:

- 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
- Maintaining data confidentiality for sensitive fisheries dependent monitoring data

2.0 Summary of Regional Fisheries Monitoring

Fishery dependent and independent data were considered throughout the development of this FMP. There are several longstanding fishery independent surveys in the vicinity of the Lease Area and along the RWEC which provide a time-series of information that can be used to characterize the regional fish and invertebrate communities prior to the start of offshore construction. In addition, several recent case studies provide high-resolution fisheries independent data for the Wind Energy Areas of southern New England. This section provides a brief synopsis of relevant fisheries-independent monitoring.

Data collected during the Northeast Fisheries Science Center (NEFSC) bottom trawl survey between 2003 and 2014 were synthesized to provide an overview of the species composition in each WEA (Guida et al. 2016). In the MA/RI WEA, little and winter skate were the dominant taxa across all seasons (Guida et al. 2016). Ocean pout, Atlantic herring, windowpane flounder, longhorn sculpin, and yellowtail flounder were dominant taxa during the cold season (i.e., winter and spring surveys), while longfin squid, scup, butterfish, northern sea robin, sea scallops, and spiny dogfish were dominant taxa during the fall surveys (Guida et al. 2016). Within the MA/RI WEA, black sea bass, Atlantic cod, ocean quahog, and sea scallops were noted as species that are commonly present and vulnerable to disturbance from the construction and operation of offshore wind farms. Friedland et al (2021) combined catch data from the NEFSC bottom trawl survey (1976-2018) with a suite of oceanographic data to create species distribution models that quantified the reliance of several species on habitats within wind energy lease areas.

Seasonal trawl surveys conducted by the Massachusetts Division of Marine Fisheries (MADMF) and the Rhode Island Department of Environmental Management (RIDEM) provide a time-series of relative abundance for fish and invertebrate resources in the nearshore waters of southern New England. Trawl surveys have also been carried out in Narragansett Bay for decades by the University of Rhode Island and RIDEM. The Northeast Area Assessment and Monitoring Program (NEAMAP) biannual trawl survey conducts sampling each spring and fall in shallow nearshore waters from Cape Hatters northward to Block Island Sound (Bonzek et al. 2017). Much of the information from these fishery-independent surveys is available through the Northeast Ocean Data Portal (http://www.northeastoceandata.org/). The Northeast Ocean Data Portal offers broad geographic coverage, enabling a characterization of the fish and invertebrate resources that may be present in the Lease Area, and also along the RWEC.

Walsh and Guida (2017) sampled during the spring within the MA/RI WEA using a two-meter (m) beam trawl and an otter trawl net (NEAMAP trawl survey) and compared the relative abundance, species composition, and length frequency distributions of fish and shellfish that were collected with each sampling gear. The beam trawl more effectively sampled juvenile and smaller fish and invertebrate prey species, while the otter trawl sampled a greater proportion of commercially important demersal and pelagic species. Walsh and Guida (2017) recommended that sampling occur throughout the year to characterize seasonal variation in the species assemblage and suggested that sampling with multiple gear types may provide a more holistic understanding of the fish and invertebrate community.

The Southern New England Cooperative Ventless Trap Survey (SNECVTS) was funded by BOEM to collect pre-construction information on the relative abundance, demographics and distribution of lobster and Jonah crab in the MA/RI WEA (Collie and King 2016). The lease areas were divided into sampling blocks, and sample locations were selected at random within each sampling block. Catches were processed using sampling protocols consistent with the Atlantic States Marine Fisheries Commission (ASMFC) protocols. Sampling occurred from May through November in 2014 and 2015, and another season of sampling occurred in 2018 (Collie and King 2016; http://www.cfrfoundation.org/sencvts). This survey provided high-resolution information on the relative abundance and spatial and temporal distribution of lobsters and Jonah crab within the MA/RI WEA and collected valuable information on important demographic parameters including sex ratios, shell disease, egg state and cull status.

From December 2015 through April 2016 Siemann and Smolowitz (2017) used scallop dredge surveys to characterize the distribution and habitat preferences of monkfish and flatfish in the southern New England lease areas and used video cameras mounted to a benthic sled to map habitat characteristics. Catches observed in the dredge survey were compared to samples from the NEFSC spring bottom trawl survey (2011 through 2015).

Malek (2015) used beam trawl and otter trawl survey tows, along with acoustics and seafloor video surveys to evaluate the fine-scale spatial structure of the demersal fish and invertebrate community in Block Island and Rhode Island Sounds. This study documented persistent seasonal variability in the fish and invertebrate community, illustrating the need for year-round monitoring to document the potential impacts from offshore wind development. Further, distinct species assemblages were identified, which were influenced by a combination of physical, oceanographic, and biological factors. This study identified summer flounder, silver hake, black sea bass, American lobster, and sea scallops as indicator species that should be considered when assessing the potential impacts of offshore wind development.

Additional data sources that characterize the pre-construction community composition in the area include:

- Industry-based trawl surveys for yellowtail flounder (Valliere and Pierce, 2007; Cadrin et al. 2013a) and winter flounder (Cadrin et al. 2013b) in southern New England.
- Trawl surveys and ventless trap surveys conducted to assess the impacts of the Block Island Wind Farm (CoastalVision 2013; Wilber et al. 2018).
- Fisheries independent surveys for the sea scallop resource including drop camera surveys (Bethoney et al. 2018), dredge surveys (Hart 2015), and towed-camera surveys (NEFSC 2010).

MADMF identified a list of priority species that could be considered as key assessment indicators of cumulative biological impacts associated with wind farm development (MADMF 2018). Their priority list was developed with consideration given to several metrics including, but not limited to commercial value, abundance in fishery-independent surveys, vulnerability to construction, and essential fish habitat (EFH). The species identified by MADMF (2018) were Atlantic cod, yellowtail flounder, winter flounder, summer flounder, monkfish, ocean pout, red hake, black sea bass, longfin squid, scup, Jonah crab, lobster, ocean quahog, sea scallop, bluefin tuna, little skate, winter skate, and sharks. MADMF (2018) also recommended that a range prey species be investigated for cumulative impacts, including sand lance, Atlantic herring, menhaden, and Atlantic mackerel.

Petruny-Parker et al., (2015) used input from a range of stakeholders to identify sampling tools, research needs, and best practices for monitoring of offshore wind development. The authors noted that sampling should be completed in collaboration with the local fishing industry and should employ a variety of gear types to target a range of species that may be impacted. Their report also identified a list of priority species to be considered during research and monitoring that included alewife, American lobster, Atlantic cod, Atlantic herring, Atlantic sturgeon, black sea bass, blueback herring, bluefish, blue mussels, butterfish, haddock, Jonah crabs, little/winter skates, longfin squid, mackerels, mako shark, menhaden, monkfish, ocean quahogs, pollock, red hake, sea scallops, scup, silver hake, spiny dogfish, striped bass, summer flounder, surf clams, thresher shark, tunas, winter flounder, and yellowtail flounder. Petruny-Parker et al., (2015) also highlighted the need for seasonal sampling prior to construction and recommended that two to three years of monitoring should occur prior to the commencement of offshore construction.

Regional monitoring studies have been recommended to better understand the cumulative impact of offshore wind development on marine resources and the fishing community, and there has been a call for developers to standardize their monitoring approaches to the extent practicable to help understand cumulative impacts of offshore wind development (McCann, 2012; MADMF 2018). While this FMP was developed with an emphasis on the species and fisheries that are most important to the Project Area, the monitoring tools and protocols described herein were selected to complement the regional monitoring described above, as well as planned and ongoing data collection efforts by Ørsted, other offshore wind developers, and state and federal agencies in the region.

3.0 Baseline Conditions

This section summarizes the existing conditions within the Lease Area and along the RWEC which were considered in development of this FMP. Complete detail regarding baseline conditions in the Lease Area and RWEC is available in the Project's Construction and Operations Plan (https://www.boem.gov/Revolution-Wind).

3.1 Habitat Considerations

Species with EFH designations for one or more life stages within the Lease Area and/or along the RWEC include the following[3]:

- New England Fish – Atlantic cod, Atlantic herring, wolfish, haddock, monkfish, ocean pout, pollock, red hake, silver hake, white hake, windowpane flounder, winter flounder, witch flounder, yellowtail flounder, little skate, and winter skate
- Mid-Atlantic Fish – butterfish, Atlantic mackerel, black sea bass, bluefish, scup, and summer flounder
- Invertebrates – sea scallop, Atlantic surfclam, longfin inshore squid, ilex squid, and ocean quahog
- Highly Migratory Species – albacore tuna, bluefin tuna, skipjack tuna, and yellowfin tuna
- Sharks – basking shark, blue shark, common thresher shark, dusky shark, sand tiger shark, shortfin mako shark, smoothhound shark complex, spiny dogfish, and white shark

3.2 Fishing Activity in The Region

Several fisheries and gear types operate in the RWF. From 2008 through 2019 the annual number of fishing trips that occurred within the RWF ranged from a low of 4,230 trips in 2019 to a high of 7,591 trips in 2008 (National Marine Fisheries Service[4]). Over the 12-year period from 2008 through 2019, the number of vessels that made at least one trip in the RWF ranged from 251 through 331. Fishing trips that occurred within the RWF lease area operated under several fishery management plans, with the summer flounder, scup, black sea bass being the most commonly represented FMP in the RWF lease area. Other fisheries management plans that commonly had active vessels within RWF during this time include: American lobster FMP, squid, mackerel, butterfish FMP, monkfish FMP, skate FMP, small-mesh multispecies FMP and the bluefish FMP. In 2019, the majority of trips within the RWF lease area were made by vessels with a home port in Pt. Judith, RI. Vessels from the following home ports made at least 100 trips within the RWF lease area in 2019: New Bedford, MA, Little Compton, RI, Newport, RI, Westport, MA and Menemsha, MA.

Commercial fishing activity in the RWF Project Area and along the RWEC was also characterized using Vessel Monitoring System (VMS) (e.g., Northeast Ocean Data Portal) and Vessel Trip Report (VTR) data, information provided in the Ocean SAMP (RICRMC 2010), through conversations with commercial fishermen, and based on input from Revolution Wind's fisheries liaisons.

[3] Technical Report - Essential Fish Habitat Assessment - Revolution Wind Offshore Wind Farm (boem.gov)
[4] https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/WIND/WIND_AREA_REPORTS/Revolution_Wind.html#select_gear_types

From 2009 through 2017, the bottom trawl fishery accounted for the highest revenue and landings in the RWF (Table 1). VMS data indicates that the majority of groundfish effort from 2011 to 2016 was concentrated in the western and northern portion of the RWF. Other fisheries that routinely operate in the RWF include the pot fishery for lobsters and crabs, the sink gillnet fishery, the scallop dredge fishery, and the midwater trawl fishery. VMS data indicated that fishing for monkfish was widespread throughout the RWF. The herring and pelagic (herring/mackerel/squid) fisheries primarily operated on the western and northern portions of the RWF. Likewise, the dredge fisheries for surfclams and ocean quahogs primarily operated in the western and northern portions of the RWF. As with the other mobile gear fisheries, the scallop dredge fishery primarily operated in the western portion of the Lease Area, although there were also some small areas of high fishing effort along the southern border of the Lease Area, adjacent to the South Fork Wind Farm Project lease area. Spatial information on lobster effort is more limited due to a lack of VMS or Automatic Identification System (AIS) requirements, but the Ocean SAMP documents indicate that fixed gear if fished throughout the MA/RI WEA (RICRMC 2018). The for-hire recreational fishery mainly operates in the southwest portion of the MA/RI WEA, including Cox Ledge (RICRMC 2018). It is noted that fisheries dependent data is heavily influenced by fisheries management, including temporal and spatial closures that are designed to limit fishing mortality, protect sensitive habitats or activities (e.g., spawning) or fulfill another management objective. Therefore, the fisheries dependent data summarized within this section cannot be considered to be wholly representative of the underlying abundance and availability of species within the lease area, or along the cable route.

Table 1. A summary of federal VTR data, by gear type, for vessels fishing in the in the RWF area from 2009 to 2017 (INSPIRE Environmental 2020[5]).

	Annual Average Revenue and Landings from within RWF		Annual Average of Total Revenue and Landings		Percent of Total Gear Values from RWF	
Gear	Revenue	Landings	Revenue	Landings	% of Revenue	% of Landings
Bottom Trawl	330,811	805,298	10,345,534	17,650,034	3.20	4.56
Pot	309,044	97,245	45,170,421	23,622,011	0.68	0.41
Sink Gillnet	263,817	383,264	4,587,604	6,446,946	5.75	5.95
Dredge	174,324	20,636	35,344,833	15,083,131	0.49	0.14
All Others	45,641	380,191	1,630,016,690	1,281,322,761	<0.01	0.03
Midwater Trawl	25,900	259,659	2,388,786	19,750,762	1.08	1.32
By Hand	5,776	1,652	566,211	236,037	1.02	0.70

Source: NOAA Fisheries, 2019c.
Notes:
Values are sorted from largest to smallest revenue values for landings data.
Landings are reported in landed pounds.
Revenue is in USD deflated to 2010 for consistency.
"Total" revenue and landings values refer to all fishing activity as reported by VTRs for fisheries active in state and federal waters from Maine to North Carolina.
% = percent

Based on federal VTR data the species that generated the most revenue and landings to the fisheries operating in the RWF from 2009 to 2017 are summarized in Table 2. Lobsters accounted for the greatest revenue across this time period. Aside from lobsters, the species that provided the greatest revenue in the RWF Project Area were flatfish, hakes, Atlantic herring, scup, black sea bass, and squid.

[5] Commercial and Recreational Fisheries Technical Report - Revolution Wind Offshore Wind Farm (boem.gov)

Table 2. A summary of federal VTR data, by species, for vessels fishing in the in the RWF area from 2009 to 2017 (INSPIRE Environmental 2020).

	Annual Average Revenue and Landings from within RWF		Annual Average of Total Revenue and Landings		Percent of Total Species Values in RWF	
Species	Revenue	Landings	Revenue	Landings	% of Revenue	% of Landings
Lobster, America	214,904	50,374	507,710,672	138,232,706	0.04	0.04
Flounders	88,240	33,976	53,080,045	23,015,911	0.17	0.15
Hakes	60,136	141,855	15,760,216	20,652,426	0.38	0.69
Herring, Atlantic	42,852	455,959	26,499,546	166,320,214	0.16	0.27
Scup	36,987	63,108	9,280,444	14,364,599	0.40	0.44
Squids	34,084	30,416	38,571,711	48,152,606	0.09	0.06
Sea Bass, Black	32,211	7,547	8,045,522	2,477,656	0.40	0.31
Whelk, Channeled	31,673	4,512	7,175,012	1,232,408	0.44	0.37
Mackerel, Atlantic	20,008	198,560	3,889,243	16,596,797	0.51	1.20
Dogfish, Spiny	14,296	81,592	3,619,191	18,787,974	0.40	0.43
Crab, Jonah	14,121	23,578	10,983,269	14,424,939	0.13	0.16
All Others	11,886	21,067	946,435,275	407,953,101	0.00	0.01
Butterfish	9,141	16,100	2,180,724	3,340,689	0.42	0.48
Bass, Striped	4,425	1,131	18,797,974	5,984,307	0.02	0.02
Bluefish	2,811	5,382	2,796,095	4,627,112	0.10	0.12
Tautog	381	128	926,176	273,651	0.04	0.05
Weakfish	263	142	319,712	207,805	0.08	0.07
Dogfish, Smooth	231	464	976,231	2,039,068	0.02	0.02
Bonito	191	86	112,986	53,480	0.17	0.16
Cunner	138	97	20,410	6,394	0.68	1.52
Spot	88	175	3,139,254	2,828,116	<0.01	0.01
Eel, Conger	40	61	49,241	68,105	0.08	0.09
Sea Robins	13	33	20,812	124,470	0.06	0.03
Whiting, King	1	1	902,941	810,033	<0.01	<0.01

Source: NOAA Fisheries, 2019c. ACCSP, 2019.
Notes:
Values are sorted from largest to smallest revenue values for landings data.
Landings are reported in landed pounds.
Revenue is in USD deflated to 2010 for consistency.
"Total" revenue and landings values refer to all fishing activity as reported by VTRs for fisheries active in state and federal waters from Maine to North Carolina.
% = percent

Based on federal VTR data, fishing vessels from Rhode Island and Massachusetts accounted for the majority of landings and revenue from the RWF area between 2009 and 2017 (Table 3).

Table 3. A summary of federal VTR data, by state, for vessels fishing in the in the RWF area from 2009 to 2017 (INSPIRE Environmental 2020).

	Annual Average Revenue and Landings from within RWF		Annual Average of Total Revenue and Landings		Percent of Total State Values in RWF	
State	Revenue	Landings	Revenue	Landings	% of Revenue	% of Landings
Rhode Island	613,467	949,843	83,808,376	83,061,985	0.73	1.14
Massachusetts	398,575	811,785	547,819,893	272,427,302	0.07	0.30
New York	41,704	24,420	53,395,207	30,909,690	0.08	0.08
All Others	16,773	9,274	558,828,937	725,429,171	<0.01	<0.01
Connecticut	9,138	7,218	16,183,340	8,793,496	0.06	0.08

Source: NOAA Fisheries, 2019c. ACCSP, 2019.
Notes:
Values are sorted from largest to smallest revenue values for landings data.
Landings are reported in landed pounds.
Revenue is in USD deflated to 2010 for consistency.
"Total" revenue and landings values refer to all fishing activity as reported by VTRs for fisheries active in state and federal waters from Maine to North Carolina.
% = percent

Several federally permitted fisheries are active along the RWEC route. The revenues and landings presented below were estimated using a 10 km-wide buffer around the RWEC, to provide a reasonable geographic extent for fisheries that may occur around the RWEC corridor. Based on VTR data, the gear types that generated the greatest revenues and landings along the RWEC were bottom trawl, mid-water trawl, pot, sink gillnet, dredge, and by hand (Table 4). VMS data indicate there was high density of effort from the northeast multispecies fishery along portions of the RWEC route, particularly in coastal areas near the southwestern portion of

Narragansett Bay. There are also areas of very high fishing activity for pelagic species (herring/mackerel/squid) along the RWEC route in coastal waters east of Narragansett and Point Judith. VMS data suggests there is little directed fishing for surf clams and ocean quahogs, and relatively low effort for sea scallops, along the RWEC route.

Table 4. A summary of federal VTR data, by gear type, for vessels fishing along the RWEC route from 2009 to 2017 (INSPIRE Environmental 2020).

	Annual Average Revenue and Landings from within RWEC Fisheries Study Corridor		Annual Average of Total Revenue and Landings		Percent of Total Gear Values in RWEC Fisheries Study Corridor	
Gear	Revenue	Landings	Revenue	Landings	% of Revenue	% of Landings
Bottom Trawl	781,301	2,186,189	10,345,534	17,650,034	7.55	12.39
Midwater Trawl	389,676	3,969,291	2,388,786	19,750,762	16.31	20.10
Pot	314,797	136,028	45,170,421	23,622,011	0.70	0.58
All Others	110,642	464,104	1,630,016,690	1,281,322,761	0.01	0.04
Sink Gillnet	99,834	213,070	4,587,604	6,446,946	2.18	3.31
Dredge	27,746	9,072	35,344,833	15,083,131	0.08	0.06
By Hand	3,293	1,356	566,211	236,037	0.58	0.57

Source: NOAA Fisheries, 2019c.
Notes:
Values are sorted from largest to smallest revenue values for landings data.
Landings are reported in landed pounds.
Revenue is in USD deflated to 2010 for consistency.
"Total" revenue and landings values refer to all fishing activity as reported by VTRs for fisheries active in state and federal waters from Maine to North Carolina.
% = percent

Herring generated the greatest revenue for federally permitted vessels fishing within the RWEC, followed by lobster, squid, flounders, and scup (Table 5). Federally permitted vessels with home ports in Rhode Island and Massachusetts accounted for the vast majority of landings and revenue within the RWEC (Table 6).

Table 5. A summary of federal VTR data, by species, for vessels fishing along the RWEC route from 2009 to 2017 (INSPIRE Environmental 2020).

	Annual Average Revenue and Landings from within RWEC Fisheries Study Corridor		Annual Average of Total Revenue and Landings		Percent of Total Species Values in RWEC Fisheries Study Corridor	
Species	Revenue	Landings	Revenue	Landings	% of Revenue	% of Landings
Herring, Atlantic	516,170	4,870,454	26,499,546	166,320,214	1.95	2.93
Lobster, America	253,817	63,112	507,710,672	138,232,706	0.05	0.05
Squids	168,823	157,838	38,571,711	48,152,606	0.44	0.33
Flounders	157,876	49,611	53,080,045	23,015,911	0.30	0.22
Scup	144,737	280,427	9,280,444	14,364,599	1.56	1.95
All Others	46,271	30,389	946,435,275	407,953,101	0.01	0.01
Butterfish	42,181	62,394	2,180,724	3,340,689	1.93	1.87
Hakes	37,112	86,198	15,760,216	20,652,426	0.24	0.42
Sea Bass, Black	27,692	7,820	8,045,522	2,477,656	0.34	0.32
Dogfish, Spiny	24,007	116,148	3,619,191	18,787,974	0.66	0.62
Bluefish	19,697	41,793	2,796,095	4,627,112	0.70	0.90
Mackerel, Atlantic	18,040	70,893	3,889,243	16,596,797	0.46	0.43
Whelk, Channeled	15,139	2,050	7,175,012	1,232,408	0.21	0.17
Crab, Jonah	14,732	28,633	10,983,269	14,424,939	0.13	0.20
Bass, Striped	12,950	3,528	18,797,974	5,984,307	0.07	0.06
Bonito	4,859	2,128	112,986	53,480	4.30	3.98
Tautog	3,728	1,495	926,176	273,651	0.40	0.55
Dogfish, Smooth	1,947	4,051	976,231	2,039,068	0.20	0.20
Weakfish	1,291	735	319,712	207,805	0.40	0.35
Whiting, King	986	1,132	902,941	810,033	0.11	0.14
Sea Robins	498	1,724	20,812	124,470	2.39	1.39
Tuna, Little	425	944	131,168	233,801	0.32	0.40
Eel, Conger	220	421	49,241	68,105	0.45	0.62
Cunner	106	49	20,410	6,394	0.52	0.77
Mackerel, Spanish	103	200	1,192,684	816,845	0.01	0.02
Whelk, Knobbed	101	64	1,041,479	647,789	0.01	0.01
Menhaden	51	309	35,974,035	410,014,306	<0.01	<.01
Sea Raven	45	37	2,734	2,213	1.65	1.67
Triggerfish	41	41	376,831	184,225	0.01	0.02
Eel, Species Not Specified	10	12	25	32	40.00	37.50
Sea Trout, Species Not Specified	0	141	592,033	273,277	0.00	0.05

Source: NOAA Fisheries, 2019c. ACCSP, 2019.
Notes:
Values are sorted from largest to smallest revenue values for landings data.
Landings are reported in landed pounds.
Revenue is in USD deflated to 2010 for consistency.
"Total" revenue and landings values refer to all fishing activity as reported by VTRs for fisheries active in state and federal waters from Maine to North Carolina.
% = percent

Table 6. A summary of federal VTR data, by state, for vessels fishing along the RWEC route from 2009 to 2017 (INSPIRE Environmental 2020).

	Annual Average Revenue and Landings from within RWEC Fisheries Study Corridor		Annual Average of Total Revenue and Landings		Percent of Total State Values in RWEC Fisheries Study Corridor	
State	Revenue	Landings	Revenue	Landings	% of Revenue	% of Landings
Rhode Island	1,216,027	2,928,234	83,808,376	83,061,985	1.45	3.53
Massachusetts	329,573	3,203,699	547,819,893	272,427,302	0.06	1.18
All Others	55,981	74,826	558,828,937	725,429,171	0.01	0.01
Maine	22,593	141,941	540,523,922	252,863,406	<0.01	0.06
New York	357	137	53,395,207	30,909,690	<0.01	<0.01

Source: NOAA Fisheries, 2019c. ACCSP, 2019.
Notes:
Values are sorted from largest to smallest revenue values for landings data.
Landings are reported in landed pounds.
Revenue is in USD deflated to 2010 for consistency.
"Total" revenue and landings values refer to all fishing activity as reported by VTRs for fisheries active in state and federal waters from Maine to North Carolina.
% = percent

A number of fisheries also occur in state waters along the RWEC route. In statistical area 539, the greatest landings by state-only permitted vessels from Rhode Island occurred in the pot and trap fisheries, followed by fixed nets, hook and line, otter trawls, and gillnets (Table 7). The species with the greatest landings by state-only permitted vessels from Rhode Island from 2009 through 2017 were scup, channeled whelk, menhaden, summer flounder, skates, striped bass, and black sea bass.

Table 7. A summary of landings, by statistical area, for state-only permitted vessels from Rhode Island from 2009 to 2017 (INSPIRE Environmental 2020).

	Average Pounds Landed per Year (2009-2018)			Total Pounds Landed (2009-2018)			Total Pounds Landed in Rhode Island State Waters (2009-2018)	% Pounds Landed out of Total Rhode Island State Waters, by Gear		
	Statistical Areas			Statistical Areas				Statistical Areas		
Gear Category	538	539	611	538	539	611		538	539	611
By Hand, Diving Gear		5,345			42,759		44,209		96.7	
By Hand, No Diving Gear		45,760			366,078		366,559		99.9	
Dip Nets		7,866			62,925		64,272		97.9	
Dredge		130			520		520		100.0	
Gill Nets		202,887			1,623,097		1,635,066		99.3	
Hand Line		2,242			17,939		18,297		98.0	
Hook and Line	359	388,116	13,033	1,795	3,881,157	117,301	4,013,013	<0.1	96.7	2.9
Long Lines		1,880			13,158		13,177		99.9	
Other Fixed Nets		540,644			4,325,156		4,325,177		100.0	
Other Trawls		32,655			195,930		195,930		100.0	
Otter Trawls		324,192			2,593,534		2,600,214		99.7	
Pots and Traps, Lobster		58,494	2,413		526,445	19,302	546,357		96.4	3.5
Pots and Traps, Other		14,249			128,238		128,274		100.0	
Pots and Traps		757,048	35,295		6,813,434	317,659	7,138,933		95.4	4.4
Rakes		4,629			32,405		32,428		99.9	
Spears		3,217			25,735		26,095		98.6	

Source: ACCSP, 2019.
Notes:
Values reflect pounds landed caught in statistical subareas relevant to RWF and RWEC.
Confidential information was redacted from the ACCSP data set.
Blank cells indicate those years when the fishing area had no reported landings or redacted confidential landings.
Average pounds landed were calculated as an arithmetic mean, using the sum of pounds landed and the count of distinct years, ignoring zero years.

4.0 Survey Methods

Revolution Wind will implement multiple fisheries monitoring surveys as part of this FMP. The first element of the monitoring plan is a trawl survey at the RWF and nearby reference areas. Two ventless trap surveys will be executed at the RWF. A Before-After-Control-Impact (BACI) ventless trap study will occur at the RWF and two nearby reference areas before, during, and after construction. In addition, a ventless trap survey will be executed within the RWF using a gradient design during the operational phase. A Before-After-Gradient (BAG) ventless trap survey will also be executed along the RWEC route in Rhode Island state waters during all three phases of the Project. An acoustic telemetry monitoring project, focused on blue sharks, bluefin tuna, and shortfin mako sharks will occur with the RWF, and other adjacent Ørsted lease sites during all three phases of the Project. Finally, a benthic monitoring plan focused on both soft-bottom and hard-bottom habitats will occur within the RWF and along the RWEC. The survey designs and protocols are described below. These surveys will occur in close collaboration with the local commercial fishing industry.

4.1 Trawl Survey

4.1.1 Survey Design

Revolution Wind is coordinating with scientists from the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST and the Commercial Fisheries Research Center (CFRF) to execute a seasonal (i.e., four sampling events per year, approximately three months apart) trawl survey using an asymmetrical BACI experimental design. The trawl survey will be conducted in collaboration with a commercial trawl vessel (likely the F/V Gabrielle Elizabeth) with extensive experience fishing in this region. An otter trawl survey is an appropriate sampling tool for the Lease Area because this gear can effectively sample several of the commercially important fish and invertebrate species present in the area. In addition, the trawl fishery is active within the RWF area, and this gear type generates the greatest revenue within the Lease Area (Table 1). The trawl survey will effectively sample for multiple species, including groundfish (e.g., winter flounder, windowpane flounder, yellowtail flounder, Atlantic cod), monkfish, skates (e.g., winter and little skates), red hake, longfin squid, and others.

In order to maximize the utility of the monitoring, the trawl survey will utilize the sampling gear and protocols of the NEAMAP survey. The use of standardized survey methods will allow the data collected at RWF and the reference areas to be evaluated at multiple spatial scales (e.g., project specific scale and regional scale) in conjunction with information obtained through other regional trawl surveys (e.g., NEFSC, NEAMAP, and Vineyard Wind trawl surveys).

The primary objective of the pre-construction monitoring is to investigate the relative abundance (i.e., kilogram [kg]/tow) of fish and invertebrate resources in the RWF Project Area ("RWF impact") and reference areas ("control") over time. The pre-construction trawl survey monitoring will also collect demographic information on fish and invertebrates including size structure, fish condition, diet, and reproductive status. The target is to complete two years of sampling (i.e., eight seasonal trawl surveys) prior to the commencement of offshore construction. Revolution wind intended to begin the trawl survey in the winter of 2021, but the survey has been delayed as the scientific team seek to obtain the necessary scientific research permits to carry out the survey. The survey will commence once the appropriate permits have been received. Sampling will continue during project construction, and a minimum of two years of monitoring will be completed following offshore construction. However, 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).

The primary objective of monitoring during construction and operation is to determine whether the construction and operational activities associated with the Project lead to a change in the relative abundance of fish and invertebrates within the Project Area. Another objective is to determine whether the construction and operational activities lead to a change in the demographics of these resources. The use of an asymmetrical BACI sampling design will allow for quantitative comparisons of relative abundance and demographics to be made before and after construction, and between the reference and RWF Project areas (Underwood 1992; Smith et al. 1993). Further, the replication of sampling across both time and space increases the ability to demonstrate that a change in abundance was caused by a human activity (Underwood 1992).

The sampling methodology and trawl gear were designed to be complementary to the NEAMAP trawl survey (Bonzek et al. 2008, 2017). By using the same sampling gear and protocols as the NEAMAP survey, the data collected through this monitoring effort can be more directly compared to fisheries-independent data collected across the broader region. NEAMAP trawl survey gear will also be employed within other Ørsted lease areas (e.g., Sunrise Wind and Ocean Wind), and South Fork Wind is also completing a trawl survey using a NEAMAP survey net along the South Fork Export Cable route in New York state waters. Further, to achieve consistency amongst developers, the survey methods and trawl net are consistent with the pre-construction data being collected by Vineyard Wind in their lease areas. To the extent practicable, concerted efforts will be made to ensure that the timing of the RWF trawl survey coincides with the NEFSC spring and fall bottom trawl surveys when the research vessel (R/V) Bigelow is operating in southern New England.

4.1.2 Sampling Stations

Benthic habitat data from Ørsted site investigation surveys were considered along with input from local fishermen to determine the areas within the RWF lease area that can be sampled safely and effectively using the NEAMAP trawl survey net. High-resolution geophysical surveys were conducted by Ørsted within the RWF and South Fork Wind (SFW) lease areas, and along the RWEC corridor, and these surveys located boulder fields throughout much of the southeastern and southwestern portion of the RWF lease site (Figure 2). Local fishermen also provided input that mobile gear fishing effort is primarily concentrated in the northern portion of the lease site, which is supported by VTR data from the otter trawl fleet in this region from 2011 through 2015 (Figure 3). Based on this information, it will not be feasible to safely and efficiently execute a trawl survey throughout the entire RWF lease area. Therefore, the RWF Project area for the trawl survey will be limited to the northern portion of the RWF lease area (Figure 4), which encompasses an area of approximately 125 km^2.

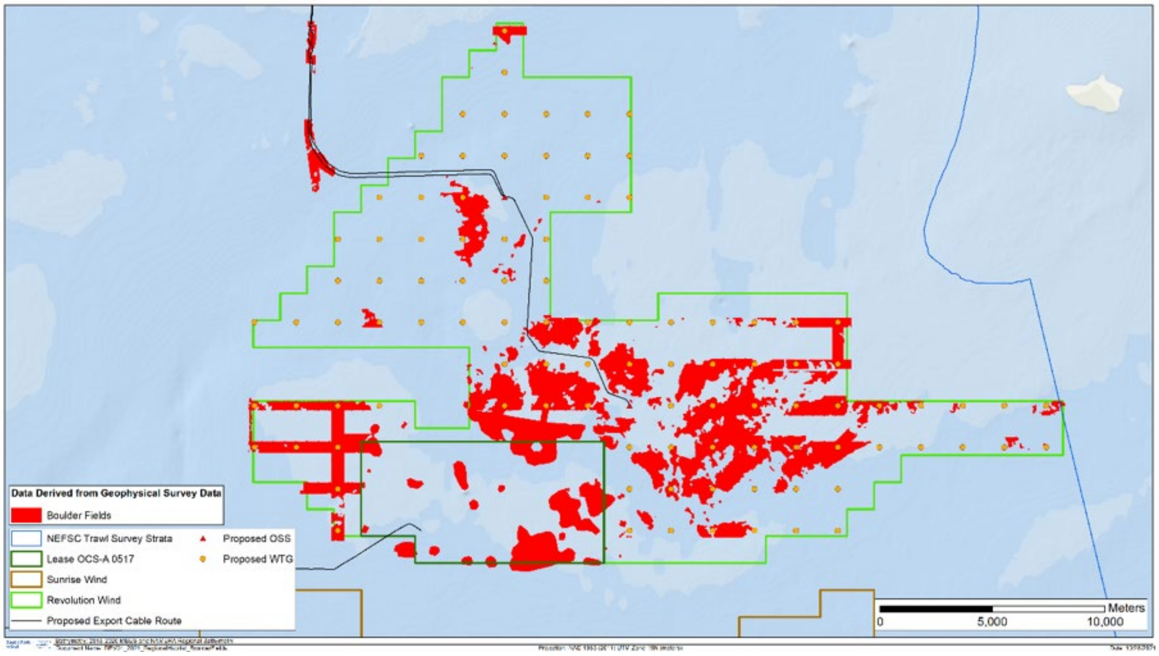


Figure 2. **Locations of boulder fields within the RWF and SFW lease sites, and along the RWEC corridor, that were mapped during high-resolution geophysical surveys conducted by Ørsted.**

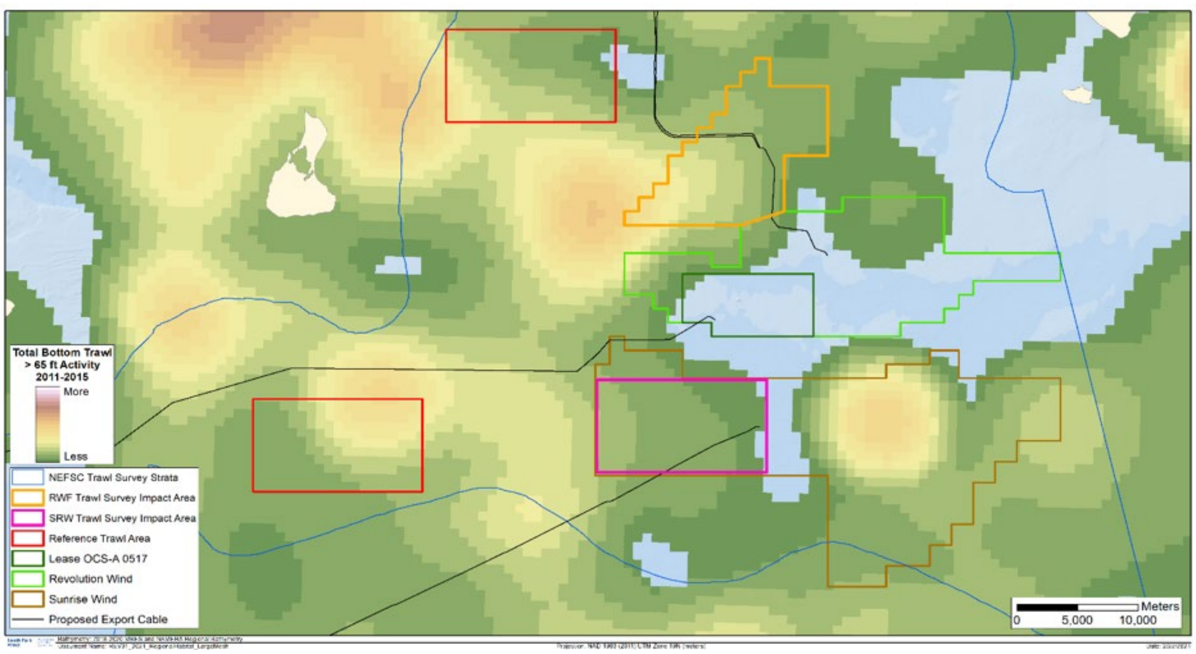


Figure 3. **VTR data from the large mesh trawl fishery (2011-2015) showing the distribution of fishing effort in the region for vessels >65 feet in length. VTR data was obtained from the Mid-Atlantic Ocean Data Portal[6].**

[6] https://portal.midatlanticocean.org/static/data_manager/metadata/html/CASMetadata.html

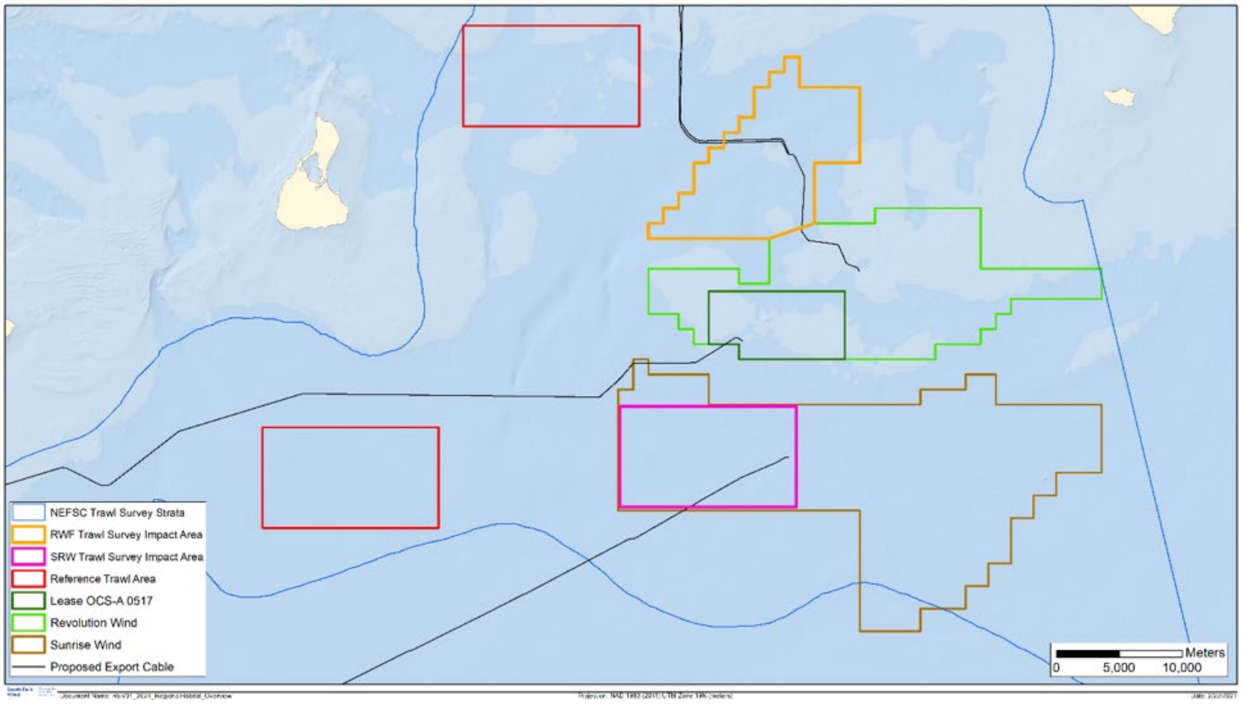


Figure 4. Location of the RWF lease site, the planned RWF Project area for the trawl survey (northern portion of RWF lease site, outlined in orange), and the location of the two planned reference areas (outlined in red).

The trawl survey will be executed using an asymmetrical BACI design, and trawl survey observations from the reference areas will serve as a regional indicator of relative abundance for fish and invertebrate species in a areas that are not currently being considered or other offshore wind development. Two reference areas (Figure 4) were selected after considering several sources of information. Firstly, the location of the RWF was evaluated relative to the survey strata used on the NEFSC trawl survey. The NEFSC trawl survey is the only regional trawl survey with spatial coverage that overlaps the RWF lease area, and the RWF lease area is located entirely within NEFSC trawl survey stratum 1050 (Figure 5). Stratum 1050 covers an area of approximately 5,213 km^2, and includes waters ranging from 27 to 55 m in depth (Politis et al. 2014). The entire RWF lease area is approximately 335 km^2, while the northern portion of the lease area where the trawl survey will occur is approximately 125 km^2. In an effort to maintain consistency with the stratification employed on the NEFSC survey, the reference areas were also sited within trawl survey 1050. Based on bathymetric data provided by the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010), the depth within the RWF trawl survey Project area ranges from 33 to 48 m, and the mean depth is 39 m (Figure 6). The depth within the northern reference area ranges from 21 to 41 m (mean depth = 36 m), while depths in the southern reference area range from 41 to 55 m (mean depth = 50 m). The location of the reference areas was also considered relative to the potential impacts from the construction and operation of the project. Of the potential project impacts, wind waken have the potential to occur at the greatest distance from the wind farm site. Christiansen et al (2022) predicted that wake effects may extend downstream of wind farms on a spatial scale of 10's of kilometers. However, the model predicted that the magnitude of wind wake effects are predicted to change rapidly as a function of distance from the wind farm (see Figure 5 in Christiansen et al., 2022), and predicted wake effects are expected to be strongest at the sea surface, with wake effects predicted to diminish quickly as a function of depth, with relatively little change in current speed predicted near the sea bed (see

Figure 6 in Christiansen et al., 2022). Given that the otter trawl and ventless trap studies are focused on sampling species with a demersal (or semi-demersal) life history, we contend that the influence of wind wake effects will have a negligible influence on catch rates at the control site, particularly given the background levels of seasonal and interannual variability associated with these stochastic populations.

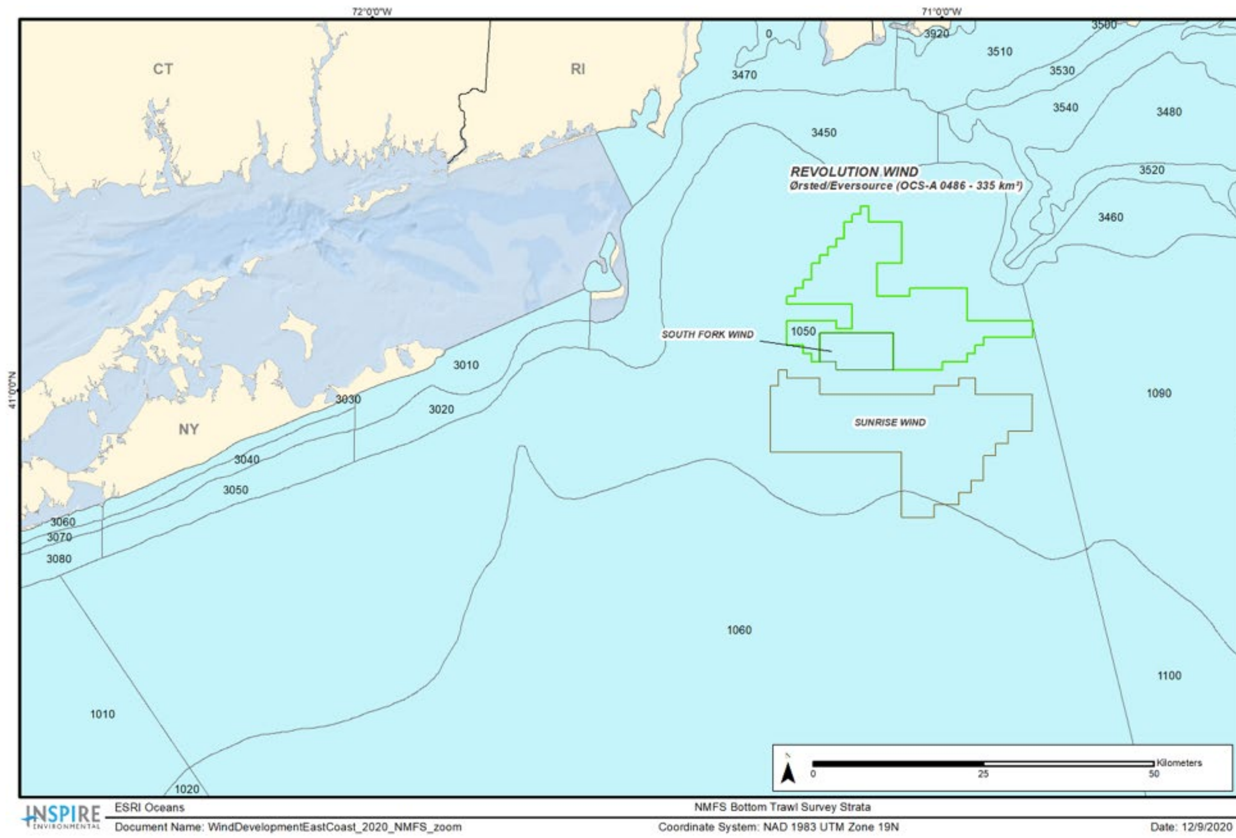


Figure 5. Location of the Revolution Wind, South Fork Wind, and Sunrise Wind lease sites relative to the survey strata used during the NEFSC bottom trawl survey. The Revolution Wind Farm lease area is located within NEFSC survey stratum 1050.

Consideration was also given to the benthic habitat present in the RWF Project area, and reference areas were selected with similar benthic habitats as the RWF Project area. Based on benthic habitat data provided from the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010), the substrates within the planned footprint of the RWF trawl survey are diverse and include: moderate flat sand, shallow depression sand, moderate depression sand, shallow depression gravel, moderate flat gravel, and high flat gravel (Figure 7), along with isolated boulder fields that were mapped during the Ørsted site investigation surveys (Figure 2). The benthic habitats within the northern reference area include: shallow depression gravel, moderate flat gravel, moderate flat sand, high flat gravel, and high flat sand. The habitats within the southern reference area are slightly less diverse, and are primarily comprised of shallow depression sand, moderate flat sand, and moderate depression sand.

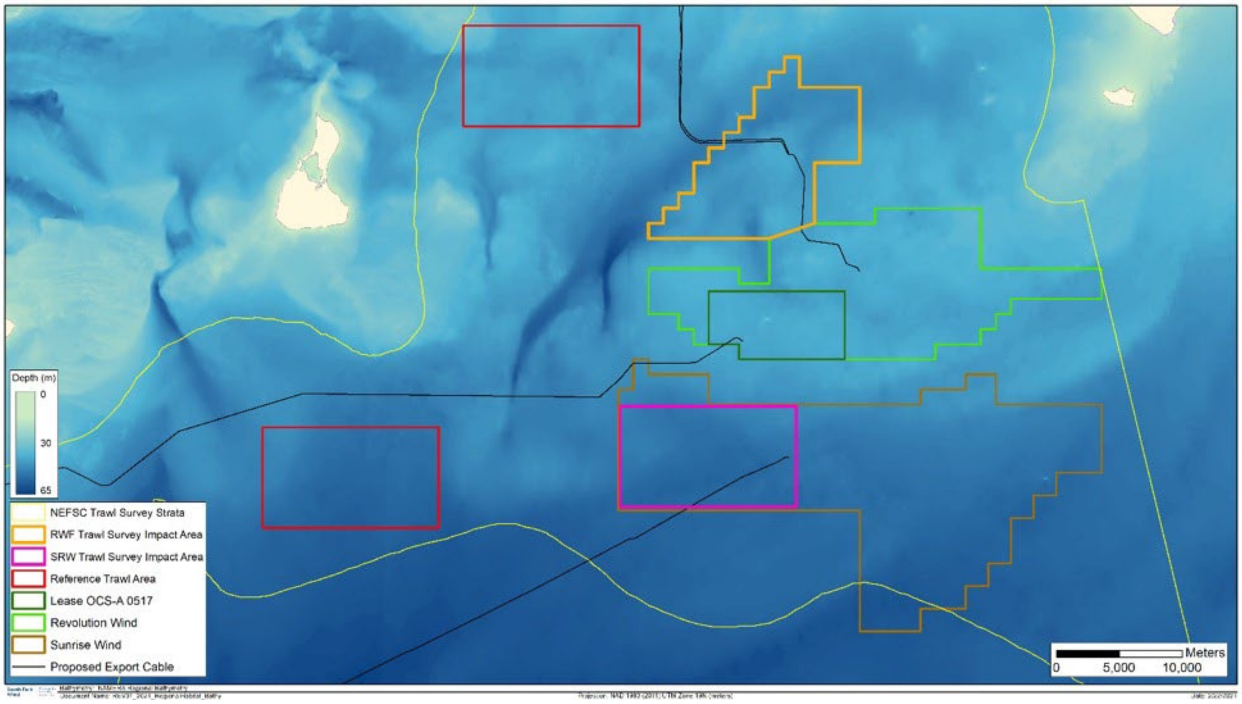


Figure 6. Bathymetric map of the RWF lease area and the planned reference areas for the trawl survey. Bathymetric data is shown in meters and was derived from the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010).

VTR data from 2011 to 2015 for trawl vessels >65 feet (ft) in length from the Mid-Atlantic Ocean Data Portal[7] indicate that a low to moderate amount of trawl activity occurred within the RWF trawl survey Project area. Similar amounts of trawling activity were generally observed within the northern and southern reference areas (Figure 3).

Care was also taken to ensure that the reference areas would not coincide with locations that are currently planned for future offshore wind development. Similarly, reference areas were not sited in locations that intersected with export cable routes. Modifications to the locations of the reference areas may be considered based on input received from the local fishing industry, as well as the scientific contractor or fishermen that are selected to execute the trawl survey.

[7] https://portal.midatlanticocean.org/static/data_manager/metadata/html/CASMetadata.html

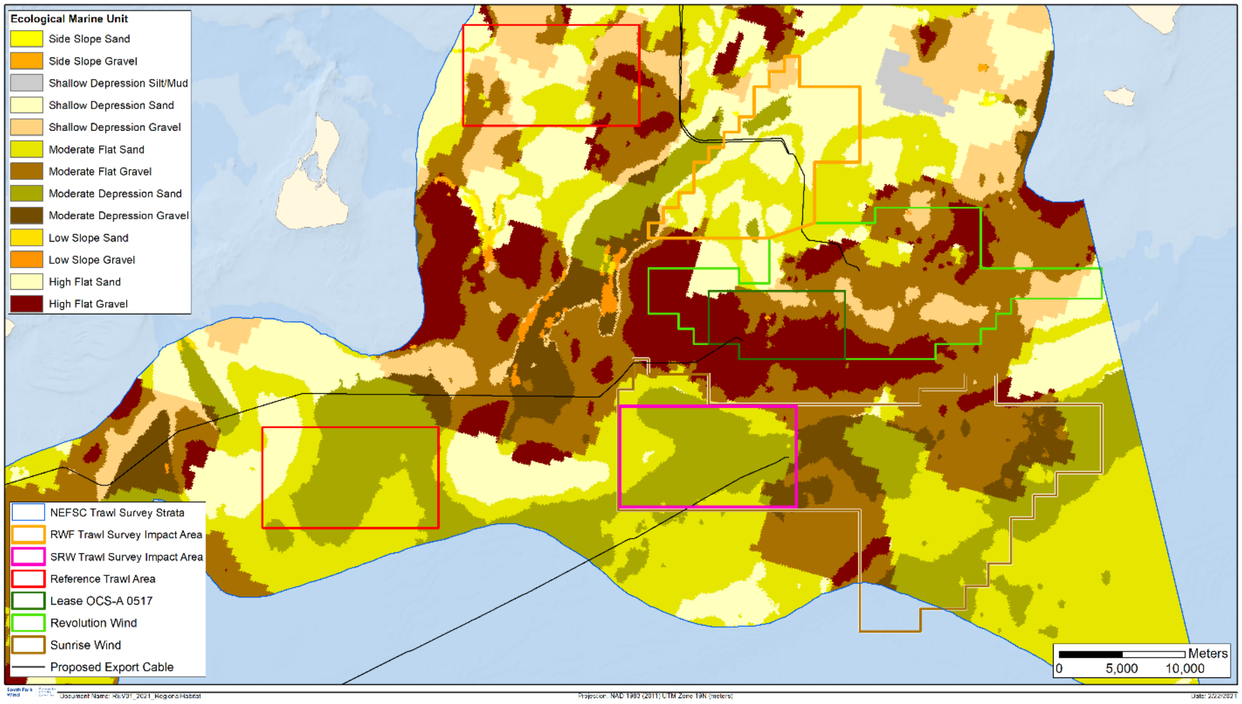


Figure 7. Benthic habitats within the RWF trawl survey footprint, and within the reference areas. Benthic habitat data was derived from the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010).

Consistent with the study design used by Vineyard Wind during their trawl survey, a spatially balanced design will be used to assign random tow locations within the RWF Project and reference areas during each seasonal survey. The RWF Project and reference areas will each be divided into 15 grid cells, and one randomly chosen location will be sampled within each grid cell during each seasonal trawl survey. The spatially balanced design will ensure that sampling effort is distributed throughout the RWF Project and reference areas. Within the RWF Project area and the reference areas, the sampling density associated with each seasonal survey will be one station per $8.3km^2$. The order in which the reference areas and the RWF trawl survey Project area are surveyed will be randomized prior to the start of each survey.

The location of trawl sampling stations may be subject to change due to the presence of fixed gear (e.g., lobster pots), or other factors that may preclude a randomly selected location from being sampled safely. Therefore, alternate sampling locations will be randomly chosen within each grid cell for each seasonal survey. If a primary sampling location is found to be untrawlable based on the captain's professional judgement, sampling will instead occur at one of the randomly selected alternate sampling locations. If any marine mammals are sighted in the vicinity of a trawl tow, sampling will be delayed at that location in order to minimize the risk of an interaction. Revolution Wind will work with the scientific contractor(s) and captain and crew of the trawl vessel(s) to evaluate whether activities associated with cable installation (e.g., cable cover), or other construction activities, will RWF impact the execution of the trawl survey after the RWF is constructed.

A power analysis was conducted using trawl survey data from the Block Island Wind Farm (BIWF) and NEFSC trawl survey datasets (Appendix 2). NEFSC trawl survey data from 2010 through 2018 were obtained from Phil Politis (personal communication), and only tows from Stratum 1050 were used to inform the power analysis. From 2010 through 2018, the NEFSC trawl survey sampled in the spring and fall. Therefore, monthly catch data from the two reference sites sampled during the BIWF trawl survey were also reviewed to determine the extent to which the seasonal NEFSC trawl survey captured intraannual biomass peaks for different species of interest. Power analysis represents the relationships among the four variables involved in statistical inference: sample size (N), effect size, and type I (α) and type II (β) error rates (Cohen 1992). Of primary interest for this study is the interaction between temporal and spatial variables, specifically the contrast between the temporal change at the RWF Project site and the average temporal change at the reference sites (Equation 2 in Appendix 2). Power curves were constructed to demonstrate how statistical power for the interaction contrast varies as a function of the variance in the catch data, the effect size (i.e., the percent change at the RWF Project site relative to the reference sites), sample size (i.e., number of trawl tows per area in each season), and the number of reference sites that are sampled (Figures 7-8 in Appendix 2). When analyzing for changes in relative abundance, we will aim to achieve a statistical power of at least 0.8, which is generally considered to be the minimum standard for scientific monitoring (Cohen 1992). This ensures that the monitoring will have a probability of at least 80% of detecting an effect of the stated size when it is actually present. A single alpha (0.10) was used for the power analysis, and the power analysis was completed assuming two years of pre-construction and post-construction monitoring will be completed.

A sample size of 15 trawl tows per area will be targeted per season in each year. Based on the results of the power analysis (Appendix 2, Figure 7), this level of sampling is expected to have at least 80% power to detect a 33% temporal decrease for those species with Coefficient of Variation (CVs) ≤ 1.2, and approximately a 40% temporal decrease for species with CVs ≤ 2.0. Further, the use of an asymmetrical BACI design, with two rather than one reference areas, leads to gains in power for a given level of sampling intensity in the RWF Project area (Appendix 3, see Figure 8). An examination of the NEFSC and BIWF trawl survey data indicates that most species exhibited moderate to high levels of interannual and intraannual (e.g., seasonal or monthly) variability in catch rates (Appendix 2, Figures 2-6 and Table 4). Given the magnitude of variability in catch rates that will likely be exhibited in the RWF trawl survey, it is not practicable to attempt to capture a small effect size (e.g., 25%) for fish and invertebrate species. Moreover, this power analysis assumes that the variance in the catch rates during the RWF trawl survey will be similar to the variance observed during the BIWF and NEFSC trawl surveys. Following the first year (i.e., four seasonal sampling events) of trawl survey data the observed variability will be calculated for abundant species in the catch. The achievable effect sizes will also be identified following the first year of the survey, once the realized magnitude of variability is better understood, and once regional guidance regarding target effect sizes has been formalized through ROSA. Given the predicted power of the study design for the anticipated magnitude of variability (i.e., range of CVs from 0.8 to 2.0), the sample sizes proposed for the first year of the trawl survey are robust.

The proposed seasonal sampling intensity equates to an annual sampling target of 180 tows per year across the RWF Project and reference areas. For comparative purposes, from 2010 through 2018, the NEFSC trawl survey completed four or five tows in Stratum 1050 during each spring and fall trawl survey (i.e., eight to ten tows per year).

4.1.3 Trawl Survey Methods

The scientific contractor that is selected to perform the monitoring will apply for a Letter of Acknowledgement (LOA) or an Exempted Fishing Permit (EFP) from National Oceanic and Atmospheric Administration (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 Code of Federal Regulations (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). Efforts will be taken to reduce marine mammal, sea turtle, and seabird injuries and mortalities caused by incidental interactions with fishing gear. For example, we will delay deploying trawl gear if marine mammals are sighted in the vicinity of the sampling station. 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 trawl survey will be carried out on a seasonal basis, with four surveys planned for each year. From 2010 through 2018 the NEFSC Spring survey sampled in stratum 1050 in March, April and May, while the NEFSC Fall trawl survey sampled stratum 1050 in September and October. In order to achieve temporal overlap with the NEFSC trawl survey, the seasons for the RWF trawl survey will be defined as follows:

- 'Winter' survey months: December, January, and February
- 'Spring' survey months: March, April, and May
- 'Summer' survey months: June, July, and August
- 'Fall' survey months: September, October, and November.

To the extent practicable, concerted efforts will be made to ensure that the timing of the RWF trawl survey coincides with the NEFSC spring and fall bottom trawl surveys when the R/V Bigelow is operating in southern New England. Within a seasonal sampling event, the replicate tows within the RWF Project and control areas will be completed within as few days as possible, given practical constraints imposed by weather or other factors (e.g., mechanical issues with vessel).

The trawl survey will be executed using the trawl net used for the VIMS NEAMAP trawl survey. The NEAMAP survey net is a 400 x 12 centimeter (cm) three-bridle four-seam bottom trawl, and the net is paired with Thyboron, Type IV 168 cm (66 inch [in]) trawl doors (Bonzek et al. 2017). Several aspects of the net design make it an appropriate tool for sampling a wide range of species and size classes. The trawl is designed to achieve a relatively large vertical opening, and the use of a 'flat sweep' (i.e., 8 cm (3 inches) cookie groundgear) allows that net to maintain close contact with the bottom and sample effectively for species that are closely associated with the benthos. A 2.5 cm (1 inch) knotless cod end liner will be used to sample marine taxa across a broad range of size and age classes.

Net mensuration equipment will be used during the survey to provide the captain and scientific crew with real-time information on door spread, wing spread, and headrope height. This information also allows the area swept (km^2) to be calculated for each tow, which is needed in order to estimate absolute abundance. In order to promote consistency amongst samples, we will work with the scientific contractor selected to execute the survey to establish a set of gear performance criteria to objectively compare the observed trawl geometry against the optimal geometry (e.g., Bonzek et al. 2017). The position, heading, and speed of the vessel will be monitored throughout each tow using a software program that is integrated with a Global Positioning System (GPS) unit (e.g., NEFSC Fisheries Logbooks Data Recording System, or similar). A temperature logger attached to the trawl net will be used to record bottom temperature continuously (e.g., every 30 seconds) during trawling.

Similar to the methods employed on the NEAMAP survey and other regional surveys (e.g., MADMF biannual trawl survey), all tows will be completed during daylight hours, and the target tow duration will be 20 minutes. The relatively short tow duration is also expected to minimize the potential for interactions with protected species and marine mammals. A target tow speed range of 2.9 to 3.3 knots will be used. The amount of wire set with each trawl to achieve the target net geometry will be left to the professional judgement of the captain, dependent upon the depth and the *in-situ* conditions.

Animals collected in each trawl sample will be sorted, identified to the species level, weighed, and enumerated consistent with the sampling approach of NEAMAP. Taxonomic guides that can be utilized to assist with species identification 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.* Species will be identified consistently with the Integrated Taxonomy Information System (ITIS). The following information will be collected for each trawl that is sampled; catch per unit effort (CPUE), species diversity, and size structure of the catch. All species captured will be documented for each valid trawl sample. If any protected species are captured during trawling, the sampling and release of those animals will take priority over sampling the rest of the catch. 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.

The biomass (weight, kg) of each species will be recorded on a motion-compensated marine scale that has been calibrated according to the manufacturer's specifications and used to calculate CPUE. Length will be recorded for the dominant species (i.e., most commonly encountered species), and priority species, in the catch. To assess the condition of individual organisms, up to 100 individuals of each species (and size class) will be measured (to the nearest cm) and weighed on a motion-compensated balance. Length (e.g., total length, fork length) will be recorded for each species consistent with the measurement type specified in the Northeast Observer Program Biological Sampling Guide. After sampling, all catch will be returned to the water as quickly as possible to minimize incidental mortality.

Biological samples will be collected for the commercial finfish species of primary interest in the reference and RWF Project areas. In order to be consistent with the regional trawl surveys, a length-stratified design will be used to ensure samples are collected across all size and age classes for each species. The following list of priority species will be considered for biological sampling, but the list may be modified based on input from regional stakeholders and feedback from the scientific contractor(s) selected to perform this work; Atlantic cod, American lobster, black sea bass, summer flounder, winter flounder, Atlantic herring, monkfish, and yellowtail flounder. Biological sampling will include measuring the length and weight of individuals, and macroscopic evaluation of sex and maturity stage consistent with the sex and maturity classification used by the Northeast Fisheries Science Center (Burnett et al. 1989). Sex and maturity stage collected during the seasonal trawl surveys can be considered alongside of other fisheries independent data and used to inform the spatiotemporal distribution of spawning within the area, and the maturity data can also be considered when evaluating the relative condition of individual fish, as sex and maturity stage can influence relative condition (Galloway and Munkittrick 2006; Wuenschel et al. 2009). In addition, up to 100 Atlantic cod will be opportunistically tagged with acoustic transmitters to support the BOEM-funded Atlantic cod spawning study (see Section 4.3.1) Biological sampling for lobsters will follow the protocols described in Section 4.2.5 of this document.

Following seven years of data collection during the Block Island Wind Farm trawl survey, INSPIRE Environmental (2021a) recommended that future diet composition studies concentrate sampling efforts on a small number of focal species with different trophic niches, rather than trying to characterize changes in prey composition for a wide range of species. Following that recommendation, stomach content analysis will be performed for two recreationally and commercially important species, black sea bass and summer flounder, to examine their prey composition and evaluate whether diet composition changes between the Project Area and reference areas prior to and after construction. An examination of catch rates from the NEFSC bottom trawl survey and the BIWF trawl survey (Appendix 2) indicate that the catch rates of these species are likely to be sufficient to allow for comprehensive sampling of diet composition. Due to their behavior and biological characteristics, better understanding whether the development of offshore wind affects the diet of these two species is of ecological importance.

Both black sea bass and summer flounder were identified as potentially serving as "key assessment indicator species" to understand the ecological impacts associated with offshore wind development (MADMF 2018). Malek (2015) identified both summer flounder and black sea bass as indicator species that should be considered when assessing the potential impacts of offshore wind development. Black sea bass and summer flounder were also noted as priority research species by Petruny Parker et al., (2015) and the Northeast Regional Habitat Assessment Prioritization Working Group (NMFS 2015). In addition, Guida et al., (2016) identified black sea bass as a species that was vulnerable to construction within the MA/RI Wind Energy Area. A recent modeling study (Friedland et al. 2021) that used 43 years of data from the NEFSC trawl survey found that black sea bass are highly dependent on habitats in the wind energy areas during the spring and fall, while summer flounder are highly dependent on these habitats in the fall, making these species good candidates for further investigation related to their diet composition and feeing behavior.

Black sea bass are characterized as opportunistic benthic omnivores, which consume a range of food including crustaceans, mollusks, and fish (Bigelow and Schroeder 1953; Kendall 1977; Drohan et al. 2007). Black sea bass are strongly associated with structured habitats including rocky reefs, cobble and rock fields, mussel beds, and stone coral patches (Drohan et al. 2007), and monitoring results from Block Island Wind Farm demonstrated an increased abundance of black sea bass near the turbine foundations following construction (HDR 2019). This observation has led some stakeholders to express consternation about potential local increases in black sea bass abundance, out of concern that black sea bass will consume juvenile lobsters within the wind farm site following construction.

Adult summer flounder have been characterized as opportunistic feeders that prey primarily on fish and invertebrates, with the following fish species included in their diet; windowpane flounder, winter flounder, pipefish, menhaden, bay anchovy, red hake, silver hake, scup, Atlantic silverside, sand lance, bluefish, weakfish, and mummichogs (Packer et al. 1999, and references therein). Summer flounder have also been reported to feed on a variety of benthic invertebrates including small bivalve and gastropod mollusks, small crustaceans, marine worms, sand dollars, and squid (Packer et al. 1999, and references therein). Summer flounder was recognized as a species with the potential to experience a negative impact due to the conversion of soft-bottom habitat to hard bottom habitat associated with the foundations, and associated scour protection8.

Up to 10 animals will be sacrificed for stomach content analyses from each trawl that is sampled, with no more than five individuals of either species sampled from a single trawl. The target sampling intensity is to analyze 200 samples per species, in each area, during the two-year pre-

[8] Technical Report - Essential Fish Habitat Assessment - Revolution Wind Offshore Wind Farm (boem.gov)

construction sampling period. Cumulative prey curves provide an estimate of how prey diversity increases as a function of sample size and can help determine the sampling levels needed to adequately characterize diet composition (Chipps and Garvey 2007). Cumulative prey curves were derived for summer flounder and black sea bass based on stomach content analysis performed during the BIWF trawl survey. For summer flounder, the prey curves were created by time period (baseline and operation) and area (BIWF impact and reference sites) combinations and demonstrate that approximately 40 samples were needed within each combination of time and area factors to characterize their prey composition (Figure 8), although not all prey curves approached the asymptote at the same rate. For black sea bass, stomach contents were only monitored during the final (i.e., post-construction) year of the trawl survey, but the prey curves suggest that approximately 40 samples should be sufficient to adequately characterize their diet in each area and time period (Figure 9). By focusing stomach sampling on summer flounder and black sea bass, it is anticipated that the Revolution trawl survey will collect hundreds of samples for each species in both the impact and reference areas across all the three phases of the project, allowing for a rigorous examination of changes in diet composition over time. Each fish sampled for stomach content analysis will be measured (to the nearest cm) and weighed (to the nearest gram) 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. Following the first year of pre-construction monitoring, cumulative prey curves will be produced to evaluate whether the sampling intensity should be modified in subsequent years.

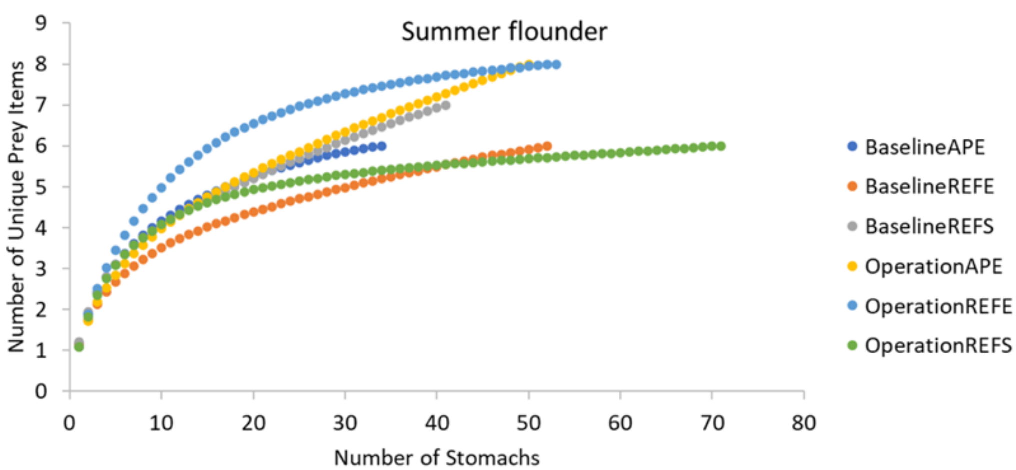


Figure 8. Cumulative prey curves for summer flounder observed during the BIWF trawl survey, in the RWF Area of Potential Effect (APE) and reference areas East and South (REFE and REFS) during the baseline and operation monitoring periods. Figure provided by INSPIRE Environmental (in progress).

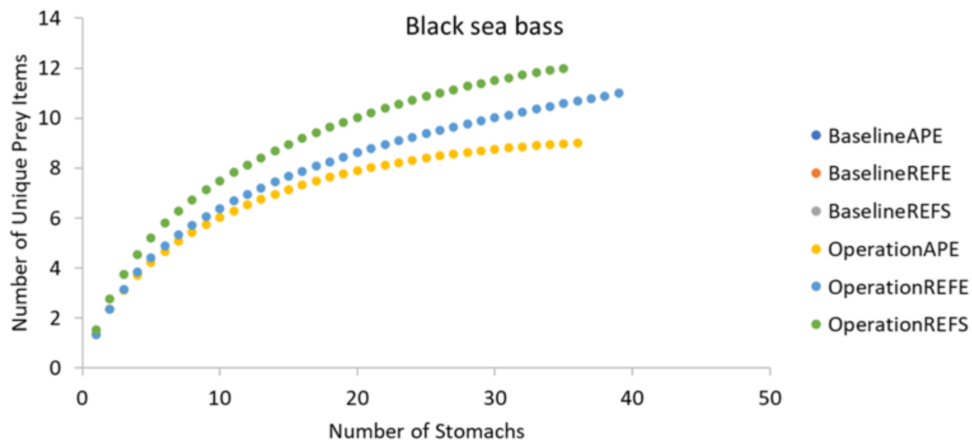


Figure 9. Cumulative prey curves for black sea bass observed during the BIWF trawl survey, in the RWF impact area (APE) and reference areas (REFE and REFS) during the operation monitoring period. Figure provided by INSPIRE Environmental (in progress).

Hydrographic data will be collected at each trawl station. A Conductivity Temperature Depth (CTD) sensor (or similar) will be used to sample a vertical profile of the water column at each trawl station. The CTD profile may be obtained at the start or end of the tow, at the discretion of the chief scientist. Bottom water temperature will be recorded at regular intervals (e.g., every 30 seconds) throughout the duration of each tow either using a temperature logger mounted on the trawl net or using temperature sensors that are part of the net mensuration hardware.

Should any interactions with protected species (e.g., marine mammals, sea birds, sea turtles, 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). If any protected species are captured during trawling, the sampling and release of those animals will take priority over sampling the rest of the catch. Reporting of interactions with marine mammals, such as small cetaceans and pinnipeds, will be dependent on the type of permit (i.e., EFP or LOA) issued to the project; once the permit type has been specified, Revolution Wind will contact National Marine Fisheries Service Protected Resources Division (NMFS-PRD) for guidance on reporting procedures. Additionally, protocols for handling live or deceased protected species of sea turtles, sturgeon, or marine mammals will be dependent on the type of permit (i.e., EFP or LOA) issued to the project. Once the permit type has been specified, we will contact NMFS-PRD for guidance on handling protocols. Entangled large whales or interactions with sea turtle species will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) and interactions with sturgeon species will be reported immediately to NOAA via the incidental take reporting email (incidental.take@noaa.gov); a follow up detailed written report of the interaction (i.e., date, time, area, gear, species, and animal condition and activity) will be provided to the NMFS Greater Atlantic Regional Fisheries Office (incidental.take@noaa.gov) within 24 hours. 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, and any genetic samples obtained from sturgeon will be provided to the NMFS Greater Atlantic Regional Fisheries Office Protected Resources Division. 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.

4.1.4 Trawl Station Data

The following data will be collected during each sampling effort:

- Station number
- Latitude and longitude at the start and end of the tow
- Time at the start and end of the tow
- Vessel speed and heading
- Water depth at the start and end of the tow
- Wind speed
- Wave height
- Weather conditions (e.g., cloud cover, precipitation)
- Tow speed
- Gear condition/performance code at the end of the tow
- Oceanographic data, as collected using a CTD and a temperature logger (see Section 4.1.3).

4.1.5 Data Management and Analysis

All field data will be reviewed for errors before being transcribed 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. We will also coordinate with our scientific Contractor(s) to disseminate the annual monitoring results through a webinar or an in-person meeting, and this meeting will also offer an open forum for federal, state, and academic scientists to ask questions or provide feedback on the data collection protocols. Likewise, following each year of monitoring we will coordinate with the Contractor(s) to host an industry workshop to disseminate the results of the monitoring activities to local fishing industry members. Although all interested stakeholders will be invited to the industry workshop, concerted efforts will be made to ensure that members of the Rhode Island Fishermen's Advisory Board (FAB) and the Massachusetts Fisheries Working group attend.

The first two years of trawl surveys will allow for characterization of the pre-construction fish and invertebrate community structure in both the Project Area and reference areas. For the pre-construction monitoring the results presented in annual reports will focus on descriptive and quantitative comparisons of the fish and invertebrate communities in the Project Area and the reference areas to describe spatial, seasonal, and annual differences in relative abundance, species composition, frequency of occurrence for each species (e.g., presence/absence), and demographic information for individual fish such as length, weight, diet, and relative condition. For the dominant (i.e., most abundant) species in the catch, relative abundance will be compared amongst the reference and RWF Project areas using descriptive statistics (e.g., mean, range) and length frequency data 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, cluster sampling). Species composition will be compared amongst the RWF Project and reference areas using a Bray-Curtis Index and multivariate techniques (e.g., analysis of similarities [ANOSIM]).

By continuing sampling during and after construction, the trawl survey will allow quantification of any detectable changes in relative abundance, demographics, or community structure associated with proposed operations. The BACI design for this survey plan allows the catch of numerically dominant species to be compared between the before and after construction periods in the two treatment types (reference and RWF Project areas), using appropriate statistical modeling. The use of reference areas will ensure that broader regional changes in demersal fish and invertebrate community structure will be captured and delineated from potential impacts of the proposed Project. Analyses presented in the final synthesis report will focus on identifying changes in the fish community in the RWF Project Area between pre-, during, 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.

The primary research question to be addressed is what magnitude of difference in the temporal changes in relative abundance are observed between the reference and RWF Project areas. This question will be addressed using point estimates and 90% confidence intervals (CIs) contrasting the temporal changes between areas. This research question can also be framed using the following null and two-tailed alternative hypotheses:

- $H_{\varnothing}$ - *Changes in relative abundance (catch per unit effort [CPUE]) between time periods (before and after) will be statistically indistinguishable between the reference and RWF Project areas.*
- H_1 - *Changes in CPUE between time periods (before and after) will be statistically different between the reference and RWF Project areas.*

In this design, there are multiple years within each time period and multiple sites within the Control treatment. Area will represent a fixed factor in the model with three levels (i.e., RWF impact area, and each reference area), which will be crossed with year, also a fixed factor. Environmental covariates (e.g., temperature, depth, and salinity) can also be included in the abundance model, either as linear or quadratic factors. The data logger attached to the trawl net will be used to record bottom temperature continuously during each tow, and the mean temperature for each tow will be included in the abundance model. The salinity at each tow will be informed by the CTD deployment, and depth will be calculated based on the average depth recorded at the start and end of the tow. The benthic habitat data provided by Greene et al., (2010) will be used to classify the dominant habitat present in each grid cell, allowing benthic habitat to be treated as a random effect within the model. Model selection will be conducted using Akaike Information Criteria (AIC) and residual diagnostics, and forward and backward stepwise elimination will be used to select the most parsimonious model (Venable and Ripley, 2002).

This asymmetrical BACI design is not suited to analysis with a simple two-factor Analysis of Vairance (ANOVA) model; instead Generalized Linear Models (GLMs) or Generalized Additive Models (GAMs) will be used to describe the data and estimate the 90% 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-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% CI for the estimated interaction contrast that excludes zero changes. A 90% confidence level is proposed to increase the power of the tests, i.e., increase the probability of identifying a significant impact of wind farm operation. This approach provides 90% confidence in the two-tailed hypothesis of "no difference", and 95% confidence in each of the one-tailed hypotheses (i.e., change at the Reference areas is less than at the windfarm, and change at the Reference areas is greater than at the windfarm).

If desired, absolute abundances estimates can be derived for commonly sampled species, using methodologies consistent with those employed on the NEAMAP survey. Estimation of absolute abundance will require assumptions regarding the efficiency of the survey gear and the availability of species to the trawl. Tow speed and tow duration collected by the chief scientist can be combined with the trawl geometry data collected using the net mensuration sensors to estimate the area swept during each tow.

Length frequency data for the dominant species in the catch will be analyzed. The first question to be addressed is how the size structure of these species change over time (before vs. after construction). The second question to be addressed is how the size structure of these species varies between areas (Project Area vs. reference areas). To answer both questions, length frequency data will be compared between times and locations for common species using descriptive statistics (e.g., range, mean) and graphical and statistical comparisons using ECDFs, a Kolmogorov-Smirnov test (Sokal and Rohlf 2001), or another appropriate method such as cluster sampling (Nelson 2014) based on the characteristics of the data.

For priority species that are subject to detailed biological sampling, fish condition will be compared between areas, and across time, to examine whether fish condition is influenced by the construction and operation of the Project. For commonly sampled species, condition indices (Jakob et al. 1996) will be calculated for individual fish as its residual from the log10-log10 regressions of mass (kg) to length (cm). For each species the fish condition data will be fit with a GAM or GLM that best describes the data, and the 90% CI will be estimated for the relevant spatial and temporal contrasts. Given the migratory nature of many of the species that will be investigated, and the uncertainty of where these species have foraged, a change in fish condition may not necessarily be considered as an impact attributable to the construction and operation of the wind farm. However, this information can be evaluated to consider whether fish condition (a proxy for fish health) changes over time and between areas after the wind farm is constructed.

Species composition will also be compared between areas and time periods to examine whether the construction and operation of the wind farm led to changes in the species composition within the Project Area. This research question can be examined using the following null (HØ) and two-tailed hypotheses (H1):

- $H_{\varnothing}$ - *Changes in species composition between time periods (before and after) will be statistically indistinguishable between the reference and RWF Project areas.*
- H_1 - *Changes in species composition between time periods (before and after) will be statistically different between the reference and RWF Project areas.*

Species composition will be compared before and after construction using a Bray-Curtis Index and multivariate techniques (e.g., Permutational ANOVA [PERMANOVA], ANOSIM). Additional data analyses will be performed as appropriate based on the nature of the data that is collected (i.e., models will be fit to the data using appropriate error distribution).

For diet data, the primary question that will be asked is whether the prey composition of focal species changes following the construction of the wind farm. This research question can be addressed for each species using the following null and two-tailed hypotheses:

- *$H_{\emptyset}$ - Changes in prey composition between time periods (before and after) will be statistically indistinguishable between the reference and RWF Project areas.*
- *H_1 - Changes in prey composition between time periods (before and after) will be statistically different between the reference and RWF Project areas.*

Seasonal 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 (Wk) of each prey item (Buckel et al. 1999a; Bonzek et al. 2008) by season 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 trawl tows that collected the fish species of interest,

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

w_i is the total weight of all prey items in the stomachs of all fish analyzed from trawl sample 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., PERMANOVA, Non-metric Multidimensional Scaling [nMDS], ANOSIM, and Similarity Percentages [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.

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

Following the first complete year of trawl sampling (e.g., completion of four seasonal sampling events), cumulative prey curves (Chipps and Garvey 2007) will be used to assess the adequacy of the sampling for diet data. For each species, the cumulative number of prey types will be plotted against the number of stomachs examined. The point at which the curves reach the asymptote can be used to estimate the minimum number of stomachs that are needed to adequately characterize the prey composition (Chipps and Garvey 2007), and if necessary this information can be used to refine sample sizes in subsequent years.

Beyond the analyses described above, additional analyses will focus on evaluating the comparability of the RWF trawl survey data with observations from other trawl surveys in the region, including the NEFSC and NEAMAP trawl surveys, as well as observations from trawl surveys completed at other lease sites (e.g., Vineyard Wind trawl survey). They use of the NEAMAP sampling protocols and trawl net will help facilitate these comparisons, which will provide valuable regional context to further evaluate whether the results observed at the wind farm are due to offshore wind development, or whether they are indicative of broader regional trends. These comparisons can be made at a variety of scales (e.g., lease site, NEFSC sampling strata, or stock area) as appropriate for the species and biological index of interest. The additional analyses may include an evaluation of several indices, including relative abundance, fish condition, and size structure.

An adaptive sampling strategy will be employed, whereby data collected early in the study will be analyzed to assess statistical power and modify the sampling scheme or sampling intensity as needed (Field et al. 2007). Upon completion the first four seasonal surveys, the power analysis will be updated to evaluate the power of the sampling design. A measure of variability associated with the relative abundance estimates for the dominant species in the catch will be calculated and the *a priori* power analysis (i.e., Appendix 2) will be updated with these estimates. Power curves will be used to demonstrate how statistical power varies as a function of effect size and sample size (i.e., number of 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 of the stated size when it is actually present. A two-tailed alpha of 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.

4.2 RWF Ventless Trap Survey – Lobsters and Crabs

American lobster and Jonah crab are targeted by commercial fishermen in New England and the Mid-Atlantic. Lobsters are jointly managed by the NMFS and the ASMFC, while Jonah crab are managed by the ASMFC. The American lobster was recognized as a priority species for monitoring in the MA/RI WEA (McCann 2012; Petruny-Parker et al. 2015; Malek 2015; MADMF 2018), and Jonah crabs were also identified as an indicator species by MADMF (2018). From 2009 to 2018, lobsters were the most valuable target species in the RWF (Table 2). Jonah crabs, which represent an expanding fishery in southern New England (Truesdale et al. 2019), generated the 11th most revenue from the RWF area over the same period (Table 2). Lobsters and crabs may not always be sampled effectively by a trawl survey (Petruny-Parker et al. 2015). Therefore, a ventless trap survey is proposed to address the question of whether the construction and operation of the RWF has any detectable effects on the relative abundance and demographics of lobsters, Jonah crabs, and rock crabs.

The primary objective of the pre-construction monitoring is to investigate the relative abundance of lobster, Jonah crab, and rock crab in both the RWF ventless trap survey impact and reference areas. The pre-construction monitoring will also collect demographic information including size structure, sex ratios, reproductive status, and shell disease. This survey is also expected to encounter several structure-associated finfish species as bycatch, such as black sea bass, tautog, and scup. Two years of sampling (i.e., 12 monthly sampling events, 7 months per year) will be targeted before the commencement of offshore construction, with the goal to initiate sampling in May or June of 2022. The pre-construction data will supplement baseline information that was collected in 2014, 2015, and 2018 through the Southern New England

Cooperative Ventless Trap Survey (SNECVTS) (Collie and King 2016). Ventless trap monitoring will continue during the construction phase, and a minimum of two years of monitoring will be completed following offshore construction, but the duration of post-construction monitoring may also be informed by guidance for offshore wind monitoring that is being developed cooperatively through the Responsible Offshore Science Alliance (ROSA).

The primary objective of monitoring after construction is to determine whether the operational activities associated with the Project lead to a significant change in the relative abundance of lobsters, Jonah crabs, and rock crabs within the Project Area. Another objective is to determine whether the construction and operational activities lead to a significant change in the demographics of these species. The use of an asymmetrical BACI sampling design will allow for quantitative comparisons of relative abundance and demographics to be made before and after construction, and between reference and impact areas (Underwood 1992; Smith et al. 1993).

The ventless trap survey is designed to be as compatible as practicable with other fisheries independent surveys in the region. This sampling will build off prior sampling efforts in the MA/RI Wind Energy Area under the SNECVTS in 2014, 2015, and 2018 (Collie and King 2016), and the proposed biological sampling protocol is informed by the methods used by the 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). A ventless trap survey using the same protocols in the adjacent South Fork Wind (SFW) Project lease area began in May 2021 and is also being executed using an asymmetrical BACI design. Performing ventless trap surveys in both lease areas will increase the ability to detect regional changes in these invertebrate resources. All ventless trap sampling in SFW and RWF will occur on commercial lobster vessels that are chartered for the monitoring surveys.

4.2.1 BACI Survey Design and Procedures

The study will be conducted using an asymmetrical BACI design with quantitative comparisons made before and after construction and between the reference and RWF Project areas (Underwood 1994). Data collected at the reference areas will serve as a regional index of lobster, Jonah crab, and rock crab abundance in areas that are not currently being considered for offshore wind development.

RWF ventless trap survey impact areas were identified within the RWF lease area (Figure 10). Mobile gear fisheries are active within the northern portion of the lease area, therefore, this area was originally excluded from the ventless trap study in order to minimize any potential gear conflicts with the mobile gear fishery. After receiving input from fisheries stakeholders that identified the northern portion of the lease area as important to the lobster industry, the northern impact area was included in the design. The northern RWF ventless trap survey impact area is approximately 52km^2, and depth in the area ranges from 33 to 46m (mean = 39m) and the southern RWF ventless trap survey impact area is approximately 51km^2, and depth in the area ranges from 30 to 39m (mean = 35m). Data from the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010) indicate that the benthic habitat within the RWF ventless trap survey impact areas includes high flat gravel, moderate flat gravel, shallow depression gravel, shallow depression sand, and moderate flat sand (Figure 11), and Orsted geophysical surveys have also documented boulder fields within the RWF ventless trap survey impact areas (Figure 2).

Input from local lobster fishermen and our scientific research partners was used to select two reference areas for the SFW ventless trap survey (Figure 10). The reference areas are each approximately 55 km^2. Diverse habitats are present within the reference areas (Figure 11).

Habitats within the western reference area include high flat gravel, moderate flat gravel, moderate flat sand, and shallow depression sand, while habitats in the eastern reference area include high flat gravel, moderate flat gravel, shallow depression gravel, moderate flat sand, shallow depression sand, and shallow depression silt/mud. Depths in both the eastern and western reference areas range from 30 to 39m (mean = 35m; Figure 12). When siting the reference areas consideration was also given to the proximity of the reference areas relative to offshore wind development that is planned in the future. Given the similarities in depth and habitat between the SFW reference areas and the RWF ventless trap survey impact area, along with the desire to minimize the number of vertical lines in the water to reduce the risk of interactions with protected species, the same reference areas will be utilized for both the RWF and SFW ventless trap surveys.

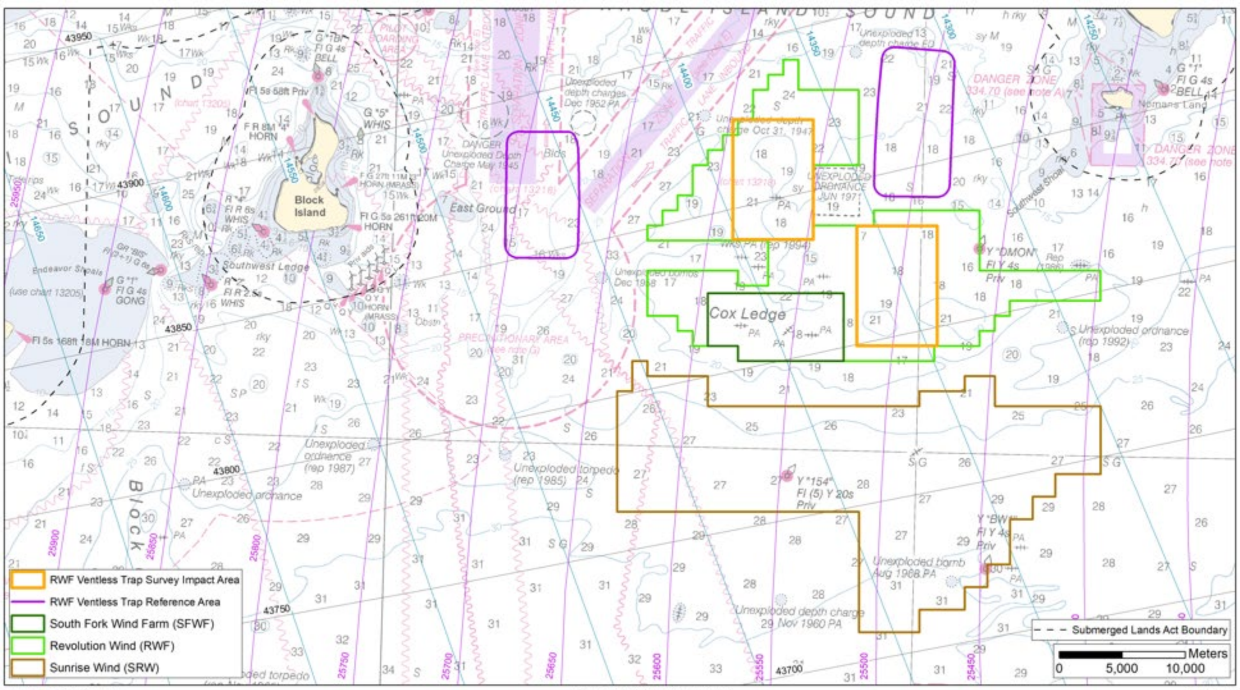


Figure 10. **Proposed RWF ventless trap survey impact and reference areas.**

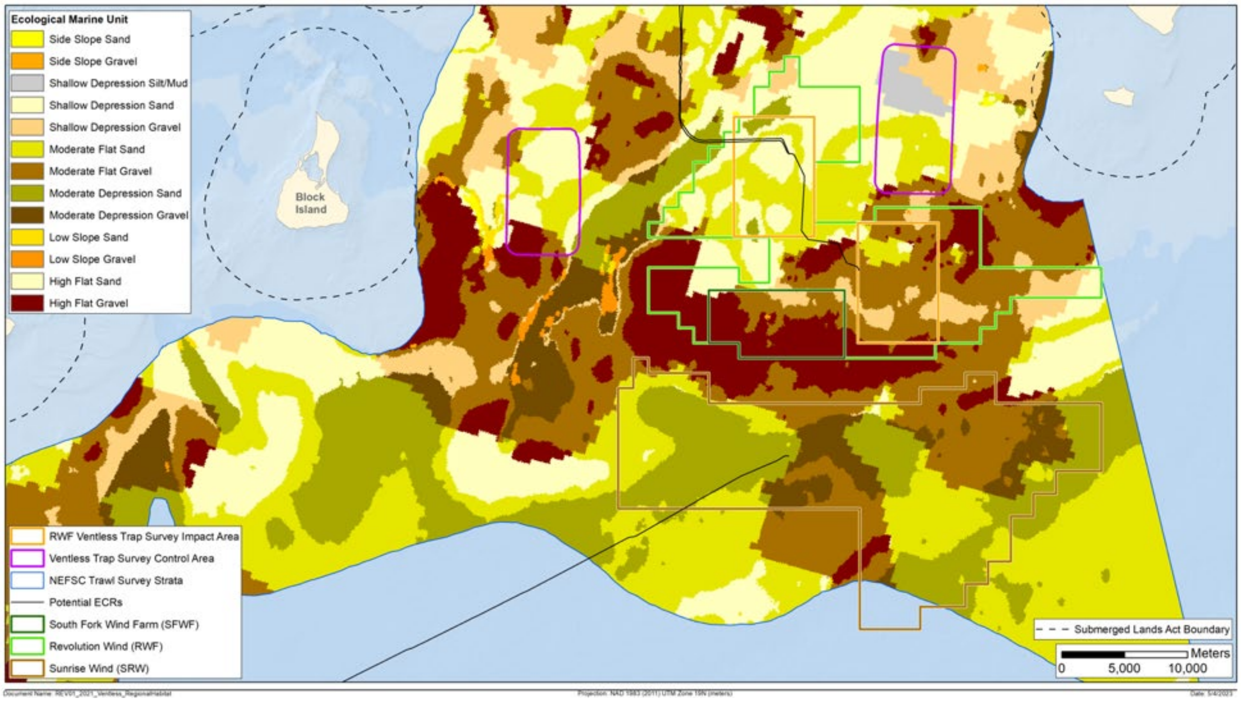


Figure 11. Benthic habitats within the RWF ventless trap survey impact area, and within the reference areas. Benthic habitat data was derived from the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010).

The spatially balanced sampling approach utilized during the SNECVTS survey (Collie and King 2016) will be utilized within the RWF ventless trap survey impact areas and the reference areas. The RWF ventless trap survey impact areas will be divided into sixteen equally sized grid cells (with effort distributed between the two areas and all data pooled), and each grid cell will be further divided into equally sized aliquots (Figure 13 provides an example of distributing aliquots). As was described in the South Fork Wind Farm Fisheries Research and Monitoring Plan (South Fork Wind, LLC and INSPIRE Environmental 2020), the eastern and western reference areas will be divided into ten grid cells, and each grid cell will be further divided into equally sized aliquots. Through consultation with local industry members, a subset of the aliquots within each grid cell will be identified as suitable sampling areas based on the desire to minimize gear conflicts with fishermen in the area. One aliquot will be randomly selected for sampling in each grid cell at the start of the year. 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). This design allows for broad sampling coverage of each area, while also allowing for random site selection to occur within each grid cell. Within the reference and RWF ventless trap survey impact areas, the same aliquot will be resampled throughout each year with a new aliquot randomly selected in each grid cell the following year. For the BACI study, sampling at the reference areas will follow the sample protocols during all three phases of the monitoring (before, during, and after construction).

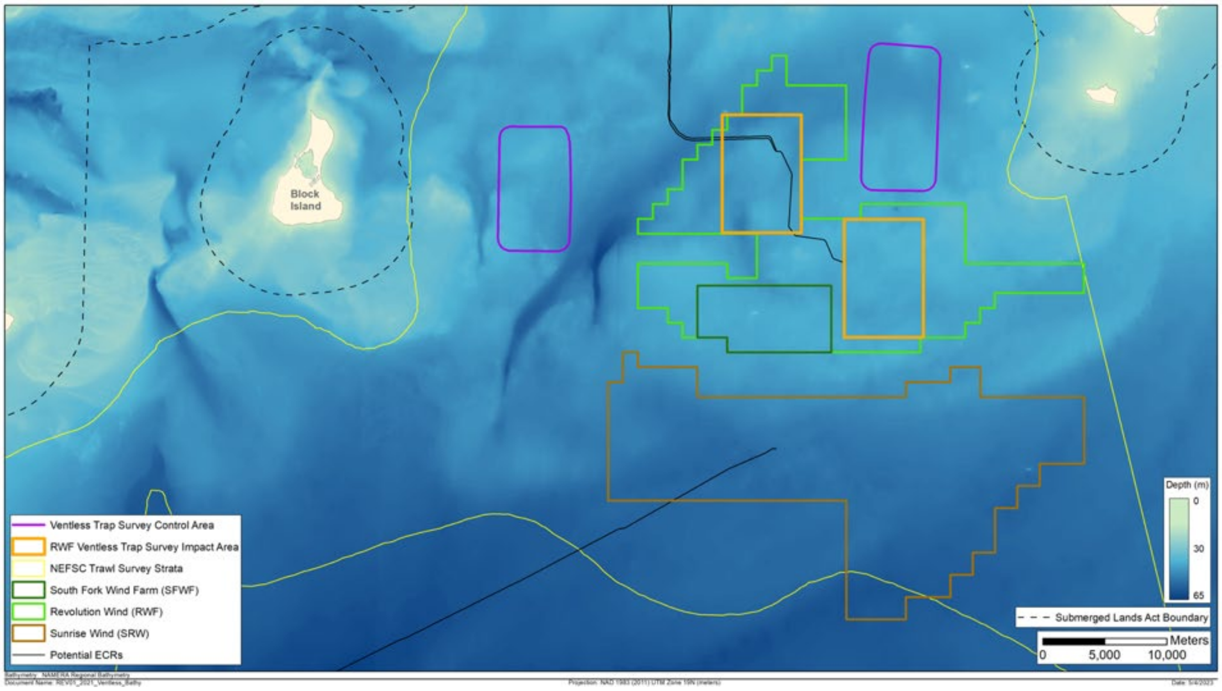


Figure 12. Bathymetric map of the RWF lease area, the RWF ventless trap survey impact area, and the planned reference areas for the ventless trap survey. Bathymetric data is shown in meters and was derived from the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010).

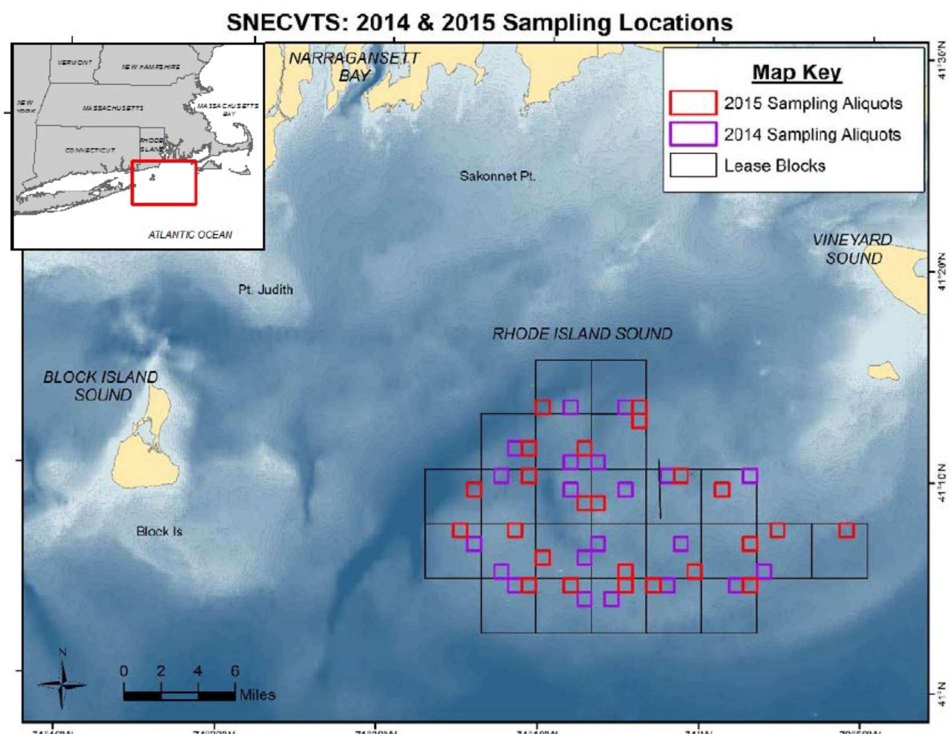


Figure 13. Example of the station selection method employed during the Southern New England Cooperative Ventless Trap Survey. The study area was stratified into 24 sampling grid cells, and each grid cell was further divided into aliquots. One aliquot from each grid was randomly selected for sampling in each year. Figure from Collie and King (2016).

To achieve consistency with the ASMFC and SNECVTS protocols, the sampling stations will be selected randomly at the start of each year of sampling and remain fixed for the remainder of the year. This sampling approach keeps the station occupied, reduces time that is spent moving traps between locations, and is similar to the routine operations of lobstermen in the region (Collie and King 2016). 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. To further minimize gear interactions, all survey gear will be ropeless. Revolution Wind will work with the scientific contractor(s) to evaluate whether activities associated with cable installation (e.g., cable cover), or other construction activities, will impact the execution of the ventless trap survey.

Benthic habitat type is known to influence the distribution and abundance of lobsters and Jonah crab (e.g., Geraldi et al. 2009; Collie and King 2016). Along with input from local fishermen, benthic habitat data from the Northwest Atlantic Marine Ecoregional Assessment (Greene et al. 2010) was used to inform the location of the reference areas and evaluate benthic habitat within the RWF ventless trap survey impact area. Habitat data was also collected within the RWF using geotechnical and geophysical surveys, as well as optical methods (Sediment Profile and Plan View Imaging [SPI/PV]), and this information will be used to produce a detailed habitat map of the RWF area. This habitat map will be used to further classify benthic habitat at each location that is sampled within the RWF ventless trap impact area. However, similar high-resolution habitat data from geophysical surveys will not be available for the reference areas. Given that the trawl locations will remain fixed across each year of sampling, and that each trawl has a limited spatial footprint, *in-situ* observations will be used to further characterize the benthic habitat at each sampling location in the reference areas. A variety of approaches may be used to characterize benthic habitat in the reference areas including grab sampling, optical techniques (e.g., underwater video or still imagery), or side-scan sonar (e.g., Collie and King 2016), and we will work with our scientific research partner to determine which method will be most suitable. These *in situ* habitat observations can be used to supplement the benthic habitat data provided by Greene et al., (2010), and better inform habitat classifications within the reference areas. The influence of habitat type will be investigated as a covariate during model fitting when examining changes in relative abundance over time in the reference areas and the RWF ventless trap survey impact areas (see Section 4.2.7).

A power analysis was conducted (see Appendix 3) to inform the pre-construction sample sizes for the RWF ventless trap study. The power analysis utilized relative abundance data for lobsters, Jonah crabs, and rock crabs that was collected during the SNECVTS in 2014, 2015 and 2018. Bootstrapping techniques (R=5000 bootstrap replicates) were used to characterize the variability in the catch rates observed during the SNECVTS. The range of coefficients of variation (CVs) estimated through bootstrapping were used in the power analysis.

Power analysis represents the relationships among the four variables involved in statistical inference: sample size (N), effect size, and type I (α) and type II (β) error rates (Cohen 1992). Power curves were constructed to demonstrate how statistical power varies as a function of the effect size (or percent decrease at the wind farm), sample size (e.g., number of trawls per area), level of variability (CV values), and the duration of post-construction monitoring (Figure 3 in Appendix 3). When analyzing changes in the relative abundance of lobster, Jonah crab, and rock crab, we will aim to achieve a statistical power of at least 0.8, which is generally considered to be the minimum standard for scientific monitoring (Cohen 1992). This ensures that the monitoring will have a probability of at least 80% of detecting an effect of the stated size when it is actually present. A two-tailed alpha of 0.10 was used for the power analysis. Based on the results of the power analysis, a sample size of 16 trawls in the impact area will be targeted in each year, paired with 10 trawls in each of the reference areas. While statistical power is optimized for a given sampling intensity when sample sizes are equal among all areas, this slight imbalance in sampling intensity amongst areas does not lead to substantial reductions in power for the RWF monitoring (see Figure 4 in Appendix 3), particularly when GLMs are used to model the abundance data.

This analysis assumes that the variance in the catch rates during the RWF survey will be within the range of variances used from the SNECVTS (Table 2, Appendix 3). Under the assumption that the CV for Jonah crabs will be 0.4, if two years of post-construction monitoring is completed at this level of sampling, the study design is expected to have at least an 80% probability of detecting at least a 33% relative decrease in the abundance of Jonah crabs (i.e., the abundance of Jonah crabs decreases by 33% at RWF, and remains unchanged at the reference areas). For lobsters, assuming the observed CV is 0.6, the study design is expected to be have at least an 80% probability of detecting at least a 40% change in relative abundance. However, for rock crabs, which exhibited greater variability in catch rates during the SNECVTS, this study design is anticipated to only have the statistical power to detect larger changes in relative abundance (e.g., ~50% - 75%) between the RWF ventless trap survey impact and reference areas. If the duration of post-construction monitoring is extended to three or four years, the statistical power associated with this sampling intensity is expected to increase (Appendix 3, Figures 3 and 4). Following the first year (i.e., June-November 2022) of ventless trap survey data the observed variability will be calculated. The achievable effect sizes will also be identified following the first year of the survey, once the realized magnitude of variability is better understood, and once regional guidance regarding effect sizes has been formalized through ROSA.

4.2.2 Gradient Study Design and Procedures

In addition to the proposed BACI sampling, a gradient sampling design will also be incorporated within the RWF ventless trap survey impact area during the operational phase of the project. The purpose of the gradient sampling design is to assess whether lobsters, Jonah crabs, or rock crabs occur in higher abundance near the foundation locations, relative to other locations within the RWF ventless trap survey impact area. While some previous offshore wind monitoring studies have investigated the influence of distance from turbine foundations on the abundance and diversity of fish (e.g., Bergstrom et al. 2013), to the best of our knowledge, similar distance-based sampling has not been performed for lobsters or crabs. The foundations and scour protection will provide lobsters and crabs with novel and complex habitat that may offer shelter from predators, and these structure-oriented species may be attracted to the foundations and scour protection (Krone et al. 2017; Roach et al. 2018). Methratta (2020; Table 1) classified 'habitat provision via turbine structures' and 'attraction to turbine foundations' as 'local effects', which were hypothesized to occur at a spatial scale of 10s to 100s of meters.

Consistent with the study design of the BACI ventless trap survey, the sampling 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. 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.

At the start of each year of monitoring during the operation period, four foundation locations in the RWF ventless trap survey impact area will be selected at random, and ten trap trawls of ventless traps will be intentionally set with the mid-point of the trawl as close to the foundation as possible (accounting for safety and logistical concerns). Assuming there is 30.5 m (100 ft) between adjacent ventless traps in a trawl, if the midpoint of the trawl were set proximate to a foundation, two ventless traps would each sample at a distance of approximately 15m from the foundation (on either side of the foundation). The next two ventless traps on the trawl would sample at a distance of 45m, and the next two ventless traps would both sample at a distance of 75m, and so on. The start and end locations of each trawl, and the orientation of the trawl, will be recorded (see Section 4.2.6) so it will be possible to approximate the distance of each trap on the trawl relative to the nearest turbine foundation. This design should produce eight traps (two traps at each of the four foundation locations) at five distance intervals ranging from approximately 15m to 140m from a foundation.

4.2.3 Ventless Trap Methods – BACI Survey

The ventless trap survey will be executed using a local lobster vessel(s) with scientists onboard to process the catch. The fishing vessel(s) will be contracted to conduct the sampling using a single parlor trap that is 16 inches high, 40 inches long, and 21 inches wide with 5-inch entrance hoops and constructed with 1-inch square rubber coated 12-gauge wire that is consistent with traps used in the ASMFC and SNECVTS ventless trap surveys. The trap is constructed with a disabling door that closes off the entrance during periods when the trap is on the bottom but not sampling. Trawls will be configured with ten traps on each trawl, which is consistent with the gear configuration used in the SNECVTS (Collie and King 2016). For the BACI survey, a combination of ventless and vented traps will be used to survey juvenile and adult lobster and crabs. Each trawl will be comprised of six ventless traps (V), and four standard vented traps (S), in the following pattern V-S-V-S-V-V-S-V-S-V, consistent with the gear configuration used on the SNECVTS (Collie and King 2016). All survey gear will have buoys and vertical lines removed. The locations of bouy-less gear will be input into the EdgeTech Trap Tracker application to communicate trawl locations. The fishermen participating in the SFW ventless trap study have provided feedback that because of the depths of the study site, a minimum spacing of 30.5 m (100 ft) will be needed between traps to ensure safety for the crew and scientists while the gear is being hauled.

It is acknowledged that the use of ten trap trawls is inconsistent with the ventless trap monitoring that is carried out by the state agencies through ASMFC, and also the ventless trap monitoring being completed by Vineyard Wind. However, there are several reasons to deviate from the monitoring protocols being completed by other groups. Fishing ten rather than six traps per trawl increases the area fished and will likely decrease the variance associated with the relative abundance estimates, which in turn will increase the statistical power of the design. Further, without increasing the number of trawls, fishing with six trap trawls, rather than ten trap trawls, would reduce the number of ventless traps that are sampled by 40%. This would, in turn provide less information about changes in the local lobster population. Local fishermen (RI FAB members) provided input that fishing longer trawls (ten traps rather than six traps) should reduce the likelihood of gear losses during the study. Similarly, the captains expressed concerns that the trap spacing used on the ASMFC ventless trap surveys (60 ft) may also lead to unsafe conditions while the gear is being hauled. Therefore, consistent with the SNECVTS protocols, the study will be executed using ten trap trawls, in order to minimize the potential for gear losses, to increase the area sampled by each trawl, and to increase the number of traps that are sampled. The spacing between individual pots on each trawl will be consistent with the spacing used at the SFW lease site and reference sites.

Pre-construction sampling will occur twice per month from May through November. However, the Project has been advised by staff at the Greater Atlantic Regional Fisheries Office (GARFO) Protected Resources Division that the survey cannot operate from December through May unless we are able to partner with a local lobster vessel and complete the survey using traps that are already allocated to the fishery, in order to minimize the risk of protected species interactions. RWF will attempt to partner with a local lobster fisherman and execute the survey using their trap tags to avoid placing additional gear in the water beyond what is already permitted to the fishery. However, if this cannot be accomplished, then the survey will instead sample from June through November, in order to avoid sampling during the month of May. The proposed sampling period of May through November was derived from industry feedback and to establish consistency with existing regional surveys, and the sampling is consistent with the ventless trap monitoring at SFW. The standard soak time will be five nights, which is consistent with local fishing practices, and the protocols used on the SNECVTS survey. Compared to the ASMFC surveys, the SNECVTS used a longer soak time because lower densities of lobsters were expected offshore compared with inshore areas of Maine and Massachusetts, and because of the logistics of sampling offshore (Collie and King 2016). The target soak time will remain consistent throughout the duration of the survey. Traps will be baited with locally available bait (likely skate), and the bait type will be recorded for each trawl. Each randomly selected location will be sampled twice per month. Between monthly sampling sessions all gear will be removed from the water and stored on land. At the start of each monthly sampling event, the lobsterman will bait and deploy the traps. After the five-day soak period, the traps will be hauled, 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 the 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.

Revolution Wind is partnering with scientists from CFRF to execute the survey. CFRF 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. However, the EFP was not approved, and the commencement of the survey has been delayed as the project team seeks to obtain the necessary scientific research permits to execute the survey. 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 sampling gear. This includes the use of gear with buoys and vertical lines removed. Additionally, all gear will be removed from the water and stored on land between monthly sampling sessions. 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:

- No buoy line will be floating at the surface.
- All sampling gear will have buoys and vertical lines removed.
- All sampling gear will be removed from the water and stored on land between monthly sampling sessions, and all gear will be removed from the water at the end of each sampling season (November).
- All groundlines will be constructed of sinking line.
- Any gear that goes missing will be reported to the NOAA Greater Atlantic Regional Fisheries Office Protected Resources Division as soon as possible.

4.2.4 Ventless Trap Methods – Gradient Survey

As described for the BACI ventless trap survey, the gradient survey will also be executed using a local lobster vessel(s) with scientists onboard to process the catch. Consistent with traps used in the ASMFC and SNECVTS ventless trap surveys, the fishing vessel(s) will be contracted to conduct the sampling using a single parlor trap that is 16 inches high, 40 inches long, and 21 inches wide with 5-inch entrance hoops and constructed with 1-inch square rubber coated 12-gauge wire. The spacing between the traps in each trawl will be consistent with the spacing used on the BACI survey. Trawls will be configured with ten traps on each trawl, but unlike the BACI survey, the trawls will be comprised of ten ventless traps, and no standard traps. The rationale to execute the gradient study using only ventless traps comes from monitoring data collected during the Block Island Wind Farm survey. The results from Block Island Wind Farm demonstrated that ventless traps typically have higher catch rates and sample a wider range of size classes than standard traps, and therefore provide more information on the abundance and demographics of the local lobster and crab population (e.g., INSPIRE Environmental, 2018b). With only ventless traps used, trap type will not need to be considered as a covariate in analysis of the data; this will allow the greatest inference from the fewest number of lines in the water.

Sampling for the gradient survey will occur on the same monthly schedule (May – November) as the post-construction BACI survey, but the timing of the survey may need to be modified to June through November dependent upon our ability to execute the survey using traps that are already allocated to the fishery (see Section 4.2.3). The standard soak time will be five nights, which is consistent with local fishing practices, and the protocols used on the SNECVTS survey. The target soak time will remain consistent throughout the duration of the survey. Traps will be baited with locally available bait (likely skate), and the bait type will be recorded for each trawl. Each randomly selected foundation location will be sampled twice per month. Between monthly sampling sessions all gear will be removed from the water and stored on land. At the start of each monthly sampling event, the lobsterman will bait and deploy the traps. After the five-day soak period, the traps will be hauled, 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 the 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.

As described for the BACI survey (Section 4.2.3) the scientific contractor will apply for a LOA or 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, and the same measures described in Section 4.2.3 will be used to minimize the potential for incidental interactions with sampling gear.

4.2.5 Biological Sampling

During both the BACI survey, and the post-construction gradient survey, the catch will be processed in a manner consistent with the ASMFC and SNECVTS ventless trap surveys. Sampling will occur at the trap level, which will allow for the catch rates to be standardized in the event that traps are lost or damaged. The following data elements will be collected for each trap sampled during the survey; total number and biomass of individuals sampled, number and biomass for each species, and length frequency distribution of dominant invertebrate species (lobster, Jonah crab, and rock crab). Fish will be measured to the nearest cm, consistent with the species-specific measurement type (e.g., total length, fork length) described in the Northeast Observer Program Biological Sampling Guide. After sampling, all catch will be returned to the water as quickly as possible to minimize incidental mortality.

Biological data for individual lobsters will be sampled consistently with the protocols used by the MADMF and RIDEM during their ventless trap surveys. Data collected for individual lobsters will include:

- <u>Carapace length:</u> Measured to the nearest millimeter (mm) using calipers.
- <u>Sex:</u> Determined by examining the first pair of swimmerets.
- <u>Eggs:</u> Examine the underside of the carapace for the presence or absence of eggs. The gross egg stage will be characterized according to the following categories:
    - Absent
    - Brown (partially developed with eyespot present and will hatch in this calendar year)
    - Green (newly spawned with no eyespot present)
    - Green with eyes (small eyespot present, but will not hatch in this calendar year)
- <u>V-notch status:</u> present or absent (according to the LCMA2 definition)
- <u>Cull status:</u> Examine the claws for condition (claws missing, buds, or regenerated).
- <u>Incidence of shell disease:</u> Shell disease will be characterized according to four categories:
    - Absent
    - Light (1-10% of the shell)
    - Moderate (11-50%)
    - Heavy (> 50%).
    - Mortality: alive or dead

Biological information will also be collected for Jonah crabs and rock crabs. All of the crabs will be sampled from two randomly selected traps (one ventless and one vented) in each trawl, in order to investigate the different selectivities of both trap types. Sampling all of the crabs in the trap can also help avoid potential biases associated with subsampling, whereby smaller crabs may be underrepresented in the subsample. For the other eight traps in the trawl, counts and weights will be recorded for Jonah crabs and rock crabs, and up to ten crabs per trap will be subsampled for biological information. The following data elements will be recorded for each rock crab and Jonah crab that is sampled:

- 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.

<u>Incidence of shell disease</u>: Shell disease will be characterized according to four categories:

Absent

Light (1-10% of the shell)

Moderate (11-50%)

Heavy (> 50%).

- Cull status: Examine the claws for condition (claws missing, buds, or regenerated)
- Mortality: alive or dead

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 will be recorded at regular intervals (e.g., every 30 minutes) throughout the sampling period using a temperature logger mounted to an interior trap on each trawl. Sea state and weather conditions will be recorded from visual observations. Air temperature may be downloaded from a local weather station if not available onboard.

Should any interactions with protected species (e.g., marine mammals, sea birds, sea turtles, 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). If any protected species are captured during the ventless trap survey, the sampling and release of those animals will take priority over sampling the rest of the catch. Reporting of interactions with marine mammals, such as small cetaceans and pinnipeds, will be dependent on the type of permit (i.e., EFP or LOA) issued to the applicant; once the permit type has been specified, we will contact NMFS-PRD for guidance on reporting procedures. Additionally, protocols for handling live or deceased protected species of sea turtles, sturgeon, or marine mammals will be dependent on the type of permit (i.e., EFP or LOA) issued to the applicant. Once the permit type has been specified, we will contact NMFS-PRD for guidance on handling protocols. Entangled large whales or interactions with sea turtle species must be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) and interactions with sturgeon species will be reported immediately to NOAA via the incidental take reporting email (incidental.take@noaa.gov); a follow up detailed written report of the interaction (i.e., date, time, area, gear, species, and animal condition and activity) must be provided to the NMFS Greater Atlantic Regional Fisheries Office (incidental.take@noaa.gov) within 24 hours. 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. Any genetic samples obtained from sturgeon will be provided to the NMFS-PRD. Due to the potential for communicable diseases all physical sampling and handling of marine mammals and seabirds will be limited to the extent Orsted health and safety assessments and plans allow.

4.2.6 Ventless Trap Station Data

The following data will be collected during each sampling effort:

- Station number
- Start latitude and longitude

- Direction of the trawl
- Start time and date
- Start water depth
- End latitude and longitude
- End time
- End water depth
- Wind speed
- Wind direction
- Wave height
- Air temperature
- Type of bait that was used
- Comments regarding damage to any of the traps
- Hydrographic data, as collected using the CTD and temperature logger (see Section 4.2.2).

4.2.7 Data Management and Analysis

All field data will be reviewed for errors before being transcribed 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 and biological data will be prepared after the conclusion of each year of sampling and shared with state and federal agencies. One final report will also be produced synthesizing the findings of the pre- and post-construction evaluations. Revolution Wind will also coordinate with our scientific Contractor(s) to disseminate the annual monitoring results through a webinar or an in-person meeting, and this meeting will also offer an open forum for state, federal, and academic scientists to ask questions or suggest revisions to the data collection protocols. Likewise, following each year of monitoring we will coordinate with the Contractor(s) to host an industry workshop to disseminate the results of the monitoring activities to local fishing industry members.

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 RWF ventless trap impact area and reference areas. Prior to construction, 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 or cluster sampling). Sex ratios will be reported for each sampling event 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.

The ventless trap survey will supplement the available pre-construction data on lobster and crab resources in the adjacent SFW site (i.e., SNECVTS survey dataset). Given that both studies will be carried out using identical trawl configurations, catch rates can be compared at the trawl level. Collie and King (2016) used GAM's that included covariates such as temperature and habitat to evaluate the spatial and temporal variability of lobster and Jonah crab catches throughout the SNEVTS area. These analyses will be repeated to include the RWF ventless trap data, to investigate changes in relative abundance over time, and to better evaluate how catch per unit effort is influenced by abiotic conditions. Pre-construction biological data collected at RWF in 2021 and 2022 can also be compared to information collected through SNECVTS to investigate interannual and intraannual differences in demographic parameters (e.g., shell disease, length frequency).

Sampling during and 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. The BACI design for this survey plan allows CPUE to be compared between the before and after construction periods in the two treatment types (reference areas and RWF ventless trap survey impact area), using appropriate statistical modeling. The use of reference areas will ensure that regional changes in the abundance and demography of lobsters and crabs are accounted for when assessing the potential impacts of the proposed Project. 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. This question can be answered using the following hypotheses:

- $H_{\varnothing}$ - *Changes in relative abundance in both the reference and RWF ventless trap survey impact areas will be statistically indistinguishable between time periods (before and after).*
- H_1 - *Changes in CPUE will not be the same at the reference and RWF ventless trap survey impact areas between time periods (before and after; two-tailed).*

In the asymmetrical BACI design, there are multiple years within each time period and multiple sites within the Control treatment. Area will represent a fixed factor in the model with three levels (i.e., RWF ventless trap survey impact area, and each reference area), which will be crossed with year, also a fixed factor. Environmental covariates (depth, temperature, and salinity) will be recorded at the level of each trawl that is sampled, and can also be included in the abundance model, either as linear or quadratic factors. Depth will be recorded as the average depth observed at the start and end of the trawl. Bottom temperature observations will be recorded *in situ* while the trawl is deployed, and the mean temperature observed during the soak time can be evaluated in the model. Habitat type will be classified for each trawl, using either *in situ* observations (e.g., underwater video, side-scan sonar) or habitat maps derived from Orsted high-resolution geophysical and benthic surveys, and treated as a random effect within the model. Model selection will be conducted using AIC, and forward and backward stepwise elimination will be used to select the most parsimonious model (Venable and Ripley, 2002). Residuals will be examined using diagnostic plots to further investigate model fit.

The design is not suited to analysis with a simple two-factor ANOVA model; instead GLMs or GAMs will be used to describe the data and estimate the 90% CI on the BACI contrast. GLMs or GAMs will be used to estimate the catch in each area and year. 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 RWF ventless trap survey impact area 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.

Spatial and temporal patterns in the biological data for lobsters (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). This research question can be addressed using the following hypotheses:

- $H_{\varnothing}$ - *Changes in demographic parameters (e.g., shell disease) in both the reference and RWF ventless trap survey impact areas will be statistically indistinguishable between time periods (before and after).*
- H_1 - *Changes in demographic parameters (e.g., shell disease) will not be the same at the reference and RWF ventless trap survey impact areas between time periods (before and after).*

GLMs or GAMs will be used to describe the data and estimate the 90% 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 RWF ventless trap survey impact area and the average temporal change at the reference areas. A statistically significant RWF ventless trap survey impact would be indicated by a 90% confidence interval for the estimated interaction contrast that excludes zero.

The power analysis for measuring changes in relative abundance will be reevaluated after the first year of the RWF ventless trap survey. The power calculations and resulting power curves use the SNECVTS dataset to make implicit assumptions regarding the expected variance in the catch rates for lobsters, Jonah crabs and rock crabs. In practice, the variance for these species in the RWF ventless trap survey may be greater or smaller than was observed during SNECVTS. Therefore, after one full year of sampling has been completed, the observed variance in catch rates (e.g., CVs) will be calculated for each species and the survey performance will be evaluated.

During the operational phase, the data collected from the gradient study design will be used to examine the influence of distance from a turbine foundation on the relative abundance of lobsters, Jonah crabs, and rock crabs. Relative abundance data will be investigated at the trap level, permitting an examination of fine-scale differences in abundance. By recording the start and end location of each trawl, and the orientation of the trawl, it will be possible to estimate the distance of each trap to the nearest turbine foundation. For the strings of ventless traps that are set adjacent to the turbines (gradient design) scatterplots can be used to graphically investigate the relationship between catch rates (dependent variable), and the distance of each trap from the nearest foundation (independent variable). These graphical relationships will help elucidate the distance at which crustaceans may be attracted to, or repelled from, the foundations. Rank correlation analysis can be used to determine if there is a significant association between proximity to the turbine foundation and the catch rates. Spatial representation of the catch data can potentially be overlaid on habitat maps of the area to investigate possible influence of habitat on catch rates. Catch rates that are observed in the ventless traps that are set adjacent to the turbine (gradient design) can also be compared to the catch rates in ventless traps deployed throughout the RWF ventless trap impact area (BACI design).

Beyond the analyses described above, additional analyses will focus on evaluating the comparability of the RWF ventless trap survey data with observations from other ventless trap surveys in the region, including the ventless trap surveys completed by state agencies through ASMFC, as well as observations from ventless trap surveys completed at other lease sites (e.g., Vineyard Wind ventless trap survey). Given that we are proposing to use 10 trap trawls, rather that the six trap trawls used during some other surveys, the relative abundance data (average annualized catch per trawl) will need to be standardized in order to facilitate appropriate comparisons with these other regional surveys. Conducting biological sampling at the trap level during the RWF ventless trap survey will help to facilitate those comparisons. Biological data for lobsters and crabs will be collected using protocols that are consistent with the ASMFC sampling protocols. Comparing relative abundance and demographics between the RWF survey and other ventless trap surveys in the region will provide greater context to evaluate whether the results observed at RWF are due to offshore wind development, or whether they are indicative of broader regional trends. These comparisons can be made at a variety of scales (e.g., lease site, sampling strata, stock area) as appropriate for the species and biological indices of interest.

4.3 Acoustic Telemetry – Highly Migratory Species

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 presence of tagged individuals on the scale of tens to hundreds of meters. Acoustic receivers also offer continuous monitoring, allowing for behavior, movements, and residence of tagged individuals to be investigated at a fine temporal scale (e.g., minutes to hours) and in relation to cyclical events (e.g., day/night, tide, etc.). By leveraging observations collected across individual receivers, and receiver arrays, telemetry can also monitor animal presence and movement over a broad spatial (tens to hundreds of kilometers) and temporal (e.g., months to years) extent. Therefore, passive acoustic telemetry is an ideal technology to monitor presence, residency, and movements of species within Wind Energy Areas (WEAs) and to evaluate short and long-term impacts of wind energy projects on these parameters.

The use of passive acoustic telemetry has grown dramatically over the past decade and continues to grow each year (Hussey et al. 2015; Freiss et al. 2021). 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.

Acoustic telemetry has been used to investigate the behavior and movements of fish species in offshore wind areas. Reubens et al., (2013) monitored juvenile cod residency patterns, habitat use, and seasonal movement at the C-Power offshore wind farm in the North Sea and found that the majority of cod aggregated near the foundations and were resident within the wind farm for extended periods of time in the summer and autumn. Winter et al., (2010) tagged sole (n=40) and cod (n=47) with acoustic transmitters and tracked their movements within the Egmond aan Zee windfarm and a nearby reference area and concluded that sole did not exhibit avoidance of the windfarm, nor did they appear to be attracted to the foundations. Instead, seasonal movements were interpreted as occurring at spatial scales larger than the wind farm. Karama et al., (2020) monitored tagged Japanese yellowtail (a highly mobile species) and red sea bream around an offshore wind turbine near the Goto Islands (Japan) over the course of a year and found that both species exhibited low affinity and residency around the turbine throughout all seasons. Acoustic telemetry has also been used to evaluate the interactions of marine organisms with power transmission cables. Klimley et al., (2017) monitored the movements of green sturgeon and salmon smolts in relation to the Trans Bay Cable within the San Francisco Estuary and concluded that the Cable did not impact the migration success of either species. Similarly, Westerberg and Lagenfelt (2008) studied the movements of European eels in the Baltic Sea around an AC power cable and observed that the swimming speed of the eels was reduced near the cable, but that the cable did not act as an impediment to migration.

Acoustic telemetry is also recognized as a valuable tool to collect data on the presence, distribution, and seasonal movements of fish species in and around WEAs. Recently, BOEM has funded several studies to collect baseline data using acoustic telemetry for species such as sturgeon, striped bass, and winter skate, as well to investigate the seasonal movements and spawning behavior of cod within the MA/RI WEAs. The cod telemetry project commenced in 2019 and is being conducted by a group of researchers from the Massachusetts Division of Marine Fisheries, University of Massachusetts Dartmouth School for Marine Science and Technology, NOAA, Woods Hole Oceanographic Institution, and the Nature Conservancy. Atlantic cod has been recognized as a priority species for offshore wind monitoring by several groups (e.g., NMFS 2015; Petruny Parker et al. 2015; MADMF 2018), and cod have been identified as a species that is vulnerable to disturbance from the construction and operation of offshore wind farms (Guida et al. 2016). In 2020, INSPIRE Environmental and the Anderson Cabot Center for Ocean Life (ACCOL) at the New England Aquarium received funding through the Massachusetts Clean Energy Center (MassCEC) to use acoustic telemetry to monitor the presence and persistence of Highly Migratory Species (HMS) at popular recreational fishing grounds within the MA/RI WEA. The project is focusing on monitoring bluefin tuna, shortfin mako sharks, and blue sharks, which are three of the most commonly captured and targeted species by the offshore recreational community in southern New England (NOAA 2019) and were identified as priority species for monitoring the potential impacts of offshore wind in the MA/RI WEA (MADMF 2018). Shortfin mako sharks and tuna were also identified by Petruny Parker et al., (2015) as priority species for monitoring, and Essential Fish Habitat is present within the study area for all three of the Highly Migratory Species.

This monitoring effort will build off of these baseline studies and expand the acoustic telemetry project by including five additional years of data collection, the addition of receivers to the telemetry array, and the deployment of an additional 150 acoustic transmitters for Highly Migratory Species.

The primary objectives associated with the acoustic telemetry monitoring are as follows:

- Objective 1: Evaluate changes in HMS presence, residency, and movements between pre-construction, construction, and post-construction.

- Objective 2: Evaluate HMS connectivity among Ørsted lease sites.
- Objective 3: Monitor tagged HMS at spatial scales greater than the Ørsted project areas

4.3.1 Acoustic Telemetry Methods

Ørsted, through the SFW project, has already provided financial support to both the cod and HMS acoustic telemetry studies. SFW provided funds to the cod telemetry project team to purchase six additional VR2W receivers, which permitted the maintenance of their full receiver array. SFW also purchased mooring equipment (e.g., line, buoys, anchors, etc.) to retrofit the receiver moorings for the cod telemetry study to help minimize the loss of receivers and allow the project to meet its monitoring objectives. SFW also provided financial support to the HMS telemetry project to purchase, deploy, and maintain four VR2-AR receivers year-round, which will bolster the resolution of the broader MA/RI WEA acoustic receiver array, particularly during the cod spawning season. As part of the Ørsted ECO-PAM project, an acoustic receiver was deployed near SFW (41.06N 70.83W) in July 2020, and that receiver is maintained by Mark Baumgartner at Woods Hole Oceanographic Institute.

With MassCEC support, fifteen acoustic receivers were deployed in July 2020 at three popular recreational fishing sites within the MA/RI WEAs identified through a previous recreational fishing survey carried out by the ACCOL (Kneebone and Capizzano 2020). These receivers were deployed strategically and in conjunction with the Atlantic cod receiver array, to maximize spatial coverage for both projects. For-hire tagging trips using local charter vessels were conducted in 2020 and will be continued in 2021 to target and tag 20 individuals of each of the three HMS species listed above (60 tags in total).

The current HMS receiver array was expanded from 17 to 32 receivers starting in May of 2022 and is monitoring across all three Ørsted lease sites within the MA/RI WEA (Figure 14). The array is comprised of 13 Vemco VR2-AR (acoustic release) receivers that were purchased through the INSPIRE Environmental/ACCOL MassCEC project, 4 VR2-AR receivers previously purchased by Ørsted, and 5 additional VR2-AR receivers that were purchased specifically for this project with financial support from Ørsted. The full receiver array will be maintained year-round continuously through 2026. This will permit monitoring throughout the pre-construction, construction, and post-construction periods of the Revolution Wind, Sunrise Wind, and South Fork Wind projects. The receivers will also gather valuable pre-construction data at popular recreational fishing grounds within the OCS-A 500 lease area.

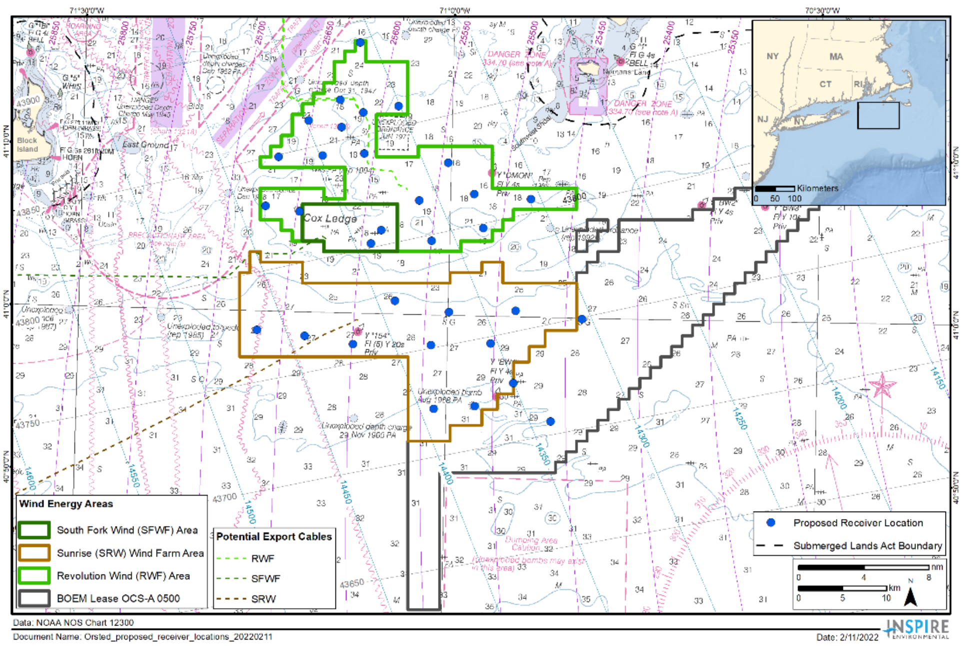


Figure 14. Current locations of acoustic receivers within Orsted lease sites. The receiver array was expanded to 32 locations starting in May 2022.

Receivers will remain in the water year-round to provide monitoring during the presumed cod spawning period of December through March (Cadrin et al. 2020; Dean et al. 2020). The existing 17 HMS receiver stations established in 2020 (Figure 14) will be retained, and an additional 15 receiver stations were selected in collaboration with cod researchers to optimize monitoring for all species. BOEM funding for the cod study is expected to end in 2022, however, Ørsted will purchase 100 additional acoustic tags to be deployed on cod caught on the trawl survey to extend the life of the project. The HMS receiver array will continue to allow for monitoring of tagged cod, and all detections of tagged cod will be shared with that research team.

Vemco model VR2-AR receivers will be rigged using standard procedures outlined by Vemco for benthic deployment https://www.oceans-research.com/wp-content/uploads/2016/09/vr2ar-deploy-tips.pdf). Ropeless technology (AR Buoys) was selected to minimize risks to marine mammals and other protected species. VR2-ARs will be maintained using a Vemco VR-100 unit and transponding hydrophone that were purchased using MassCEC funding.

Acoustic receiver download and maintenance trips will be conducted in the spring and fall of each year of the project. During each trip, receivers will be summoned, downloaded, and cleaned of any biofouling. They will be re-rigged and re-deployed at sea. Receiver deployment and maintenance will be done primarily in collaboration with a local commercial fishing vessel.

Acoustic receivers will monitor for the presence of the 60 Vemco V16 high power transmitters that were/will be deployed on HMS as part of the 2020 – 2021 MassCEC project, as well as an additional 150 transmitters that will be deployed from 2023 – 2025 on HMS (target of 50 transmitter releases per year) as part of this monitoring plan. These transmitters will emit unique, coded signals every 60 – 120 seconds and have an estimated battery life ranging from 1000 – 2500 days, depending upon the specifications of the transmitters. Therefore, long-term monitoring of HMS will occur throughout and beyond the duration of the project (2026). VR2-AR receivers will also monitor and record water temperature and ambient noise every hour throughout the entirety of the study.

The VR2-AR receivers will also opportunistically collect detection data from the thousands of marine organisms including fish, invertebrates, sharks, sea turtles and marine mammals that are currently being tracked in the northwest Atlantic using acoustic transmitters. At present, the majority of acoustic receivers deployed in southern New England are located close to shore, often in estuaries. Therefore, establishing a high-resolution and long-term acoustic receiver network in the offshore waters of the continental shelf will help fill spatial gaps in acoustic telemetry monitoring, and provide valuable data to supplement the dozens of ongoing telemetry studies in the region.

HMS will be tagged both internally and externally with acoustic transmitters. Bluefin tuna and smaller sharks will be tagged internally, and larger sharks will be tagged externally. External transmitters will be rigged on stainless, multi-strand cable and implanted into the dorsal musculature of the fish with a small titanium anchor. Internal transmitters will be implanted using standard surgical techniques outlined in our approved New England Aquarium Animal Care and Use Protocol.

4.3.2 Data Analysis and Data Sharing

Scope of monitoring - Due to the highly mobile nature and anticipated large home range of HMS, monitoring will occur in aggregate over the Revolution Wind, Sunrise Wind, and South Fork Wind project areas. Data aggregation will serve as a more biologically and ecologically appropriate manner to examine impacts on species that can use large areas of the southern New England region over variable periods of time (e.g., days to months). Accordingly, the data analyses described below will be performed, at a minimum, using all acoustic detection data collected by the 36 receivers deployed in the Revolution Wind, Sunrise Wind, and South Fork Wind project areas. Finer-scale monitoring of HMS activity within each individual project area will be accomplished if sufficient data are available over the time series.

Additional data sources - Acoustic telemetry has recently been adopted as a multi-species monitoring platform throughout several MA/RI and MA offshore wind leases. Thus, monitoring opportunities under this plan will be bolstered and expanded through collaboration, cooperation, and data sharing with ongoing projects funded by other developers/entities. Efforts will be made to establish working relationships or formal agreements among various telemetry projects to maximize the amount of data that will be included in this monitoring plan. For example, detection data from acoustic transmitters that are deployed on HMS as part of non-Ørsted monitoring projects may be used in this monitoring plan contingent upon the establishment of a data sharing agreement with the entity that purchased the transmitter. Similarly, detection data for Ørsted transmitters that are logged by receivers deployed in other MA/RI or MA lease areas may be included in the analyses outlined in this monitoring plan. The potential for data sharing and cooperation across projects will become more apparent over time as data sharing agreements are reached amongst developers. However, there is great potential to establish acoustic telemetry as a regional monitoring platform across numerous lease areas during the project period (2021 – 2026).

Data Analysis - The detection data will be compiled after each download and analyzed with the overall goal of establishing information on species presence and persistence across the Ørsted lease areas in the MA/RI WEA. Several metrics will be analyzed including short- and long-term presence, site fidelity (i.e., residency/persistence), fine- and broad-scale movement patterns, and inter-annual presence (i.e., whether individuals return to the receiver array each year). Deliverables will include detailed detection history plots for each tagged individual that depict all detections logged for an animal by individual receivers, as well as by all receivers, over each year of monitoring. Summary tables and figures will be generated that describe: the total number of receivers an individual and/or species was detected on in the broader receiver array as well as in each project area, the number of times each fish was detected by each receiver, movements between individual receivers and project areas, and monthly/seasonal/annual patterns in presence and persistence in relation to environmental conditions (e.g., sea surface or bottom water temperature, photoperiod).

To examine animal home range, we will estimate individual and species' utilization distribution using statistical analyses such as the Brownian Bridge Movement Model (e.g., Dean et al. 2014; Zemeckis et al. 2019) or a spatial point process model (Winton et al. 2019), both of which are effective when used with passive acoustic telemetry data. Connectivity and movements between receiver locations will be examined using a network analysis, which has been used previously to examine movements and space use with passive acoustic telemetry data (e.g., Lea et al. 2016). Analytical techniques for telemetry data are constantly evolving, therefore, we will also consider using novel statistical methods to analyze our data, such as state-space or multi-state models, should they become available during the course of the study. As appropriate, we will integrate information on sea surface temperature, bottom water temperature (measured hourly by each receiver), season (or month), water depth, photoperiod, and substrate type into all analyses to examine the influence of physical processes and environmental conditions on each metric.

The acoustic telemetry data can be evaluated across a range of spatial scales, depending on the scale of interest. To examine the factors that influence presence/absence of HMS at individual or groups of receivers, individual project areas, or the broader acoustic receiver array, we will construct a series of logistical regressions. Regressions will test whether a series of fixed or mixed effects (e.g., water temperature, month, photoperiod, distance from construction location, distance from inter-array cable or export cable, etc.) influence the presence or absence of a species (the response variable). External data collected on ambient noise levels may be included in these regressions, as appropriate.

To examine potential effects of construction and operation on HMS, all analyses will be structured around the following objectives and hypotheses:

Objective 1: Evaluate changes in HMS presence, residency, and movements between pre-construction, construction, and operation.

HMS presence in the southern New England has been documented to be driven by environmental (e.g., water temperature, photoperiod) or biological/physiological (e.g., ontogeny, thermal tolerance) factors. Thus, the presence, persistence, and movements of HMS in the Revolution Wind, Sunrise Wind, or South Fork Wind project lease areas likely varies naturally from month to month or year to year.

Accordingly, we will establish baseline, pre-construction levels for several standard metrics related to the presence/residency and movements for each species throughout the entire HMS receiver array including: minimum, maximum, and mean annual/seasonal residency times, presence in relation to environmental conditions (e.g., surface and bottom water temperature), nature of movement (e.g., long-term presence vs. transit/migratory corridor), and inter-annual patterns in presence/residency or movement (e.g., present in acoustic array annually, or sporadic, inconsistent presence over multiple years). These metrics will serve as the basis by which to examine the impacts (if any) of construction and operation of the Projects.

To examine impacts of construction or operation, the aforementioned metrics will be created for each species during the construction and operations (if appropriate) phases of each project. For example, decreased residency times or the avoidance of an area that is otherwise biologically or environmentally-suitable for a species may be an indication of spatial displacement resulting from construction or operational activities. In contrast, more frequent detection (observation) or extended residency times of HMS in certain areas may be indicative of aggregation in response to the presence of fixed structures such as wind turbines.

H_0: HMS presence and movements are driven by environmental features (e.g., water temperature, prey distribution) and animal biology or physiology and are not affected by construction or operation of offshore wind turbines or the presence and activity of electrical transmission cables.

Objective 2: Evaluate HMS connectivity among Ørsted lease sites.

Given the differing construction timelines of the Revolution Wind, Sunrise Wind, and South Fork Wind projects, individual acoustic receivers will be monitoring locations that are at different stages of project development (e.g., pre-construction, construction, operation). To examine potential effects of construction or operation on HMS presence and movements in adjacent Ørsted lease sites/project areas that are at an earlier stage of development, we will calculate the metrics outlined in Objective 1 for all projects in a given phase. For example, if construction has begun in South Fork Wind, we will compare the standard metrics for South Fork Wind to those of Revolution Wind and Sunrise Wind (which will still be in the pre-construction phase). If appropriate, we will employ the aforementioned logistic regression to test whether proximity to the construction site (e.g., linear distance away) impacts presence or avoidance for individual animals, or for species.

H_0: HMS presence and movements are driven by environmental features (e.g., water temperature, prey distribution) and animal biology or physiology and are not affected by construction or operation of offshore wind turbines or the presence and activity of electrical transmission cables.

Objective 3: Monitor tagged HMS at spatial scales greater than the Ørsted project areas

In addition to the local-scale acoustic monitoring achieved by the proposed HMS receiver array, regional or broad-scale movement data will be accomplished through data sharing with related HMS monitoring projects in other offshore wind lease areas, and through regional telemetry data sharing programs (e.g., MATOS, see Data Sharing section below). Our first priority will be to establish data sharing agreements with other developers that have established acoustic telemetry monitoring frameworks for HMS. Sharing transmitter metadata and acoustic detection data across projects will permit 1) the monitoring of a larger number of HMS in the Ørsted acoustic array, and 2) the monitoring of HMS tagged under this monitoring plan that are detected in adjacent receiver arrays in MA/RI or MA WEAs. Such data sharing will enable monitoring on a more regional level, which is more appropriate for highly mobile fishes, such as HMS, and this regional scale monitoring will help to elucidate cumulative impacts for these species. We will adjust the statistical tests and analyses presented herein to incorporate all available data and adjust the spatial and temporal extent of this broader monitoring plan as appropriate.

Participation in regional telemetry data sharing networks will allow us to obtain detection data from our tagged animals wherever else they are detected in the greater Atlantic region. Any detection data obtained through our participation in regional telemetry data sharing networks will be incorporated into our analyses as appropriate, particularly to examine the distribution and movements of species beyond the confines of Ørsted lease areas. Information on the presence of tagged HMS beyond the receiver array (in the Ørsted project areas) will be particularly important to evaluate whether the lack of detection/observation of an individual (or species) is due to the avoidance of the area (i.e., presence in some other region) or tag loss or mortality (i.e., lack of detection of a tag over extended periods provides evidence of tag shedding or mortality). This analysis will also help to better understand connectivity between offshore wind development areas and adjacent habitats throughout the Northwest Atlantic.

Data sharing - All detection data from Atlantic cod that were tagged as part of the BOEM-funded telemetry study will be provided to the Principal Investigators of that study, and the data can be evaluated to evaluate several metrics including site fidelity, residence times, and spatial distribution of cod throughout the Sunrise Wind, South Fork Wind, and Revolution lease areas. The high-resolution data collected using acoustic telemetry can be utilized to improve the understanding of cod habitat use and spawning behavior in the region. The year-round deployment of the receiver array will improve monitoring during the winter cod spawning season, which is a time period that is not well sampled by the existing fishery independent surveys, and for which there is limited fishery-dependent data collected for the recreational fishery. Given that the cod transmitters have an expected battery life of 1400 days, cod detections should be recorded throughout the duration of the study. Maintaining the receiver array over several years will provide valuable information of spawning site fidelity, interannual variability of habitat use, and the influence of offshore wind development on cod behavior.

All detection data for other species 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 this HMS monitoring effort and disseminate that information to the tag owners every six months (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 Ørsted lease sites at no additional cost. If a large amount of detection data is obtained for a given species over the course of monitoring, we will engage in conversations with the owner(s) of detected transmitters to explore the potential of adding those species to this monitoring plan. Thus, the choice to use acoustic telemetry in our monitoring framework provides the potential to expand the monitoring efforts described herein beyond HMS and Atlantic cod.

Due to the proven ability of acoustic telemetry to monitor a large number of animals over variable spatial and temporal extents, this technology has already been adopted in several wind energy-related projects along the US east coast. Given this, there is growing potential for coordination and data sharing (as well as cost sharing) across projects. However, in order to achieve efficient and successful coorination and data sharing, project leaders need to be aware of ongoing telemetry projects in the region and establish data sharing plans before or during the early stages of projects. To promote collaboration and coordination, a workshop is planned in Q4 2021 to bring developers and users of acoustic telemetry together and establish a set of 'best practices' for coordination and data sharing. From this workshop, a white paper will be drafted and published to serve as the basis for data sharing among offshore wind telemetry projects moving forward.

4.4 State Water Ventless Trap Survey – Export Cable

Revolution Wind will collaborate with researchers at the Rhode Island Department of Environmental Management Division of Marine Fisheries (RIDEM DMF) to execute a ventless trap study for lobsters, crabs, and fish in Rhode Island state waters along the RWEC route. RIDEM DMF will contract a local lobster vessel to execute the sampling. The cable route passes to Quonset Point from the offshore wind farm through federal and Rhode Island state waters. These waters provide habitat to a variety of commercially, ecologically, and culturally valuable fish and invertebrate species. Submarine cable installation can disturb sensitive habitats during construction and generate electromagnetic fields (EMF) during operation. Habitat disruption may include physical disturbance and increased turbidity, pollution, and noise, which are considered to be short-term impacts. EMF is generated for the life of the operation and is thus considered long-term impacts; however, uncertainty remains regarding the impacts of EMF (Taormina et al. 2018).

Physical disturbance to benthic habitats during installation or from cable mattressing will directly affect the species utilizing such habitat, while EMF may affect resident species and those transiting through the area. Given potential exposure, EMF sensitivity and habitat preference, species of primary interest include American lobster (*Homarus americanus*), Jonah crab (*Cancer borealis*), whelk (channeled: *Busycotypus canaliculatus*, knobbed: *Busycon carica*), black sea bass (*Centropristis striata*), and tautog (*Tautoga onitis*). American lobsters have demonstrated to be magnetoreceptive and exhibit an exploratory response over a high voltage direct current (HVDC) cable (Hutchison et al. 2020a), suggesting that benthic invertebrates should be focal species for future EMF work. Black sea bass and tautog are important species in both the commercial and recreational fisheries in southern New England that 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 and scup (*Stenotomus chrysops*) in the region.

The RIDEM DMF began a lobster ventless trap survey in 2006 as part of a regional effort to provide fisheries-independent abundance indices for juvenile lobsters (McManus et al. 2021). As part of this survey, lobster abundances are monitored in Rhode Island state waters (Narragansett Bay, Rhode Island Sound, and Block Island Sound). The RIDEM DMF Ventless Trap Survey (RIVTS) provides a substantial baseline dataset with which to compare cable survey results. However, given the stratification and random sampling nature of the survey design, this dataset alone is not sufficient for assessing prospective impacts from the cable. For this reason, a dedicated cable VTS is needed, but we propose to use similar sampling methodology to the RIVTS to provide regional comparison for the state waters and leverage overlapping spatiotemporal datasets when possible. A before-after-gradient (BAG) ventless trap survey will be conducted to collect pre-, during-, and post-construction data on lobster and crab resources in the proposed Revolution Wind cable corridor. The objective of this study is to evaluate the spatial and seasonal patterns of relative abundance of lobster and Jonah crab in the corridor area before, during, and after construction. In addition, the proposed study will classify the demographics of the lobster and Jonah crab resources (as well as any bycatch) including size structure, sex ratios, molt condition, reproductive status, and shell disease. Pre-construction data collected in this study may be used to assess whether detectable changes occur in the presence, relative abundance, or demographics of lobsters and crab resources during and after construction.

Considering the target species and the area to be sampled, a ventless lobster pot survey with some similarities to the RIVTS methodology will be carried out prior to, during, and after installation of the RWEC. This allows for additional RIVTS baseline data collected throughout Rhode Island state waters to be considered alongside cable-specific data collection and analysis. This survey will also include acoustic receivers attached to select lobster pots to evaluate area usage by tagged species, including various elasmobranchs and highly migratory species. The methods proposed herein have been developed using input from local fishermen, and may be refined following additional input from the fishing industry, namely the RI CRMC FAB.

4.4.1 Survey Design and Methods

The study will be conducted using a Before-After-Gradient (BAG) experimental design for direct effects, where samples occur along a spatial gradient with increasing distance from the cable. Use of a BAG design eliminates the need for identification of representative control areas and allows for assessment of spatial scale. Distance from the RWEC can be incorporated as an independent variable in analyses to explore changes in spatial relationships over time (Methratta 2020).

Sampling will occur twice per month at four locations at fixed locations along the cable route; locations will be selected based on depth strata, habitat type, and fishing industry input. Industry input will be essential in avoiding gear conflicts. Sediment type will also be considered in the selection of sampling locations; harder substrates may be associated with a lower likelihood of cable burial achieving target depth. At least one of the stations selected with industry input will be situated at or adjacent to an area where at least one of the cables did not, or is not expected to, achieve target burial depth. The number of locations and samples was evaluated using a power analysis and it was determined that a 10% change in lobster abundance would be detectible at greater than a 0.9 statistical power in both vented and ventless traps, which were evaluated independently (Appendix 4).

At each of the four sampling stations three six-pot trawls will be laid parallel to the cables (to the extent practicable) with the first trawl set between the two cables (or as close to the two cables as possible). The two additional trawls will be set in parallel from the first trawl (Figure 15). The trawl set on top of one cable or between the cables will serve as the impact distance bin, the trawls at 15 - 30 m distance will serve as the medium gradient, and the trawls 50 m or more away as the largest gradient, which is situated outside the EMF signal or sediment plume. These distances were selected based on modeled EMF outputs from the proposed cable design outlined in the Revolution Wind Construction and Operations Plan (Exponent, 2021). Setting trawls at the correct distance bins will come with some level of error; however, the survey will leverage the expertise of the commercial fishing captain to get as close to the target sampling locations as possible. These proposed distance bins are preliminary at this time and will be discussed with the fishing industry to determine feasibility of setting trawls at the desired spatial resolution.

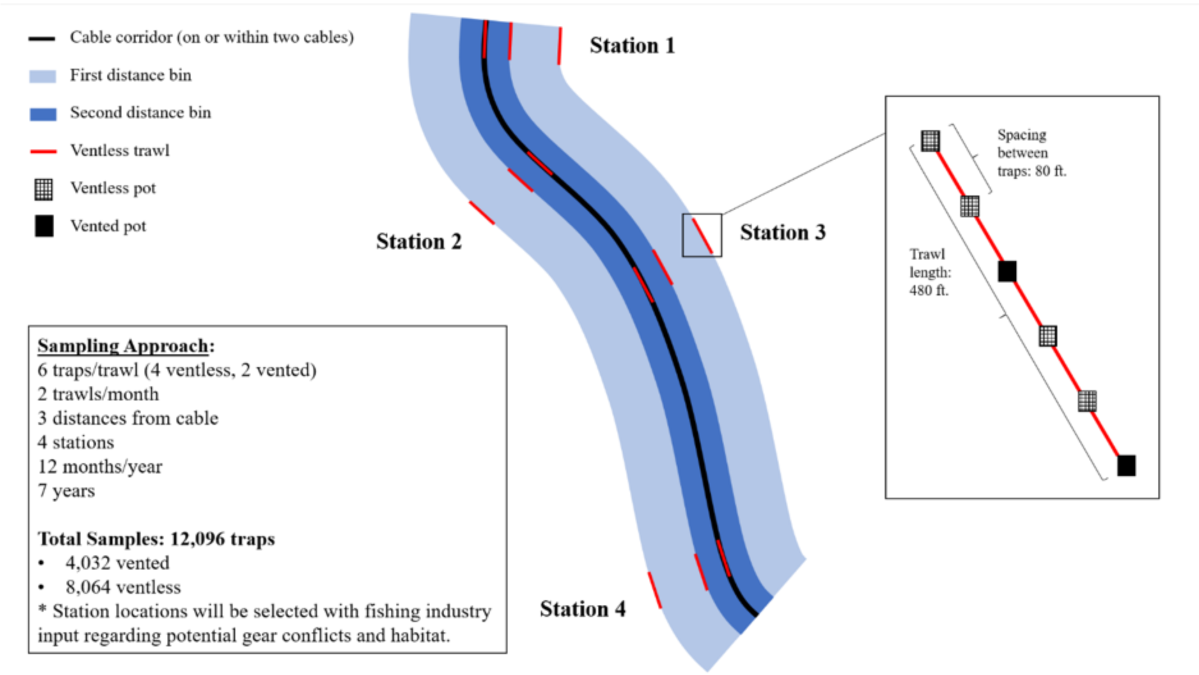


Figure 15. Sampling design schematic. Cable route, distance bins, and station locations are not representative of the actual experimental design but are presented to help conceptualize the study design. Sampling stations will alternate which side (east or west) of the RWEC the trawls are set on.

If at any time during sampling a trawl position is found to have poor conditions for setting fish pots (e.g., gear conflicts, high risk of the gear loss due to boat traffic) it may be moved to an alternative location within the same distance bin from the cables, as well as habitat and depth strata. Whether a trawl should be moved will be at the discretion of the vessel captain.

At each sampling station, lobster traps will be set to estimate CPUE for lobsters, Jonah crabs, and other species of interest to the recreational and commercial fishery. The gear at each station will comprise lobster traps (Figure 16) attached to a ground line, with each ground line end linked to up-and-down lines (or end line) that are attached to floats. These floats and end lines are used to haul the ground line and traps, referred to in its entirety as a ‘trawl’. There will be four ventless traps and two vented traps on each ground line, spanning over 400 ft of ground line, with traps separated from each other by approximately 80 ft (just under 14 fathoms). In the RIVTS, each trawl has three ventless traps, and three vented traps in an alternating pattern. Ventless traps are generally used to assess sublegal (or recruit) lobster abundances, while vented traps are used to compare abundances between ventless traps and a commercial trap (i.e., vented trap). However, given the focus of the proposed cable survey is to assess potential changes in abundance of lobster and other target species, each trawl will consist of four ventless and two vented pots. In the RIVTS, the vents are 5 ¾ inches wide and 1 15/16 inches tall, corresponding to vent regulations of Lobster Management Area 1, and as used in the MA VTS. Vents for the proposed cable survey could match that of Lobster Management Area 2 (5 ¾ inches wide and 2 inches tall), given the desire to also understand potential impacts to commercial catch. The RIVTS operates during the summer months in RI state waters. Sampling has been intended for the months of June, July, and August; however, in years where funding constraints delayed the project, sampling occurred in July, August, and September. In the case of proposed cable monitoring, a longer sampling period may be necessary to evaluate any potential changes in target species’ abundance in relation to the transport cables. Therefore, cable VTS sampling will occur all twelve months per year.

Lobster traps will be baited with bait chosen by the commercial fishing participant, per the RIVTS approach. The selection is typically the result of bait availability and/or using bait that will break down well and "fish" effectively. While bait types have varied through time for the RIVTS, the most common bait type that has been used is skates. Traps will be baited and left for five nights (i.e., 5-night soak). Each station will be sampled twice per month, following a typical schedule of baiting traps (sample day one), sampling traps and rebaiting them five days later (sample day two), and another sampling of traps five days after that and leaving the traps on site but not fishing (sample day three). Since gear will be left in the water while not fishing, gear rotation (or cooking pots) will be built into the sampling regime to avoid severe fouling on cages that may prevent traps from fishing correctly.

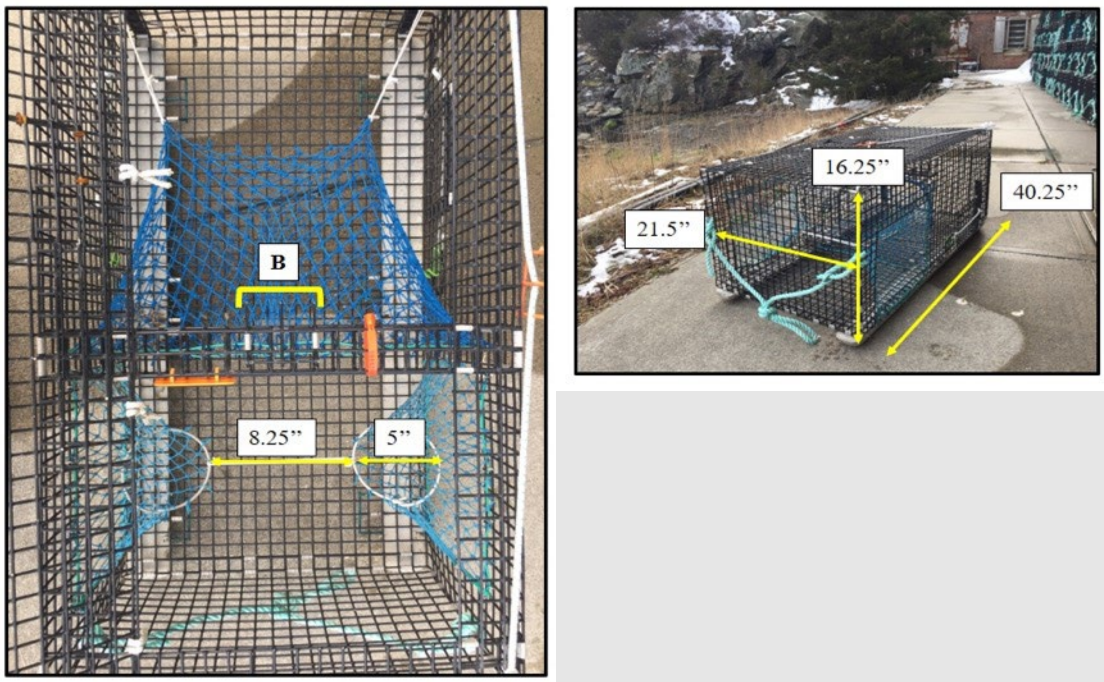


Figure 16. General trap configurations for a RIVTS trap. 'B' signifies where the bait is strung and hung into the kitchen. Length dimensions are in inches.

Acoustic receivers will also be attached to one trawl per station, on the trawl closest to the cables. These receivers will collect data during soak times and while gear is left unbaited in the water between sampling periods. Acoustic data collected will provide valuable information on tagged species utilization of the area before, during, and after construction, as well as during wind farm operation. A variety of electrosensitive species (i.e., elasmobranchs and highly migratory species) have been tagged in other studies and may move throughout the survey area. Elasmobranch species including white, sand tiger, and sandbar sharks, as well as winter skate have all been identified on the RIDEM acoustic receiver network. Other tagged species of interest documented in RI waters include Atlantic sturgeon, striped bass, and river herring. Furthermore, recent regional studies have tagged Atlantic cod, bluefin tuna, blue sharks, and shortfin mako sharks (see Section 4.3) which may also be detected if they move through the area. Starting in June 2021, striped bass, black sea bass, winter flounder, skates, and summer flounder will be tagged along the south coast of Long Island with acoustic transmitters as part of long-term telemetry study to investigate the potential impacts of the South Fork Wind export cable. Added acoustic receivers will broaden the suite of species addressed through the VTS and will collect data on area usage by other target species.

4.4.2 Biological Sampling

The catch will be sorted by species. All specimens from each trap (both fishes and invertebrates) will be identified, enumerated, and measured for size (when appropriate and with few exceptions). All catch data will be recorded at the trap level. Lobsters will have a suite of biological data collected. Lobster count, carapace length (mm), and sex will be recorded. Lobster conditions will also be recorded: shell hardness, shell disease state, egg stage for females bearing eggs, cull status (or claw damage), and V-notch presence (Table 8). Jonah and rock crab will be sexed, measured by carapace width (mm), presence/absence of eggs, molt condition, and shell disease state will be recorded. Fork length will be recorded for all fishes with a forked tail. Total length will be measured for all other fishes. Miscellaneous invertebrates (e.g., worms, hermit crabs, snails, spider crabs) will be counted but not measured. Any trap malfunctions or odd characteristics will be noted during the hauls.

Table 8. Lobster conditions

Condition	Stages
Shell hardness	Hard shell (3); Newly molted, paper shell (2); Soft shell (1)
Shell disease state	No disease (0); Less than 10% body coverage of disease (1); 11-50% coverage (2); >50% coverage (3)
Egg stage (for females bearing eggs)	Old, brown; new, dark green; gray/green; light gray/green with blue eyespots; tan/yellow with black eyespots; dead eggs; spent (formerly egg-bearing); unfertilized
Cull status (or claw damage)	Missing one or both claws; one or both claws small (recently regenerated); one or both claws limb buds; any combination of the above claw conditions
V-notch presence	Old or new v-notch, filled in (>1/8 inch or <1/8 inch); re-notched

Bottom temperature will be measured using HOBO temperature loggers attached to one of the middle traps in each trawl to record water temperature continuously throughout the survey period to understand how seasonal patterns in the catch correspond to environmental conditions.

A subset of lobsters and Jonah crabs will also be tagged with t-bar (anchor) and cinch tags, respectively. If anchor tags are used, lobsters greater than 40 mm in carapace length will be tagged using Floy anchor tags (inserted using a hypodermic needle, per the methods of Courchene and Stokesbury (2011). The anchor tags are retained during molting and will contain a unique identification number and a phone number for reporting recaptures. Knuckle tags may not be retained when crabs molt. Tagging will allow for evaluation of movement patterns of lobsters and crabs within seasons. RIDEM staff will consult with the Massachusetts Division of Marine Fisheries regarding tagging methods given their past experience tagging with the Atlantic Offshore Lobstermen's Association.

4.4.3 Ventless Trap Station Data

The following data will be collected during each sampling effort:

- MM/DD/YYYY
- Depth
- Station number
- Start latitude and longitude
- End latitude and longitude
- Sediment type
- Soak time
- Bait type used
- Bottom temperature
- Start time and date
- Start water depth
- End time and date
- Wind speed
- Wind direction
- Wave height
- Air temperature

4.4.4 Data Management and Analysis

The BAG ventless trap survey will provide pre-construction data on lobster and crab resources in the proposed cable route. The pre-construction monitoring data will be used to evaluate the spatial and seasonal patterns of relative abundance of lobster and Jonah crab in the area. The BAG survey design with sampling at increasing distances from the cables may also allow for characterization of pre-construction community structure of fish species associated with the cable area while examining the spatial scale of impacts on the surrounding habitat and associated fish species. Sampling during and after construction will allow for quantification of any changes in the relative abundance and demographics of the lobster and crab resources.

Analysis of the pre-construction data will be performed in accordance with the BOEM fishery guidelines. Input from the local fishing industry will be considered in the design of data analysis.The spatial distribution of the lobster and crab resources will be assessed for both years of pre-construction monitoring. Catch per unit effort statistics will be summarized for both lobster and Jonah crab, and length frequency distributions will be examined. Catch rates and length frequency distributions will also be provided for black sea bass, tautog, and scup. Regression tools, such as GLMs, GAMs, or mixture models of these (e.g. GLMMs, GAMMS), will be used to examine the influence of biotic and abiotic factors on the catch rates and distribution of lobster and Jonah crab. Spatial and temporal patterns in the biological data for lobsters (shell disease, sex ratios, reproductive status) will be summarized and reported. Results may be compared alongside RIVTS data to address representativeness to regional trends.

Acoustic receiver data will be analyzed and will be shared with the researchers that tagged each respective organism via the Mid-Atlantic Acoustic Telemetry Observation System (MATOS). Detection data can also be used to describe phenology of tagged species (i.e., ingress and egress during and after cable installation).

Crustacean tag data may be analyzed using a variety of geospatial methods in R, Python, or ArcGIS. Mapping and analysis of catch locations of tagged lobsters may help to determine variations in distribution and movement patterns.

Data collected through this survey effort and associated metadata will be accessible to the public via standard data request guidelines through the State of Rhode Island. Only data that have undergone quality assurance/quality control (QA/QC) and are considered final will be available for request.

4.5 Benthic Monitoring

Installation and operation of Offshore Wind (OSW) projects can disturb existing benthic habitats and introduce new habitats. The level of impact and recovery from disturbance can vary depending on existing habitats at the site (Wilhelmsson and Malm 2008; HDR 2020). Physical disturbance associated with cable and foundation installation can temporarily affect sediment and boulders, removing or damaging existing fauna. Over time (~3-10 years), the introduction of novel hard substrata (WTG surfaces, scour protection layers, and cable protection layers) can lead to extensive biological growth on the introduced surfaces with a complex pattern analogous to shoreline intertidal to subtidal zonation (artificial reef effect, Petersen and Malm 2009; Ruebens et al. 2013; Degraer et al. 2020). Depending on the community composition and density, this biological growth may lead to substantial shifts in the transfer of energy from the water column to other compartments of the ecosystem including the sediments and upper trophic levels.

Observations from existing OSW projects lead to four prevailing hypotheses of likely benthic effects resulting from the development of Revolution Wind:

1. Introduction of novel surfaces that extend from the intertidal to the seafloor (foundations and scour protection layers) will develop epifauna that vary with depth and change over time.

2. Relocation of existing natural hard bottom habitats (boulders) will alter physical habitat characteristics (rugosity, complexity, density) with potential for rapid colonization of relocated boulders.

3. Enrichment of seafloor conditions from the WTG artificial reef effect will lead to fining and higher organic content of surrounding seafloor habitats (1-250 m from WTG) over an intermediate time frame.

4. Physical disturbance of soft sediments from cable installation will temporarily disrupt function of infaunal community with rapid return to pre-disturbance conditions.

The consequences of these predicted effects may affect the role of soft and hard bottom habitats in providing food resources, refuge, and spawning habitat for commercial fish and shellfish species (Reubens et al. 2014; Krone et al. 2017). This operational monitoring plan is organized according to these four prevailing hypotheses associated with the Revolution Wind project and describes the overall approach to tracking changes in the benthic habitats associated with OSW development. A comprehensive outline of the benthic monitoring plan, including the hypotheses, sampling schedule, and general approach for each component is provided in Figure 17.

Hard bottom habitat monitoring, at turbine foundations and the surrounding seafloor, scour protection layers, and relocated boulders, will focus on measuring changes in percent cover, species composition and volume of macrofaunal attached communities (native and non-native species groups) and physical characteristics (rugosity, boulder density). These parameters will serve as proxies for resulting changes in the complex food web, specifically abundance, diversity and biomass (conversion from volume). It is expected that increased biomass of filter feeders inhabiting the novel OSW hard surfaces will facilitate the export of organic material from the water column to the benthos and to higher trophic levels.

Soft bottom habitat monitoring will focus on measuring physical factors and indicators of benthic function (bioturbation and utilization of organic deposits, Simone and Grant 2020), which will serve as a proxy for functional changes in the community composition. It is expected that the introduction of fines and organic content sourced from the epibenthic community on the WTGs will support increased deposit feeding benthic invertebrate communities in the soft sediments around the WTGs. The monitoring approach can support rapid data collection and analysis, will provide quantitative data, and lead to data needed to inform effective management actions (mitigation). This monitoring plan is not designed to answer research questions about specific causes and effects on individual species.

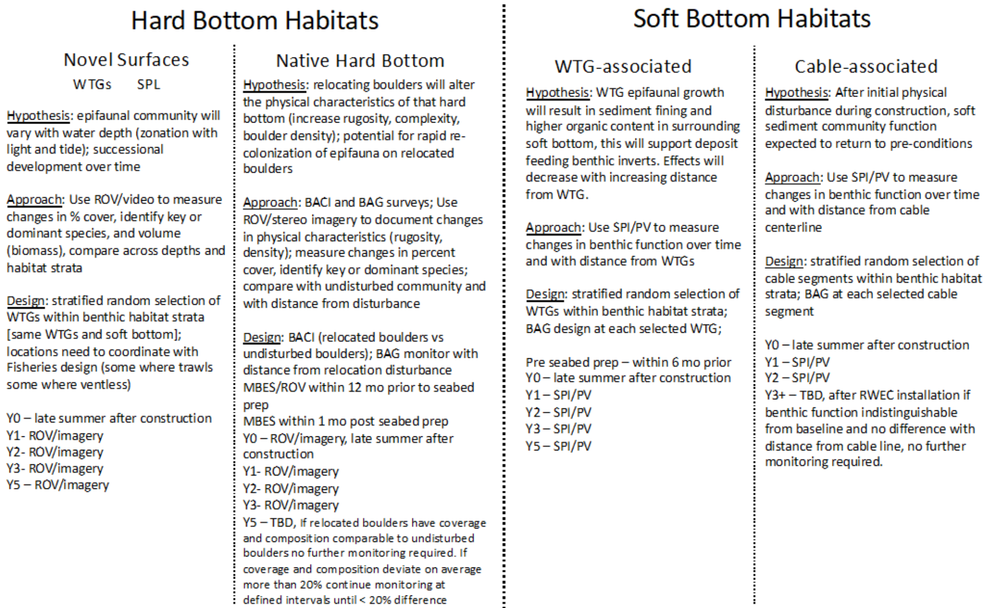


Figure 17. Summary of the benthic monitoring plan including hypotheses, approach, and sampling schedules for each component

4.5.1 Hard Bottom Monitoring – Novel and Native Habitats

Hypothesis 1: Introduction of novel surfaces that extend from the intertidal to the seafloor (foundations and scour protection layers) will develop epifauna that vary with depth and change over time.

Hypothesis 2: Relocation of existing natural hard bottom habitats (boulders) will alter physical habitat characteristics (rugosity, complexity, density) with potential for rapid colonization of relocated boulders.

The hard bottom monitoring will include an examination of two habitat components: novel surfaces and native hard bottom habitats. The primary objective of the hard bottom monitoring is to measure changes over time of the nature and extent of macrobiotic cover of hard bottom associated with OSW development. Specifically, the epifa unal growth on novel hard surfaces (turbine foundations, scour protection layers) will be monitored over time. Biological features associated with any natural hard bottom at the base of the foundations and the surrounding seafloor will also be monitored. In addition, the recolonization of boulders relocated during seafloor preparation for cable installation will be assessed by comparing with epifaunal communities extending away from the habitat directly impacted by seabed preparation and on nearby undisturbed boulder areas.

For both components (novel and natural hard bottom habitats), the primary objective is to monitor for changes to the biological attributes of the habitats. Macrofaunal percent cover, identification of key and dominant species, and the relative abundance of native and non-native organisms will be documented (see Section 4.5.5.1 for detailed list of metrics) on the selected novel structures and natural hard bottom habitats using a Remotely Operated Vehicle (ROV) and optical monitoring approach. Distinguishing non-native organisms will likely require physical sampling for accurate identification, which will be facilitated by a sampling arm attached to the ROV.

It is expected that the epifaunal community that colonizes the WTG foundations will vary with water depth, dictated by the availability of light and tides, similar to zonation patterns commonly observed at rocky intertidal habitats. Previous studies have found biological growth has led to dense accumulations of filter feeding mussels on the turbine foundations followed by amphipods, tunicates, sponges and sea anemones in the subtidal in Europe (De Mesel et al. 2015) and at the BIWF (HDR 2020; Wilber et al. 2020; Hutchison et al. 2020b). Other studies have tracked and documented vertical zonation of epibenthic communities along the surface of wind turbine structures (Bouma and Lengkeek 2012; Hiscock et al. 2002; HDR 2020). At any given depth of the WTG foundation structure, the epifaunal species composition is expected to develop successionally, with rapid opportunistic organisms pioneering the structure and being replaced by more long-lived established species. Tracking the changes in species composition and density (percent cover) will inform predictions about changes in prey availability to fish and will be integrated with results of the stomach content data for black sea bass and summer flounder obtained during the fisheries monitoring surveys.

The second objective of the hard bottom survey is to characterize changes to the physical and biological attributes of natural hard bottom habitats, specifically hard bottom habitats surrounding the WTG foundations and in areas disturbed by seabed preparation (boulder relocation) for installation of the IAC. The following metrics will be examined; rugosity, boulder height, boulder density, epifaunal percent cover, species composition, and relative contribution of non-native taxa to the community (see Section 4.5.5.1 for detailed list of metrics from each imagery stream). Preparation of the seafloor (i.e., boulder relocation) for installation of the WTGs and IAC is expected to create clusters of natural hard bottom habitat subject to epifaunal recolonization. These discrete areas will likely have increased rugosity and boulder density which can provide structural complexity and refuge for finfish and decapods. These physical habitat attributes, which are not expected to return to pre-project conditions, have direct links to the level of use of these habitats by commercial finfish and decapods. This survey objective will be accomplished using a high-resolution acoustic surveying approach coupled with ROV/imagery collection.

4.5.1.1 Hard Bottom Survey Design Overview

An acoustic and ROV imagery monitoring approach is planned to monitor hard bottom substrata within subareas of the RWF project area. These substrata include introduced novel habitats (turbine foundations, scour protection layers), directly and indirectly disturbed natural hard bottom habitats (natural hard bottom habitats at segments of the IAC where boulders were relocated and surrounding WTG foundations), and undisturbed natural hard bottom habitats. The same turbines that will be selected for the soft sediment monitoring will be monitored as part of the hard bottom survey (stratified random design, with benthic habitats as strata, see Section 4.5.2.6). This will help facilitate synthesis between the degree of enrichment in the surrounding soft sediments and the epifaunal community composition and density colonizing the turbine foundations at any given time and location. At the selected WTG locations and along segments of the IAC that are installed within natural hard bottom habitat, stereo-camera imagery and SPI/PV imagery will be used, in combination, to document potential indirect effects of cable and WTG installation resulting in shifts in biological attributes of the natural hard bottom habitat.

The sampling schedule for the hard bottom component will mirror the WTG soft bottom habitat monitoring schedule (Figure 17). Monitoring using ROV and underwater imagery at the novel habitats and native hard bottom will occur after construction is complete during late summer/fall timeframe, and sampling will be repeated at time intervals of 1, 2, 3, and 5 years after construction. Sampling will occur during late summer or fall to capture peak biomass and diversity of benthic organisms in alignment with previous studies. Existing benthic data from the

North Atlantic in the vicinity of the RWF project site 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 2020; NYSERDA 2017; Stokesbury 2013, 2014; LaFrance et al. 2010, 2014). Benthic habitats, particularly hard bottom habitats, in the northwest Atlantic are generally stable with little seasonality in the absence of physical disturbance or organic enrichment (Steimle 1982; Reid et al. 1991; Theroux and Wigley 1998; HDR 2020).

The selection of WTGs, segments of the IAC within natural hard bottom (where boulder relocation was required), and regions of undisturbed hard bottom will be informed by the habitat mapping results and directed acoustic surveys and is described in more detail below (Section 4.5.1.3 and 4.5.1.4). Multibeam Echosounder (MBES) and side-scan sonar (SSS) surveys will be used to map hard bottom habitat (as informed by the habitat mapping results) within 12 months before installation (timed to avoid conflict with other surveying activities in the project area) and again within one month after seabed preparation is complete (Figure 17). The sampling area selection will be based on these detailed before-after acoustic maps; areas with modified boulder density (boulders > 1 m in diameter) will be identified to form the sampling frames for the ROV imagery survey, as well as to characterize overall changes to the physical habitat attributes within the areas surveyed. Underwater imagery will be used to monitor the selected undisturbed and relocated boulder habitats along the IAC approximately one month after seabed preparation (i.e., boulder relocation) has been completed, and again at 1, 2, 3, and 5 years post construction (Figure 17). This design is based on an understanding of the rate 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 RWF project area.

4.5.1.2 Acoustic and ROV Approach

To accomplish the objectives of the hard bottom monitoring, high resolution acoustic data and underwater imagery (HD video imagery and UHD stereo imagery) captured using an ROV will be employed. Multibeam acoustic data will be used to map the physical characteristics of the hard bottom habitats prior to and after boulder relocation. Underwater imagery will be used to document epifaunal community characteristics on the hard surfaces (WTGs, scour protection layers, undisturbed boulders and relocated boulders).

Along the randomly selected turbine foundations, state of the art underwater video and stereo imagery will be collected at predefined depth intervals and analyzed using photogrammetry methods. Photogrammetry is the process in which images are interpreted to provide detailed information about the physical objects observed in space. Photogrammetry generates high-resolution, photo-realistic 3D models from static images captured from multiple perspectives. By digitally reconstructing segments of the WTG foundations, the resulting model can be analyzed for quantitative variables including percent cover, standing biomass, and abundance of individual taxa of interest (as reviewed in Marre et al. 2019). Using imagery to construct spatial photogrammetric models of segments of the WTGs soon after construction will provide initial reference conditions that can be used to track biological changes over time following subsequent years of data collection. Biological data obtained through photogrammetry will be used to estimate ecological functions including secondary production, and physiological rates such as biodeposition associated with the epifaunal community. These biological processes have implications to the transfer of energy to higher trophic levels and to the sediments and habitats at the base of the WTGs. This approach will provide an estimate of the increase in standing stock biomass at the basal trophic levels where filtering feeding epifauna (e.g., blue mussels, sea squirts) exist. This information can inform ecosystem models that seek to understand how these changes to the basal trophic level may alter food web dynamics, objectives that are beyond the scope of this monitoring plan.

4.5.1.3 Sampling Stations – Novel Surfaces

The same turbines that will be randomly selected for the soft sediment survey will be monitored as part of the hard bottom survey (stratified random design, with benthic habitats as strata, see Section 4.5.2). Turbine foundations will be selected for monitoring in triplicate within each of the three main habitat types: coarse sediment (complex), sand and muddy sand + mud and sandy mud (soft bottom), and Glacial Moraine A (large-grained complex), as informed by the benthic habitat mapping results (Figure 19) (INSPIRE 2021). Although, the number of WTG replicates within each habitat type, particularly the large-grained complex habitat type, may be less than three due to the potential limited number of WTGs constructed in this habitat following micrositing.

Within one month after all WTGs have been installed, an ROV will be used to collect reference imagery of the underwater surface of the turbine foundations and the benthic habitats extending away from the WTG along transects on the surrounding seafloor. The survey will be repeated at annual intervals indicated in Figure 17, coinciding with the soft bottom SPI/PV survey. These visual surveys of the foundations will occur around the circumference of the structures and at different elevations from the sediment surface (including the scour protection layer and extending 250 m from the base of the foundation) to the water surface.

The entire WTG foundation will be scanned during each sampling event. Continuous stereo imagery will be collected down the length of the selected foundations to provide general context on the community composition and how and where dominant species shift with deptha. Then, UHD imagery will be randomly subsampled at depth intervals (four replicate subsamples per depth stratum) within pre-defined depth intervals as informed by the initial continuous footage. These depth intervals will be dependent on the community composition shifts with depth as seen in the continuous footage. The UHD images will be used to identify organisms to the lowest taxonomic level. The stereo imagery will be used to construct 3D models of each WTG foundation to derive an estimate of biomass or biovolume.

Data will be collected on the percent cover of macrofauna and macroalgae, composition of native and non-native organisms, and distribution of key suspension feeding organisms that could contribute to benthic enrichment (e.g., mussels, tunicates, tube-building amphipods, etc.). This information on the epifaunal community will be considered as explanatory variables for the magnitude and range of benthic enrichment observed in the soft bottom habitat surrounding the turbines.

4.5.1.4 Sampling Stations – Natural Hard Bottom Areas

The primary objective for this component of the hard bottom survey is to measure changes over time in the nature and extent of macrobiotic cover in both disturbed and undisturbed natural hard bottom areas (along the IAC and at the base of the foundations). A secondary objective is to characterize overall changes to the physical attributes of the hard bottom habitat resulting from seabed preparation.

Underwater imagery will be collected using an ROV beyond the base of each selected WTG foundation, particularly at the WTGs selected within complex, hard bottom habitat strata. Following the scan of the WTG foundation (Section 4.5.1.3), the ROV will transit from the base of each foundation away from the turbine collecting imagery of the surrounding benthic habitats. The ROV will collect UHD stills and HD video imagery along the seafloor in the benthic habitats surrounding each selected WTG foundations. Imagery transects will extend from the base of each sampled turbine out to 250 m from the end of the scour protection mat. This continuous imagery will be supplemented by the SPI/PV imagery that will be collected at stations in a BAG design at each selected turbine as described in Section 4.5.2. The underwater imagery collected by the ROV will be used to assess the biological and physical characteristics of any natural hard bottom habitats surrounding the base of the WTG foundations while the SPI/PV stations will be useful in characterizing any natural soft bottom habitat surrounding the WTGs.

Benthic habitats at the RWF include areas with scattered boulders and cobbles on sandy substrata (Glacial Moraine A) (INSPIRE 2021). Within the areas targeted for seafloor preparation (IAC routes), directed acoustic surveys will be conducted prior to and after seafloor preparation activities are completed. Detailed maps derived from these acoustic data will be used to identify areas where boulders were undisturbed after seafloor preparation and areas where boulders were relocated directly adjacent to the prepared IAC route (i.e., disturbed hard bottom). A single sampling frame will be identified within each of the selected disturbed and undisturbed boulder areas; selection will be based on habitat type, derived from the benthic habitat mapping results (INSPIRE 2021), and will consist of two replicates per habitat type where seafloor preparation occurred as possible (Figure 18).

At each selected sampling frame underwater imagery will be collected both in a BAG design and along a transect parallel to the disturbance corridor (boulder relocation) (Figure 18). This will allow for monitoring of the recolonization of specific relocated boulders and for the monitoring of any changes in epifaunal community composition on undisturbed hard bottom habitat extending from the relocation activity (assessing potential indirect impacts).

Initially, the ROV will transit parallel to the disturbance (boulder relocation) corridor and collect imagery of discrete relocated boulders. A systematic random sample of 20 boulders will occur within each sampling frame of paired disturbed/undisturbed areas, as described in more detail below. This type of non-probability (opportunistic) sampling will provide biological characteristics within these areas but does not allow inference to the windfarm in general. The boulder sampling will be conducted at regular distance intervals within each sampling frame (5 m wide and 200 m or more in length) within each selected area (one each in disturbed/undisturbed areas with at least two targeted WTGs within each habitat with boulders), placed to capture sufficient density of boulders. The ROV will progress along the centerline of each frame sampling boulders at 10m intervals until approximately 20 boulder samples have been obtained. The final target sample size will be informed by the results of the boulder relocation survey that will be performed at South Fork Wind. Boulders may not be present at every planned distance 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 percent cover will be estimated 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, percent cover of native and non-native species, and species composition from the ROV survey.

Underwater imagery will also be collected (continuous ROV stereo imagery) in a BAG design to assess indirect impacts associated with boulder relocation activity. To assess effects of boulder relocation on the surrounding benthic habitats, underwater imagery will be collected along triplicate transects positioned perpendicular to the selected segments of the IAC corridor where boulder relocation occurred (Figure 18). These data will be analyzed for the same biological parameters described above.

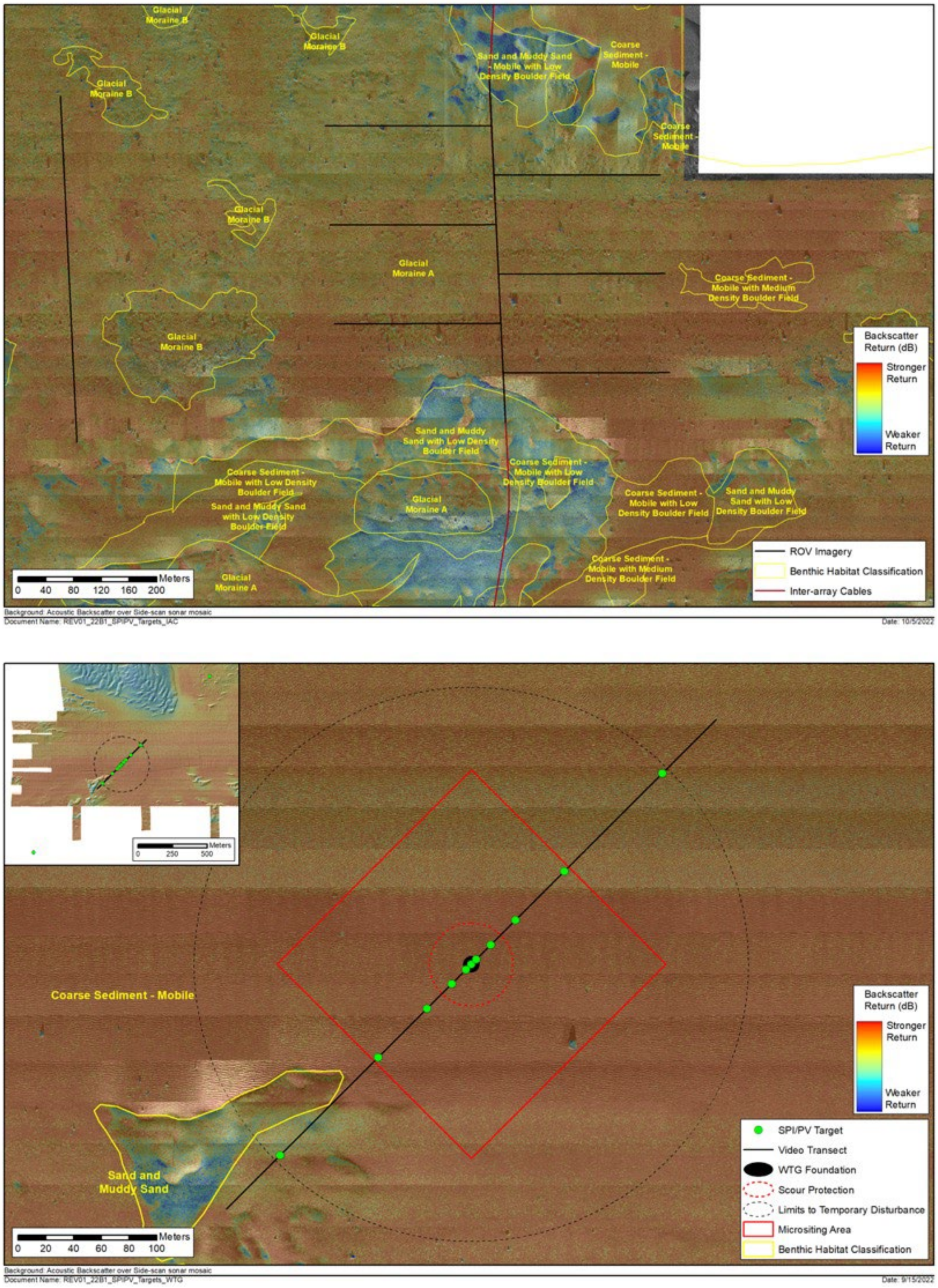


Figure 18. Example hard bottom benthic survey sampling designs where stereo imagery will be collected along the IAC where boulder relocation may occur (Glacial Moraine A) (top) and a combination of stereo imagery and SPI/PV will be collected on the seafloor surrounding a WTG within coarse sediment (relatively high backscatter)(bottom) .

4.5.2 Soft Bottom Monitoring

Hypothesis #3: Enrichment of seafloor conditions from the WTG artificial reef effect will lead to fining and higher organic content of surrounding soft bottom habitats (1-250m) over an intermediate time frame.

Hypothesis #4: Physical disturbance of soft sediments from cable installation will temporarily disrupt function of infaunal community with rapid return to pre-disturbance conditions.

The overall objective of the soft bottom monitoring survey is to measure potential changes in the benthic function of soft bottom habitats over time and with distance from the base of the WTGs and RWEC centerline. Specifically, benthic functioning of the soft bottom habitats will be captured by documenting physical parameters (grain size major mode) and biological factors (bioturbation and utilization of organic material) with a SPI/PV imaging system. It is expected that the epibenthic community that colonizes the WTG foundations will supply organic matter to the sediments below through filtration, biodeposition, and general deposition of detrital biomass. This organic material sourced from the activity of the epibenthic community on the turbine foundations will likely alter the infaunal community activity, increasing sediment oxygen demand and promoting the activity of deep-burrowing infauna. The effects of the WTG foundation on the surrounding soft sediment habitat are expected to decrease with increasing distance from the WTG.

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, physical changes, and recovery from physical disturbance following the construction and during operation of RWF and RWEC. Additionally, PV data will characterize surficial geological and biotic (epifaunal) features of hard-bottom areas within the sampling area but will not replace a dedicated hard bottom monitoring survey (ROV/stereo imagery) (Section 4.5.1). In addition to characteristics associated with site assessment and Coastal and Marine Ecological Classification Standard (CMECS) descriptors, the SPI/PV system will collect quantitative data on measurements associated with physical and biological changes related to benthic function (bioturbation and utilization of organic material) that might result from construction and operation of RWF. Details of these measurements are in Section 4.5.5.2 and are standard tools for assessment of response to disturbance and enrichment (Germano et al. 2011).

4.5.2.1 Survey Design Overview

The soft bottom habitat monitoring will be conducted using a BAG survey design to determine the spatial scale of potential impacts on benthic habitats and biological communities within the RWF site (Section 4.5.2.3) and along the RWEC (Section 4.5.2.4). A single benthic survey will be conducted in late summer (August to October), about six months prior to the start of seabed preparation for construction to document benthic habitats prior to potential disturbance at WTGs and along the RWEC. It is expected that final locations of the WTG's and the planned RWEC route will be known prior to the six-month period before construction so sampling sites can be selected for the survey. Subsequent surveys will be conducted in the same seasonal time frame at one-year intervals for three years, and at five years after completion of construction (Figure 17). Sampling will occur during late summer or fall to capture peak biomass and diversity of benthic organisms in alignment with previous studies. Existing benthic data from the North Atlantic in the vicinity of the RWF project site 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 2020; NYSERDA 2017; Stokesbury 2013, 2014; LaFrance et al. 2010, 2014). Benthic habitats in the northwest Atlantic are generally stable with little seasonality in the absence of physical disturbance or organic enrichment (Steimle 1982; Reid et al. 1991; Theroux and Wigley 1998; HDR 2020). Further details on the survey designs associated with the sampling at the base of the WTGs and along the RWEC are provided in Sections 4.5.2.3 and 4.5.2.4, respectively.

4.5.2.2 SPI/PV Approach

Monitoring of soft bottom habitats using SPI/PV will focus on measuring physical changes and indicators of benthic function (i.e., bioturbation and utilization of organic deposits) as a proxy for measuring changes in community composition. SPI/PV will be used as the monitoring approach for the soft sediment habitat surveys to capture potential changes in sediments in relation to sediment fining and organic material processing. The SPI and PV cameras are state-of-the-art monitoring tools that capture benthic ecological functioning within the context of physical factors through high-resolution imagery over several meters of the seafloor (plan view) and the typically unseen, sediment–water interface (profile) in the shallow seabed. The SPI/PV imagery approach is more cost effective and comprehensive than benthic infaunal sampling approaches. 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, this approach supports higher spatial density as a result.

In addition to allowing for greater spatial resolution facilitated through lower operating costs compared to sediment grab samples, SPI/PV imagery provides the ability to document aspects of the sediment architecture that is entirely missed during benthic infaunal sample collection. This spatial and contextual information, such as oxygen penetration depths (apparent redox potential discontinuity [aRPD] depth), infaunal bioturbation depths, and small-scale grain size vertical layering are critical pieces to assessing the ecological functioning of soft sediment habitats. Specifically, ecological functions related to organic matter processing, secondary production, and the forage-value of the benthic community are of particular importance when assessing impacts of OSW development on soft sediment habitats. Taxonomic analysis of sediment grab samples provides information on the benthic community composition (specifically, which species are there) and infaunal abundances at any given location and time. But, without making substantial inferences to relate presence and species counts to activity, the sediment grab approach is severely limited in its ability to assess impacts of OSW development to soft sediment functioning. Further, given the inherently dynamic and patchy nature of infaunal populations, benthic community count data generally requires extensive replication, substantial transformations for normalization, and overextending inferences to relate species composition to function. SPI/PV imagery provides an effective snapshot of the overall ecological health and condition of the sediments as reflected and integrated over time and space by the continuous activity of the infaunal and epifaunal communities present (Germano et al. 2011). It is this holistic community activity, not necessarily the identity of community members, that requires careful assessment to determine impacts of OSW on soft sediment habitats.

4.5.2.3 Sampling Stations – Seafloor Surrounding Turbine Foundations

The objective for the soft bottom benthic survey at the base of the turbine foundations is to measure changes over time in the benthic habitat and physical structure of sediments along a spatial gradient. This survey was designed to investigate the hypothesis that colonization by epifaunal filter feeders on the turbines will result in changes to the surrounding benthic habitat by supplying organic matter to the sediment through filtration, biodeposition, and general deposition of detrital material. Enrichment of seafloor habitats from the artificial reef effect is expected to be most pronounced down current and weaker up current. It is expected that evidence of sediment enrichment will dissipate with distance from the WTG bases.

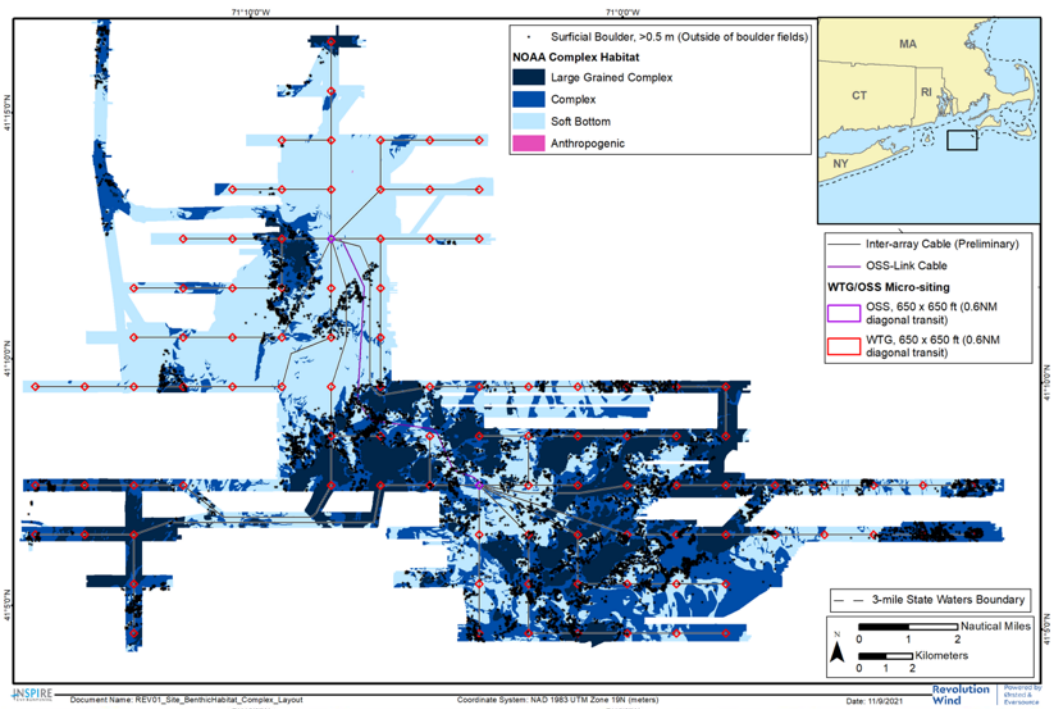
To accomplish the objective of this survey, data will be collected before and after installation and operation of RWF using a BAG survey design with statistical evaluation of the spatial and temporal changes in the benthic habitat (Underwood 1994; Methratta 2020). This BAG design is based on an understanding of the complexities of habitat distribution at RWF (INSPIRE 2021), and an analysis of benthic monitoring results from European wind farms and the RODEO study at BIWF (HDR 2020; Coates et al. 2014; Dannheim et al. 2019; Degraer et al. 2018; LeFaible et al. 2019; Lindeboom et al. 2011). 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).

SPI/PV surveys have been previously conducted within the RWF and along the RWEC to provide detailed assessment of benthic habitat for EFH consultation (INSPIRE 2020; INSPIRE 2021). The detailed information on habitat distribution at RWF will be used to design the surveys specified in this and the following section (RWEC sampling). By design, the turbine locations at RWF will be sited to avoid placement in close proximity of hard bottom habitat. Mapping of benthic habitat types within 200 m of each planned RWF turbine location include predominantly sand and muddy sand (soft bottom) (67%), coarse sediment (complex habitat)(24%), and mud and sandy mud (soft bottom) (6%) (Figure 19). Despite these habitat types cumulatively accounting for 97% of the 200 m WTG buffers, the benthic survey of the seafloor surrounding the WTGs will focus on all mapped benthic habitat types where WTGs are installed, with sand and muddy sand habitat type grouped with mud and sandy mud habitat type. Sampling transects will be specifically sited to avoid adjacency to the IAC route; monitoring the potential effects of a buried power cable is the focus of a separate survey (Section 4.5.2.4).

A stratified random sample of turbines will be selected, with the strata determined by benthic habitat type. There will be three habitat type strata: (1) sand and muddy sand + mud and sandy mud (soft bottom habitat); (2) coarse sediment (complex habitat); and (3) Glacial Moraine A (large-grained complex habitat). The target is to sample at least three turbine locations within each of the benthic habitat strata. However the number of turbines constructed in Glacial Moraine A after micrositing may limit the number of replicates available for sampling withgin that habitat strata. The selected turbines, transect positions, and distance bands will remain fixed for the duration of the survey (see below).

It is expected that the most pronounced sediment enrichment and impacts from WTGs on the surrounding seafloor habitats will occur in alignment with the prevailing currents in the area, and as such the station design will consider these currents. Current meter data collected for the RI Ocean SAMP indicated that monthly mean currents near RWF are relatively strong from March through October and generally to the west-southwest (Ullman and Codiga 2010). Two belt transects (25 m wide) of SPI/PV stations will be established to the northeast (up current) and southwest (down current) of each of the selected turbine locations to avoid IAC locations (Figure 20). If additional current data is available prior to construction the alignment will be adjusted. Pre-construction transects will begin at the center point of the planned WTG foundation with two stations at equal intervals up to the maximum planned extent of the scour protection area and then at intervals of 0-10 m, 15-25 m, 40-50 m, 90-100 m, 190-200 m, and 900 m 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 20). 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 2020). The turbines are proposed to be built in a regular grid pattern, with 1 nautical mile spacing between adjacent turbines. The maximum sampling distance (900 m) was selected to cover half of the (diagonal) distance between adjacent turbines. These 900 m 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 directly associated with the enrichment hypothesis adjacent to the turbines.

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



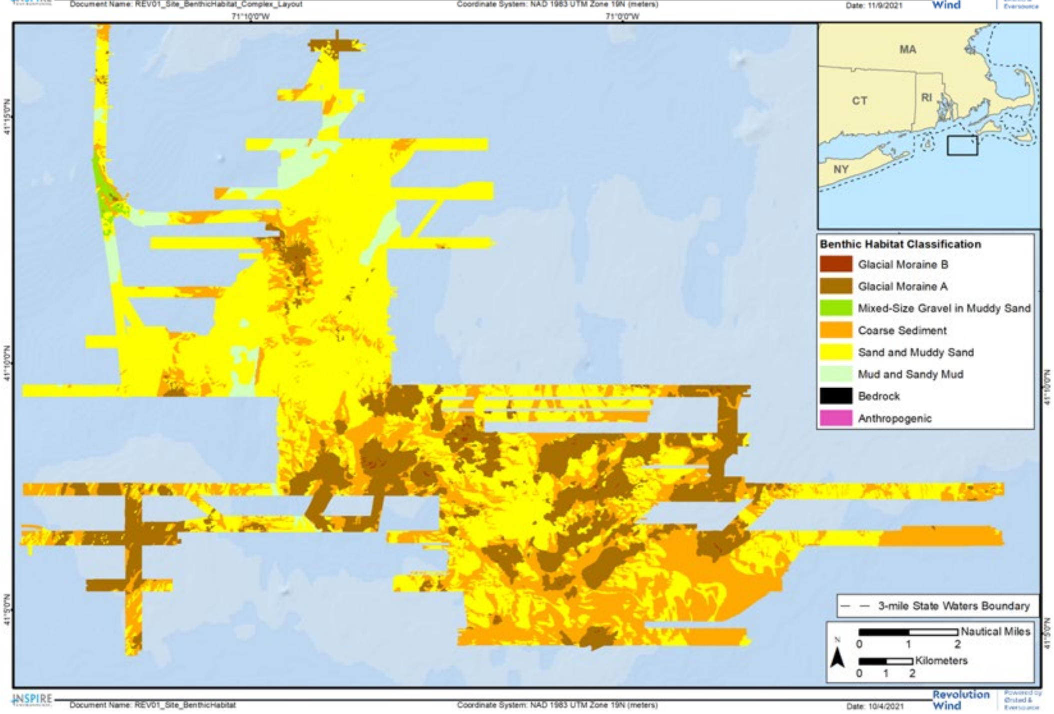


Figure 19. Benthic habitat types mapped at the RWF, categorized using the NOAA categories focused on the degree of complexity (top) and based on benthic habitat classification defined in INSPIRE 2021(bottom). Turbine foundations will be selected for monitoring in triplicate within each of the three main habitat types: coarse sediment (Complex), sand and muddy sand (Soft Bottom), and Glacial Moraine A (Large Grained Complex).

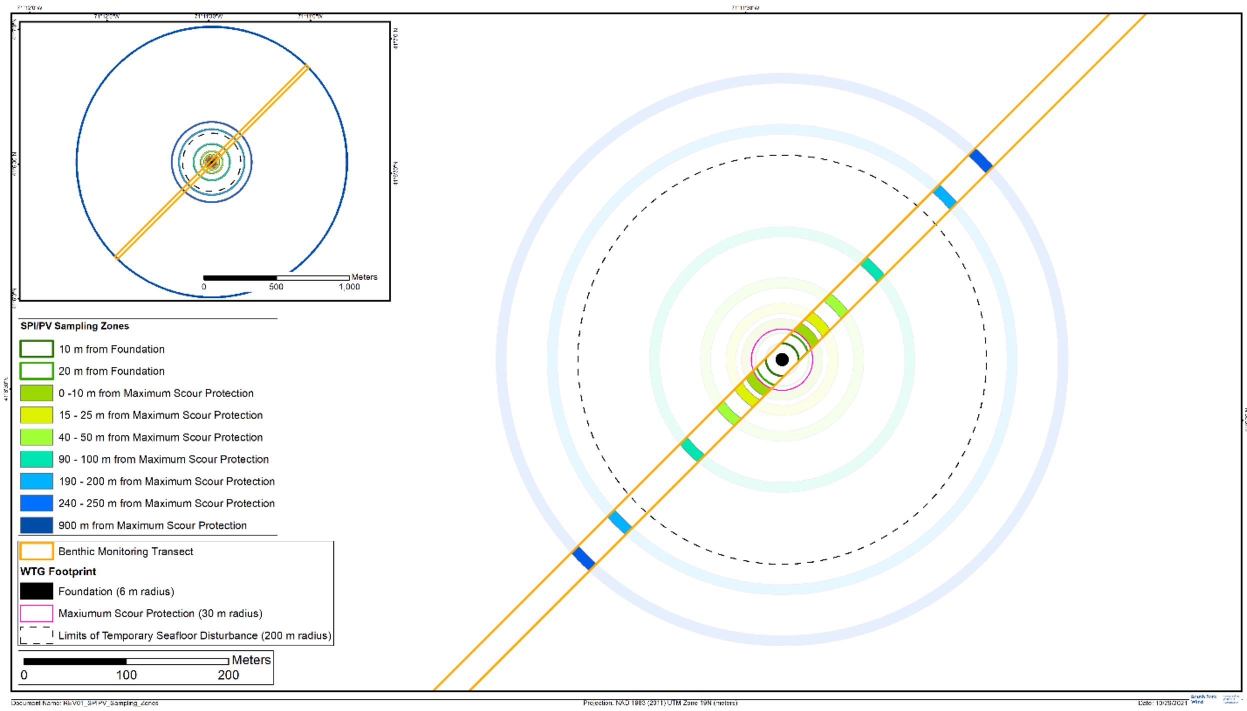


Figure 20. Conceptual diagram of the benthic SPI/PV survey sampling distances on the seafloor surrounding a WTG foundation.

4.5.2.4 Sampling Stations – Export Cable (RWEC)

The objective for the soft bottom benthic survey along the RWEC is to examine the effects of installation and operation of an export cable on the benthic habitat over time and along a spatial gradient with distance from the cable centerline. Any effects of installation and operation of the cable are expected to be roughly equivalent along the length of the cable within similar benthic habitat types. The primary effect of cable installation in the corridor is physical disturbance of the sediment with minor sediment resuspension and temporary loss of infauna. Some effects associated with the 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 RWEC route. Any potential impacts of the cable on soft bottom habitats are expected to decrease over time after installation and with distance from the RWEC.

To accomplish the goals of this survey, SPI/PV data will be collected about six months prior to construction, after installation, and during operation of the RWEC at selected locations, using a BAG design like that proposed for the turbine foundations (Section 4.5.2.3) (Underwood 1994; Methratta 2020). The benthic habitats along the RWEC were documented previously during the baseline benthic characterization survey in 2019, which followed BOEM guidelines for sampling design (BOEM 2019b; INSPIRE 2020) Another year of pre-construction data will be collected using a BAG survey design, which will provide robust, pre-construction baseline data along the cable route that will inform our understanding of benthic habitat recovery following cable installation. Details describing the BAG design approach and its value in evaluating potential temporal and spatial changes following construction are provided in the section above (Section 4.5.2.3).

The soft bottom survey sample design will focus on representative sections of the RWEC based on four mapped habitat types: coarse sediment (complex), mixed sediment (complex), sand and muddy sand (soft bottom), mud and sandy mud (soft bottom) (Figure 21). Areas of coarse sand with > 30% cobbles or boulders will be avoided, as monitoring the effects of boulder relocation will be addressed in the hard bottom survey (Section 4.5.1). A 25 m wide belt transect will be laid perpendicular to the cable route at triplicate locations in either direction from the cable centerline within each benthic habitat stratum along the RWEC (Figure 22). At each transect, a total of eight stations will be sampled (six total transects, with eight stations along each transect, per habitat type). Near the centerline these stations will be distributed 10 m apart and the distance intervals between stations will increase with distance from the centerline (Figure 22). Four replicate SPI/PV image pairs will be collected at each station; results from three replicate pairs with suitable quality images will be aggregated to provide a summary value for each metric by station.

Sampling along the RWEC will occur about six months prior to construction, within the year post installation (Y0), and at year 1 and year 2 during operation. After year 2, if benthic function measured with SPI/PV is indistinguishable from baseline conditions, and no difference is observed with distance from cable centerline, no further monitoring will occur. Alternatively, if benthic function is impaired (e.g., aRPD depth and/or successional stage) and differences along the RWEC persist compared with baseline and with distance from cable centerline, monitoring will continue at defined intervals until the benthos resemble baseline conditions or are no longer impaired.

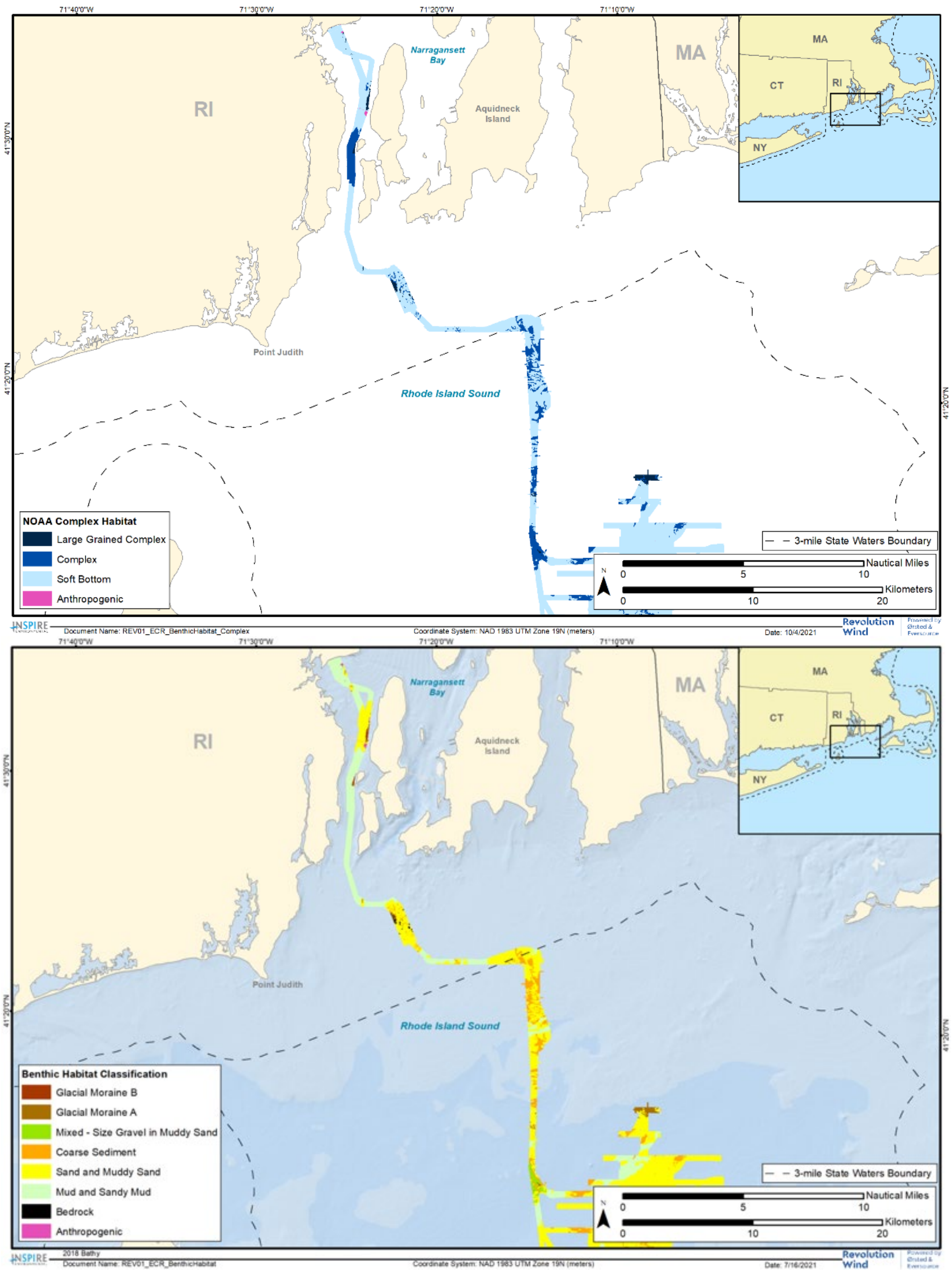


Figure 21. **Distribution of benthic habitat types along the RWEC categorized using the NOAA defined complexity groups (top) and the benthic habitat classifications defined in INSPIRE 2021 (bottom).**

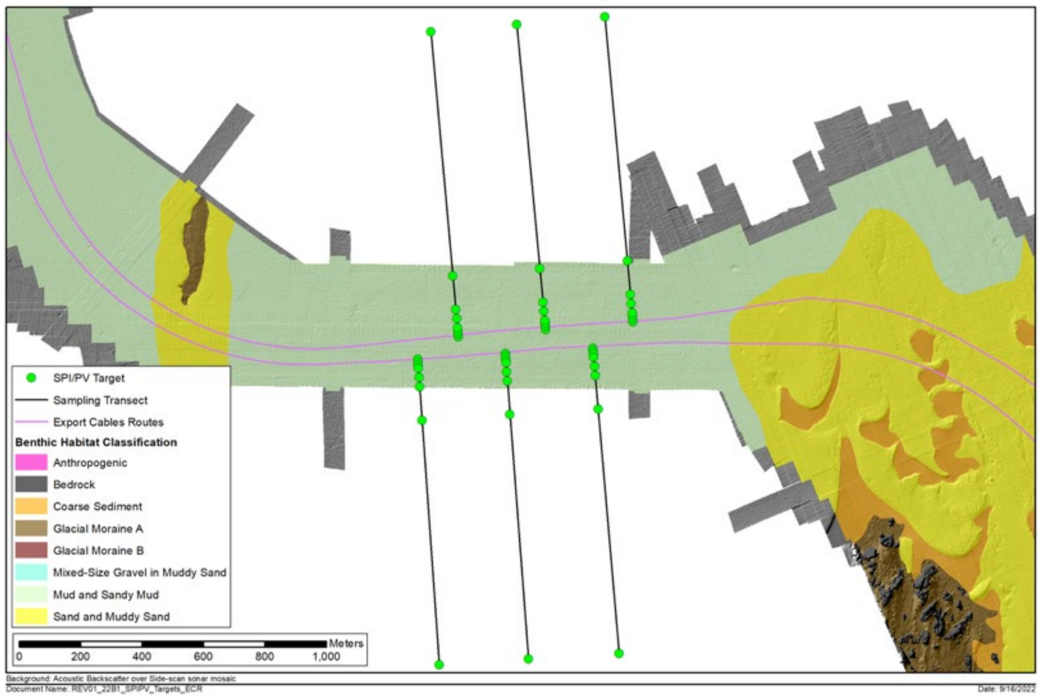


Figure 22. Conceptual diagram of the proposed soft bottom benthic survey sampling design within one habitat stratum along the RWEC with green dots indicating SPI/PV stations situated along transects perpendicular to the RWEC, and independent triplicate transects sampled in both directions.

4.5.3 Overview of Field Methods

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. For-hire vessels will be selected based on criteria including survey suitability, experience, safety record, knowledge of the area, and cost. All survey activities will be conducted with strict adherence to Ørsted health and safety protocols to reduce the potential for environmental damage or injury.

Accurate vessel heading and differential position accuracy within a meter will be achieved using a V102 Hemisphere vector antenna (or equivalent) on the vessel. 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.

4.5.3.1 SPI/PV Field Data Collection

By combining SPI and PV paired imagery, the SPI/PV sampling approach allows for the assessment of benthic functioning over a spatial scale of several square meters at each station. PV images provide a much larger field-of-view than SPI images, or sediment grab samples, and provide valuable information about the landscape ecology and sediment topography in the area where the pinpoint "optical core" of the SPI is taken. Distinct surface sediment layers, textures, or structures detected in SPI can be interpreted considering the larger context of surface sediment features captured in the PV images. The scale information provided by the underwater lasers allows for accurate organismal density counts and/or percent cover of attached epifaunal colonies, sediment burrow openings, larger macrofauna and/or fish which are missed in the SPI cross section. A field of view is calculated for each PV image and measurements are taken of specific parameters outlined in the survey workplan.

The SPI/PV surveys associated with the Soft Bottom Monitoring components (at the RWF and along the RWEC) will be conducted from research vessel(s) with scientists onboard to collect images utilizing a SPI/PV camera system. Collecting seafloor imagery does not require disturbance of the seafloor or collection of physical samples. Once the vessel is within a five meter radius of the target location, the SPI/PV camera system will be deployed to the seafloor. As soon as the camera system contacts 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. Results from the targeted number of replicates with suitable quality images will be aggregated to provide a summary value for each metric by station (mean, median, or maximum depending on the metric, see Section 4.5.5). After all stations have been surveyed the navigator will export all recorded positional data into a Microsoft Excel© spreadsheet. 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, while the ability of the SPI system to collect usable images is dependent upon the penetration of the prism.

4.5.3.2 Acoustic and Stereo-imagery Collection

Targeted high-resolution acoustic surveys (SSS and MBES) will be conducted over the selected IAC corridors prior to 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 18 and 19).

To accomplish the objectives of the novel and native hard bottom monitoring surveys, we will collect high-definition (HD) video imagery and ultra-high definition (UHD) stereo imagery using a compact ROV. This imagery will be used to document epifaunal community characteristics on the hard surfaces (WTG foundations, scour protection layers, native hard bottom substrate). The compact ROV will be equipped with a surface differential positioning system, an Ultra Short Baseline (USBL), and motion and depth sensors. The ROV will host 1) one downward facing UHD stereo camera to observe and capture high-resolution images of the seafloor surface, 2) one forward facing UHD stereo camera to collect data on vertical surfaces and avoid collisions, and 3) one HD video camera.

The positioning components of the ROV would include a surface differential positioning system, an 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 could be accomplished using a towed video system.

High lumen light-emitting diode (LED) lights will be mounted onto the ROV frame to increase visibility and aid in species identification. 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 digital video recorder (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 position, heading, depth, date and time as well as field observations.

High resolution underwater imagery can provide preliminary information about the identity of encrusting fauna, including non-native organisms (Figure 23). However, because some species such as *Didemnum vexillum* require microscopic investigation to accurately identify, samples will be collected to confirm species identified in the still images. The ROV will contain a manipulator arm and basket to collect voucher specimens of encrusting species to ensure accurate identification. The option to collect a specimen sample for identification, will be made by the chief scientist, who will be familiar with the potential non-native organisms in the area. The chief scientist will consult the National Estuarine and Marine Exotic Species Information System, a database maintained by the Smithsonian Environmental Research Center, when determining the need for a voucher specimen.

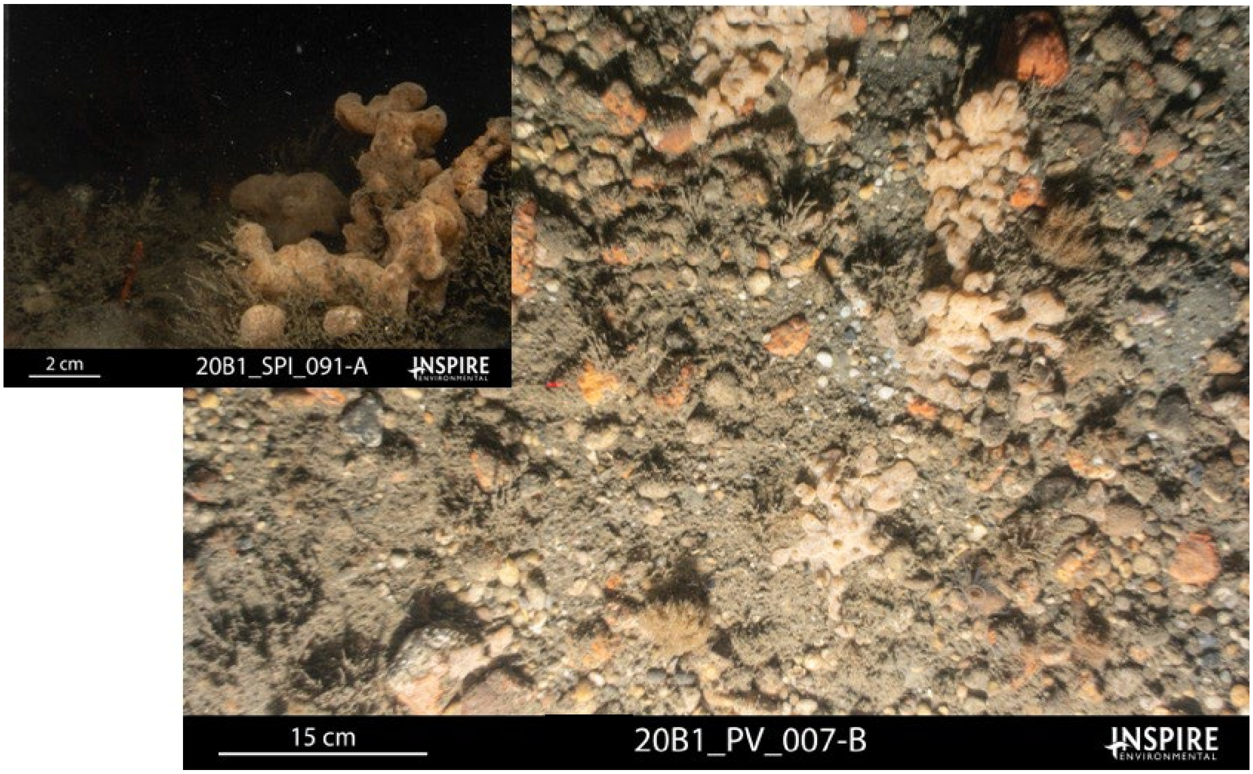


Figure 23. Examples of high resolution SPI and PV imagery of an encrusting organism that is potentially *D. vexillum*, a non-native colonial tunicate

4.5.4 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 digital logs 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 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. 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. Options for optimal data sharing including images, video, and analysis results will be considered and determined at a future date. Possible delivery methods include an Azure database, a secure fileshare, and/or an interactive popup map. Interactive popup maps allow users to explore still and video imagery concurrent with acoustic data, project-specific boundaries and locations (e.g., WTGs, IAC), and interpretative data obtained from the imagery (e.g., presence of non-native taxa).

4.5.5 Data Analysis

4.5.5.1 Hard Bottom Underwater Imagery and Acoustics

Underwater imagery will be reviewed during acquisition and observations will be logged to document biological species and geological features for each video transect. An experienced video analyst will view logs, photos and videos and confirm or add annotations. The video system will have the capability of taking still images from all the input video signals to document features of interest.

For the native hard bottom survey, specific physical hard bottom habitat characteristics will be summarized using the acoustic dataset. For each sampling frame the following metrics will be mapped and quantified; rugosity, boulder height and the ratio of hard bottom to soft bottom habitat. Imagery from the ROV will provide additional quantitative details of habitat characteristics and quality, including categorical levels for the presence of fish and decapods, presence of refuge and surrounding substrata (sediment type), and the percent cover of emergent fauna. The footage will also be analyzed for other biological features including macrobiotic percent cover, proportion of native versus non-native species, and species composition (identified to the LPIL).

For the novel hard bottom survey, the focus of the analysis will be biological features, identifying any non-native organisms, identifying the key epifauna inhabiting the novel substrate, and quantifying the biomass of the dominant members of the epifaunal communities. Biomass estimation will be achieved through photogrammetry methodology as described in Section 4.5.1.2.

The metrics collected from each stream of underwater imagery to support the objectives of the native and novel hard bottom monitoring surveys will include:

UHD stereo images:

- Community assemblages
  - Percent cover of encrusting or colonial taxa
  - Number of solitary taxa
- Species identification to the lowest possible taxonomic level
  - non-native species
  - species of concern (Guida et al. 2017)
  - sensitive species (e.g., slow growing species)
  - ecologically valuable taxa (e.g., biogenic structure-forming taxa such as emergent fauna)

HD Video:

- CMECS Substrate Group and Subgroup
- CMECS Biotic Subclass and Group
- Presence of fish, identified to lowest possible taxonomic level

3D model reconstructed from UHD stereo images:

- Rugosity
- Volume

4.5.5.2 Soft Bottom SPI/PV

Monitoring of soft bottom habitats using SPI/PV will focus on measuring physical changes and indicators of benthic function (i.e., bioturbation and utilization of organic deposits) as a proxy for measuring changes in community composition. SPI/PV is an effective tool in assessing changes in benthic function of soft sediments in response to offshore wind development. Ecologically important benthic functions of soft sediment communities on the outer continental shelf of the northwest Atlantic include the provision of biogenic structures as habitat, facilitating organic matter processing (carbon and nutrient cycling), and provision of food to upper trophic levels (secondary production). These ecosystem functions are detectable using data obtained from SPI/PV imagery.

Seafloor geological and biogenic substrates captured in SPI/PV imagery will be described using the Coastal and Marine Ecological Standard (CMECS; FGDC 2012). Specifically, the modified CMECS substrate definitions included in the NMFS Recommendations for Mapping Fish Habitat will be used (NOAA, 2021). The Substrate and Biotic components of CMECS will be used to characterize the sediments and biota observed in the SPI/PV imagery. Replicate images taken at each station will be summarized to a single value per analytical metric per station (e.g., predominant CMECS Substrate Subgroup, maximum infaunal successional stage, maximum and median feeding void depth, and mean aRPD depths). Categorical values such as CMECS Substrate Subgroup will be summarized across replicate images by taking the most frequently observed value for that station. If there is not a predominant value, then the imagery will reviewed again at a station level (as opposed to a replicate level) and the analyst will determine the CMECS Substrate Subgroup that most accurately describes all three replicate images at the station. Measurement and interpretation of these indicators are presented in previous benthic assessment report for RWF (INSPIRE 2020). Additionally, the benthic macrohabitat (*sensu* Greene et al. 2007) types gleaned from the SPI/PV imagery 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, species composition and total percent cover of attached fauna on the scour mat and changes in benthic community with distance from the scour protection layer will be evaluated.

SPI/PV provides a more holistic assessment of benthic functioning that captures the relationship between infauna and sediments compared with infaunal abundance assessments using sediment grab sampling (Germano et al. 2011; see Section 7.2.2). Although infaunal abundance and density measurements are not generated from SPI/PV analysis, other metrics that will be collected as part of the benthic biological assessment include lists of infaunal and epifaunal species, the percent cover of attached biota visible in PV images, presence of sensitive and non-native species, and the infaunal successional stage (Pearson and Rosenberg 1978; Rhoads and Germano 1982; Rhoads and Boyer 1982).

Indicators of benthic function (bioturbation and utilization of organic material) include infaunal succession stage, feeding voids, methane, *Beggiatoa* and the depth of apparent redox potential discontinuity (aRPD depth). These biological metrics measured using SPI/PV are proxies for measuring changes in community composition. Of these, the successional stage and aRPD depth have the strongest predictive power for benthic functional response to physical disturbance and organic enrichment (Germano et al. 2011) and will be the key metrics used during the soft bottom surveys.

Infaunal successional stage describes the biological status of a benthic community and is useful in quantifying the biological recovery after a disturbance. Organism–sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (Pearson and Rosenberg 1978; Rhoads and Germano 1982; Rhoads and Boyer 1982). This continuum is divided subjectively into four stages: Stage 0, indicative of a sediment column that is largely devoid of macrofauna, occurs immediately following a physical disturbance or in close proximity to an organic enrichment source; Stage 1 is the initial recolonizing tiny, densely populated polychaete assemblages; Stage 2 is the start of the transition to head-down deposit feeders; and Stage 3 is the mature, equilibrium community of deep-dwelling, head-down deposit feeders. The presence of feeding voids in the sediment column is evidence of an active Stage 3 community. If the level of organic enrichment exceeds the capacity of the benthic community to consume the deposits the successional stage will revert to Stage 1, aRPD depths will be visible but very shallow, and eventually methane and *Beggiatoa* will appear as diagnostic conditions of organic over enrichment (Germano et al. 2011).

The aRPD depth is a measure of the depth within the sediment column where dissolved oxygen concentrations are depleted. This depth is dependent on several factors but is largely determined by the amount of organic matter load to the sediments (organic matter decomposition consumes oxygen) and the amount of bioturbation by macrofaunal organisms (bioturbation mixes oxygen from surface waters deep into the sediments). With SPI analysis, the aRPD depth is described as "apparent" because of the potential discrepancy between where the sediment color shifts and the complete depletion of dissolved oxygen concentration occurs. In sandy sediments that have very low sediment oxygen demand (SOD), the sediment may lack a visibly reduced layer even if a redox potential discontinuity (RPD) is present. Because the determination of the aRPD requires distinction 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. It is expected that as sediments surrounding the WTGs will increase in organic enrichment and fines, the aRPD will become more 'apparent' and provide a quantitative measure of enrichment. The aRPD has been shown to be a sensitive and specific indicator of hypoxic conditions experienced over the preceding 1 day to 4 weeks (Shumchenia and King 2010), and to be correlated to concurrent *in situ* dissolved oxygen concentrations (Sturdivant et al. 2012).

4.5.5.3 Summary of Statistical Analyses

Underwater imagery acquired during the hard bottom ROV video surveys (novel and native hard bottom habitats) will be analyzed for macrobiotic percent cover, relative contribution of native versus non-native species, and species composition of the dominant taxa (detailed in Section 4.5.5.1). The WTG foundation surveys will also provide the biomass of dominant members of the epifaunal communities. The univariate metrics (e.g., percent cover, proportion of native versus non-native species) will be statistically analyzed using the mean difference between the temporal change at disturbed sites and the temporal change at undisturbed sites with the 90% confidence interval.

For the novel hard bottom dataset collected at WTG foundations and scour protection layers, data analysis will include exploratory multivariate approaches (e.g., non-metric Multidimensional Scaling [nMDS]) to identify patterns among responses (community composition; relative abundance of sensitive taxa, species of concern, non-native species, and ecologically valuable taxa; rugosity, and volume) and predictors (e.g., depth; distance from the turbine; time since construction). Covariates in the model for the turbine foundation dataset will include direction (categorical); variability among turbines will provide site-wide random error. For individual metrics that are consistently measured across turbines, parametric or non-parametric regression (e.g., generalized modeling such as GLM or GAM; or regression trees) will be applied if the data prove to be sufficient and appropriate for these tools. Additionally, graphical methods and descriptive statistics will be used to assess changes in the community composition and relative abundance over time and as a function of depth, and distance and direction from the novel structures (e.g., turbines). These graphical techniques may help to elucidate the spatial scale at which the greatest changes in benthic habitat quality occur.

The native hard bottom datasets will include sampling frames along the boulder relocation corridor (20 boulders sampled along the transect), perpendicular to the boulder relocation corridor (BAG design), and at undisturbed hard bottom habitat. Comparing the disturbed and undisturbed hard bottom habitats will use estimates of the BACI contrast (i.e., the difference between the temporal change in mean cover values at disturbed sites and the temporal change in means at undisturbed sites), which will be reported as a mean difference with the 90% confidence interval. Temporal changes in the community composition (with organisms identified to the LPIL) will be contrasted between disturbed and undisturbed sampling frames using exploratory multivariate techniques (e.g., nMDS). Additional exploratory graphical displays will be used to visualize and describe spatial and temporal patterns in the data. The sampling transects set perpendicular to the boulder relocation corridor will be analyzed based on the BAG sampling design. For individual metrics that are consistently collected along each transect extending from the source of disturbance, parametric or non-parametric regression (e.g, generalized modeling such as GLM or GAM; or regression trees) will be applied if the data prove to be sufficient and appropriate for these tools. Additionally, graphical methods and descriptive statistics will be used to assess changes in the metrics over time and as a function of distance and direction from the boulder relocation corridor. These graphical techniques may help to elucidate the spatial scale at which the greatest changes in benthic habitat quality occur.

For the soft bottom datasets (BAG design at the base of the turbines and at selected locations along the RWEC), data analysis will include exploratory multivariate approaches (e.g., non-metric multidimensional scaling, nMDS) to identify patterns among responses (SPI/PV metrics, e.g., aRPD, successional stage, feeding voids, presence of methane or *Beggiatoa*) and predictors (e.g., quantitative or categorical epifaunal/epifloral cover estimates on the turbine foundations; and distance from the turbine). Covariates in the model for the turbine foundation dataset will include habitat type (categorical) and direction (categorical); variability among turbines will provide site-wide random error. For individual metrics that are consistently measured across stations (e.g., aRPD), parametric or non-parametric regression (e.g., generalized modeling such as GLM or GAM; or regression trees) will be applied if the data prove to be sufficient and appropriate for these tools. Additionally, graphical methods and descriptive statistics will be used to assess changes in the SPI/PV metrics over time and 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.

Table 9. Summary of planned statistical analyses for the benthic monitoring surveys at RWF.

Survey	Report Section	Area	Design Type	Design Overview	Design details	Metrics of Interest	Research Question	Post-Construction Statistical Methods
Hard Bottom Surveys	4.5.1.3	Novel Surfaces	SS	WTGs; random samples stratified by habitat type; single season.	**Sampling frame** = turbines with mobile sediment classes up/down current **Observational unit** = imaged quadrat (at systematically sampled intervals within frame) **Response variable** = macrobiotic cover, relative abundance of native vs non-native. **Error variance** = among samples within same area	**ROV**: cover (macrobiota, relative abundance of native vs. invasive).	What is the magnitude of difference in mean response with depth and across introduced hard bottom (WTGs) , at each survey event?	Estimate 90% CI on the difference of means for discrete depth intervals and WTG's blocked by habitat type, at each survey event. Compare the temporal profiles between depths and WTGs by habitat type
	4.5.1.4	Disturbed and Undisturbed Boulders	SS and BAG	Disturbed and Undisturbed along IAC; random samples; single season.	**Sampling frame** = Boulders within Disturbed and Undisturbed hardbottom; **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 area	**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? What is the pattern of temporal change in metrics relative to direction and/or distance from boulder relocation?	Estimate 90% CI on the difference of means for disturbed and undisturbed areas, at each survey event. Compare the temporal profiles between disturbed and undisturbed areas. Fit a parametric generalized model (e.g., GLM, GLMM or GAM) or non-parametric regression tree that best describes the data. Compare the temporal profiles across spatial gradients. Calculate similarity between stations; graphically depict relationships between stations from different years, directions, or distances with nMDS.
Soft Bottom Surveys	4.5.2.3	RWF	BAG	Impact only (no reference sites); stns at distances ranging from ~10m to ~900m from turbines; 2 directions from each turbine along prevailing current; single season	**Sampling frame** = turbines within each habitat type, up/down current **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 in metrics relative to direction and/or distance from turbine?	Fit a parametric generalized model (e.g., GLM, GLMM or GAM) or non-parametric regression tree that best describes the data. Compare the temporal profiles across spatial gradients. Calculate similarity between stations; graphically depict relationships between stations from different years, directions, or distances with nMDS.

Table 10 (continued). Summary of planned statistical analyses for the benthic monitoring surveys at RWF.

Survey	Report Section	Area	Design Type	Design Overview	Design details	Metrics of Interest	Research Question	Post-Construction Statistical Methods
Soft Bottom Surveys	4.5.2.4	RWEC	BAG	Impact only (no reference sites); stns at distances ranging from ~5m to ~1km from cable; ≥3 transects within each habitat stratum in either direction of the cable centerline.	**Sampling frame** = soft bottom areas of RWEC **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 in metrics relative to distance from export cable?	Fit a parametric generalized model (e.g., GLM, GLMM or GAM) or non-parametric regression tree that best describes the data. Compare the temporal profiles across spatial gradients. Calculate similarity between stations; graphically depict relationships between stations from different years, directions, or distances with nMDS.

5.0 Data Sharing Plan

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 asked to provide a formal data request. 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, reports, 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, we anticipate 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.

Revolution Wind acknowledges that regional guidance related to data sharing for fisheries monitoring studies is being developed cooperatively through ROSA. To that end, the data sharing agreement outlined above will likely evolve over time as regional guidance is developed.

As stated above, Revolution Wind will also coordinate with our scientific Contractor(s) to disseminate monitoring results through a webinars or in-person meetings, offering an open forum for state, federal, and academic scientists to ask questions or suggest revisions to the data collection protocols. Likewise, following each year of monitoring we will coordinate with the Contractor(s) to host an industry workshop to disseminate the results of the monitoring activities to local fishing industry members.

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APPENDIX 1: Overlap Between High-Resolution Geophysical Surveys and Fisheries Monitoring Surveys

High-Resolution Geophysical (HRG) surveys are conducted by wind energy developers for site investigation to inform engineering and design, as well as for archaeological assessments and benthic habitat mapping. 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 whether any spatial and temporal overlap of HRG surveys with fisheries monitoring surveys could bias the results of the pre-construction fisheries monitoring.

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. Instead offshore wind HRG surveys employ a variety of equipment types, other than seismic air guns, as summarized in Table 1. Offshore wind HRG equipment operate at a range of frequencies. The acoustic characteristics of HRG survey equipment used during offshore wind development are well known. Table 1 includes all equipment authorized for use under the approved 2019 Ørsted IHA application and 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. 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 in offshore wind HRG surveys, non-airgun sub bottom profilers known as 'sparkers' and 'boomers' operate at the lowest frequency range, and thus are most relevant to assess further for any potential to impact the distribution and behavior of fish in the region, based on their hearing sensitivity. For this reason, HRG equipment commonly used in offshore wind surveys have been studied by BOEM.

In the BOEM Final Programmatic Environmental Impact Statement (EIS) for Geological and Geophysical Surveys in the Gulf of Mexico, several alternatives were considered, which included >180,000 km of non-airgun HRG surveys using equipment such as boomers, sparkers, CHIRP sub-bottom profilers, side-scan sonars and multibeam echosounders. For all alternatives, the EIS concluded that non-airgun HRG equipment would have little to no measurable impacts on fisheries resources, Essential Fish Habitat, on commercial and recreational fisheries, and on benthic communities (BOEM, 2017). The Vineyard Wind Supplemental EIS concluded that impacts of HRG survey noise to finfish, invertebrates and Essential Fish Habitat were negligible (BOEM, 2020).

Ørsted does not plan to use 'sparkers' and/or 'boomers' in the Revolution Wind lease area in 2021. However, this equipment may be used for a brief period (e.g., one month) at the Revolution Wind site in 2022 to map subsurface boulders. While the HRG equipment is likely to change over time, Ørsted commits that seismic air guns will never be used for site investigations surveys on the SFW or Revolution Wind farms.

Given the lack of temporal overlap and minimal spatial overlap that are anticipated to occur between the low frequency HRG surveys (e.g., boomers and sparkers) and the REV fisheries monitoring surveys, we do not anticipate there to be any impacts on the results of the fisheries monitoring surveys. In addition, the reference areas for the REV fisheries monitoring studies will be located well outside of the Revolution Wind lease areas, in areas that have not been directly surveyed using HRG equipment. The Ørsted site investigations team records the time, date, and location that each piece of HRG equipment is deployed during site investigations surveys, and this information can be considered in the context of the fisheries monitoring results, as appropriate.

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Table 1. Summary of the operating frequencies and source levels of HRG equipment from the 2019 Ørsted IHA application and issued authorization.

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

Appendix 1 References

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APPENDIX 2: Power Analysis for Trawl Survey of Fish and Invertebrates

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EXA Data and Mapping

1.0 Introduction

For the trawl survey, an asymmetrical BACI design is planned for the Revolution Wind Farm (RWF) project area. The RWF trawl survey will use NEAMAP survey gear and sampling protocols and is intended to capture a range of benthic and pelagic fish species, as well as commercially important invertebrate species.

This appendix covers two topics:

1. A review of existing trawl survey datasets in the vicinity of RWF project area, including data from the NEFSC trawl survey (Politis et al., 2014) and data collected in the reference areas during the BIWF trawl survey (Wilber et al., 2020). These datasets were evaluated to establish the proximate range of a meaningful effect size in measuring change over time, as well as reasonable ranges for interannual and intraannual variability (i.e., the coefficient of variation [CV]) to use in the power analyses.

2. A power simulation study for a BACI design and analysis contrasting fish/invertebrate biomass (kg/tow) between an impact area and reference areas. Effect sizes and CVs were derived from the NEFSC and BIWF trawl survey datasets (topic 1 above).

2.0 Power Analysis Elements

A statistical power analysis requires specification of the following:

- Study design specifics (e.g., number of replicates, number of sites, number of seasons/sampling events, sampling duration 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 biomass might be modeled with a generalized linear or additive model with normal errors and a log-link; catch data as counts might be modeled with a generalized linear or additive model with Poisson errors, or with a negative binomial if the count data are over-dispersed; presence/absence data might 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 a measure of change in the data that the study design and modelling approach will be used to estimate. Measures of effect size can be summarized in a number of different ways (e.g., Durlak 2009); standardized effect sizes such as the magnitude of difference expressed as a percent of the standard deviation are useful for comparisons across studies. These can be difficult to understand, however; and when the unit of measure itself is meaningful (e.g., catch ratios) it is more useful to present results in terms of unstandardized effect sizes. For the purposes of this appendix, unstandardized effect sizes are expressed as the temporal change at the impact site relative to temporal change at the reference sites. Since this value is not standardized to variance, power for relative change values is evaluated across a range of variance estimates.

Statistical analysis of this OSW monitoring data from the BACI design will focus on the BACI interaction contrast between period and location, which is specified as a contrast (differences on the log-scale; ratios on the original scale) between the temporal change at the Reference site(s) and the temporal change at the Impact site, with responses averaged across seasons and years within each period, and over multiple sites within each location type (Eq. 1). The relative proportional change (PC) at the impact site is the proportional change between periods of the mean catch per tow at the Impact site relative to the proportional change between periods of the mean catch per tow at the Reference site(s).

$$\text{Interaction Contrast} = \frac{\left(\bar{X}_{Reference,After}/\bar{X}_{Reference,Before}\right)}{\left(\bar{X}_{Impact,After}/\bar{X}_{Impact,Before}\right)} \qquad \text{[Eq. 1]}$$

$$\text{Proportional Change (PC)} = \left[\frac{\left(\bar{X}_{Impact,After}/\bar{X}_{Impact,Before}\right)}{\left(\bar{X}_{Reference,After}/\bar{X}_{Reference,Before}\right)} - 1\right] \qquad \text{[Eq. 2]}$$

For example, a PC of –0.33 (-33%) could represent a 33% decrease in catch at the impact site and no change at the reference site(s) (i.e., (1-0.33)/1 -1 = -0.33). The same PC could represent any number of ratios. This PC of -0.33 could also represent a 50% decrease at the impact site and a 25% decrease at the reference site (i.e., (1-0.5)/(1-0.25) - 1 = 0.5/0.75-1= -0.33); or a 20% decrease at the impact site and 20% increase at the reference (i.e., 0.8/1.2-1 = -0.33); or other similar combinations that yield a PC value of -0.33.

In the context of statistical power analysis, a threshold effect size considered to be meaningful (Δ_M) is specified and the probability this difference would be statistically significant at the designated α, is the power (power = 1-β, where β is the type II error). Outside of statistical power analysis, observed effect size or level of change is a way of summarizing the metric of interest that can be compared across studies, and is not inherently tied to statistical significance or statistical power. In fact, the observed proportional changes among reference areas are used to establish what constitutes a meaningful threshold effect size or level of proportional change (Δ_M) for impact studies.

- **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 threshold effect size (Δ_M). In the BACI design setting, it is the probability of finding the interaction BACI contrast to be statistically significant (e.g., Eq.1 is significantly different from one for a model fit on the log-scale) when a proportional change of size Δ_M is present in the populations.

- **Alpha (α)** is the Type I error, or the probability of rejecting the null hypothesis in error because the true difference is null. 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 proportional change imposed on the data was 0. For this study, α = 0.10 was used for the two-tailed null hypothesis which allows us to say whether results (Eq. 1) are significantly greater than or less than one (the one-tailed hypotheses), with 95% confidence (α = 0.05) on each side.

- **Sample size** encompasses the number of sites, replicates, and time periods that are sampled and determines the degrees of freedom for the statistical tests. In this analysis, the overall design was set (i.e., 1 impact site and 2 reference sites; 2 years of monitoring before and after construction, and 4 seasonal trawl surveys per year) and sample size refers to the number of tows per season in each area. Precision for the annual estimates can be improved by appropriate survey timing (i.e., surveys are timed to not miss the seasonal peaks in biomass/abundance), using consistent survey methods, and greater replication (tows per season, years per period, or areas per location). All else being equal, as replication increases, the precision estimates for the model parameters increase. This will result in higher power for a specific level of change, or a smaller detectable level of change for a specific level of power.

3.0 Review Existing Datasets

3.1 NEFSC

Station level catch data from the NEFSC trawl survey was provided by Phil Politis. The data request was limited to species of recreational and commercial importance that were expected to occur in Strata 1050. The NEFSC (Politis et al., 2014) trawl dataset was used to establish 1) a proximate range of proportional change over time, and 2) the expected distributional form for the catch as biomass and reasonable variance estimates. The NEFSC dataset was screened to only include:

- tows from Stratum 1050, which includes the location for the RWF project (Figure 1).
- selected species of commercial and recreational importance (Table 1).

This NEFSC survey design included four to five (random) replicate tows per season in survey strata 1050 from Spring (late March to early May) and Fall (late September to early October) in the years 2010 to 2018, with replicate tows for each season generally occurring on the same day. This dataset provides an adequate representation of the spatial variance among tows during each survey event (i.e., the within-season variability) for this approximately 5,100 km^2 stratum and provides estimates of the natural levels of inter-annual changes in catch. The NEFSC trawl survey is limited to spring and fall. Therefore, monthly data from the Block Island Wind Farm (BIWF) trawl survey were also reviewed (Section 3.2) to determine the extent to which the seasonal NEFSC trawl survey captured intraannual biomass peaks for different species of interest. Given that biomass and abundance can vary substantially throughout the course of the year within the proposed Project area, it is important to ensure that this intraannual variability is accounted for when estimating the expected variance for the species of interest in the seasonal trawl survey.

The tows in the NEFSC dataset are at a lower spatial density than what is planned for the RWF trawl survey. We expect the NEFSC estimates of spatial variance to be conservatively high relative to the variance expected from the RWF monitoring, because the RWF survey will occur over a smaller spatial area, so less spatial heterogeneity may be expected amongst replicate tows. The RWF trawl survey will maintain the same spatial sampling densities within the impact and the reference areas (i.e., the three areas will all be the same size, and within the boundaries of Stratum 1050).

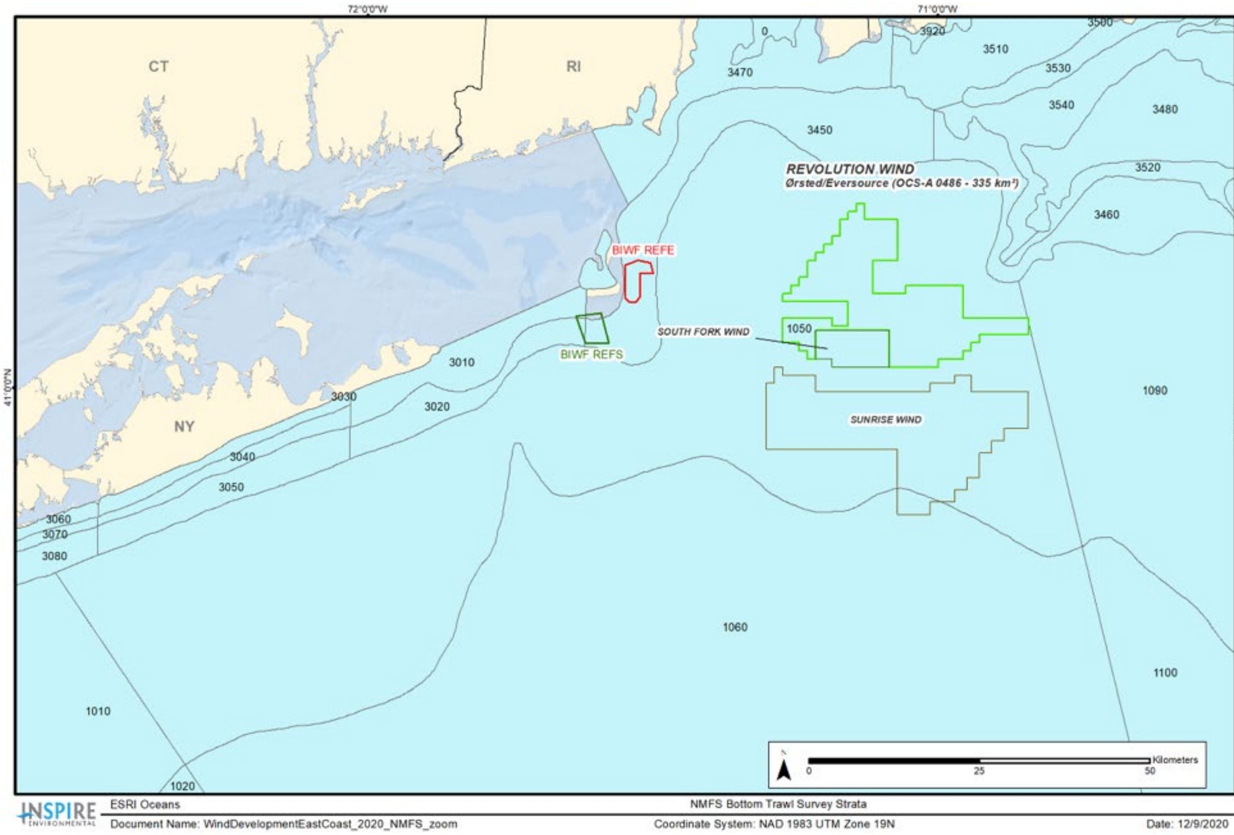

Figure 1. Map of NEFSC strata and the Revolution Wind project area. Trawl survey data sampled in strata 1050 from 2010-2018 were used in the analysis. The reference sites used in the BIWF Trawl survey (REFE and REFS) are also shown for reference.

Table 1. Summary of total catch (biomass, kg) for individual fish and invertebrate species from the NEFSC trawl survey (Politis et al., 2014) sampled in Stratum 1050 from 2010 through 2018. These catch data were used in this analysis.

Species	Total biomass (kg)
Longfin squid	523
Little skate	6422
Summer flounder	507
Windowpane flounder	119
Winter skate	2709
Winter flounder	481
Butterfish	587
Atlantic herring	580
Black sea bass	276
Silver hake	576
Scallop	418
Yellowtail flounder	277
Scup	1471
Red hake	29
Atlantic mackerel	17
Goosefish	124
Bluefish	50
Atlantic menhaden	0
Channeled whelk	0
Knobbed whelk	0
Spanish mackerel	0
Tautog	0
Minimum	0
Maximum	6422
Median	276

To demonstrate the seasonal variability in mean catch rates in stratum 1050, a summary of the mean catch per tow (kg) for the species shown in Table 1 is presented by season and year in Figure 2.

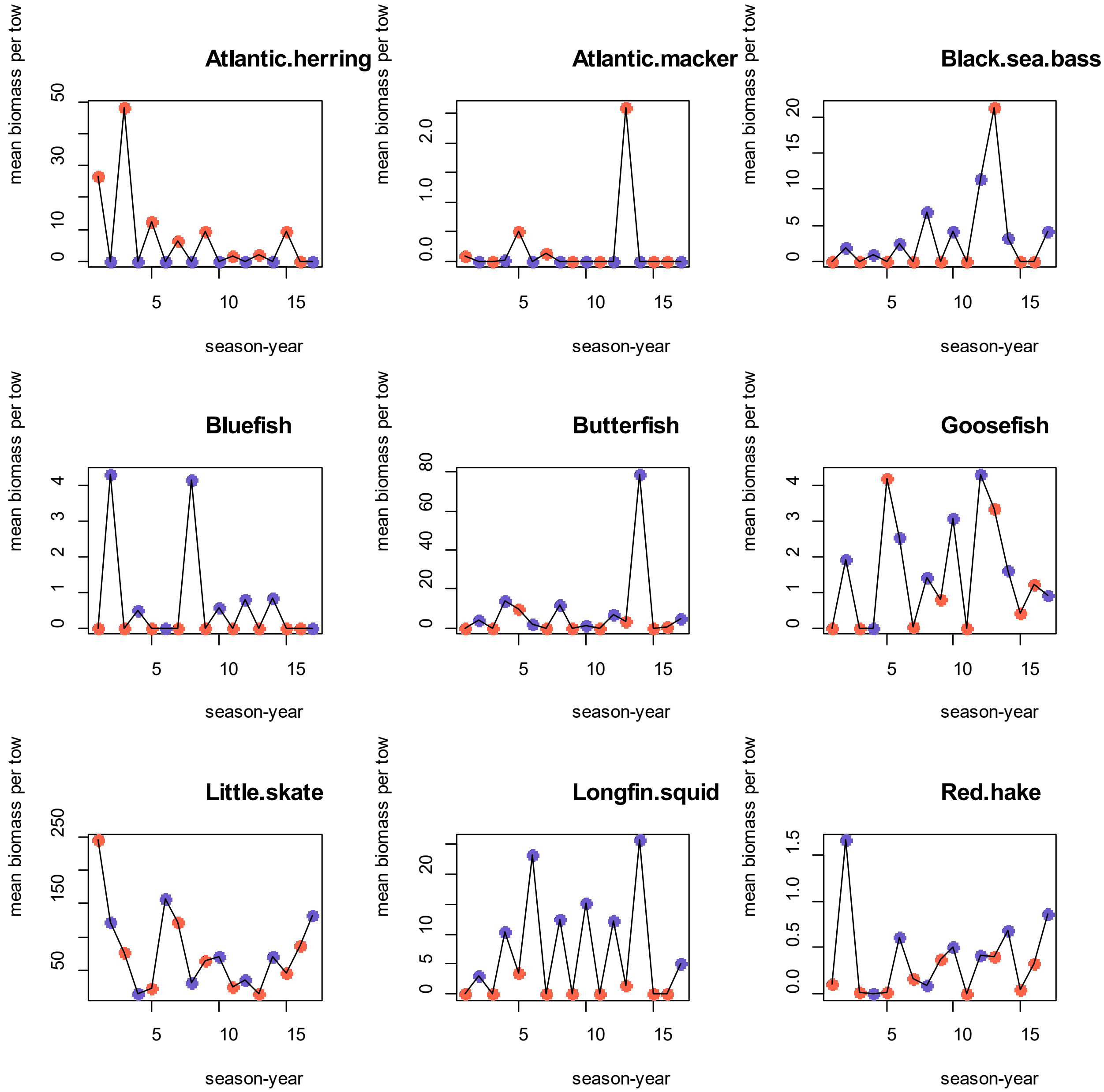

Figure 2a. Mean seasonal catch per tow (kg) across season and year, for selected species (Atlantic herring to Red hake) sampled in strata 1050 during the NEFSC seasonal trawl survey from 2010 through 2018. The orange dots represent spring surveys, blue dots represent fall surveys.

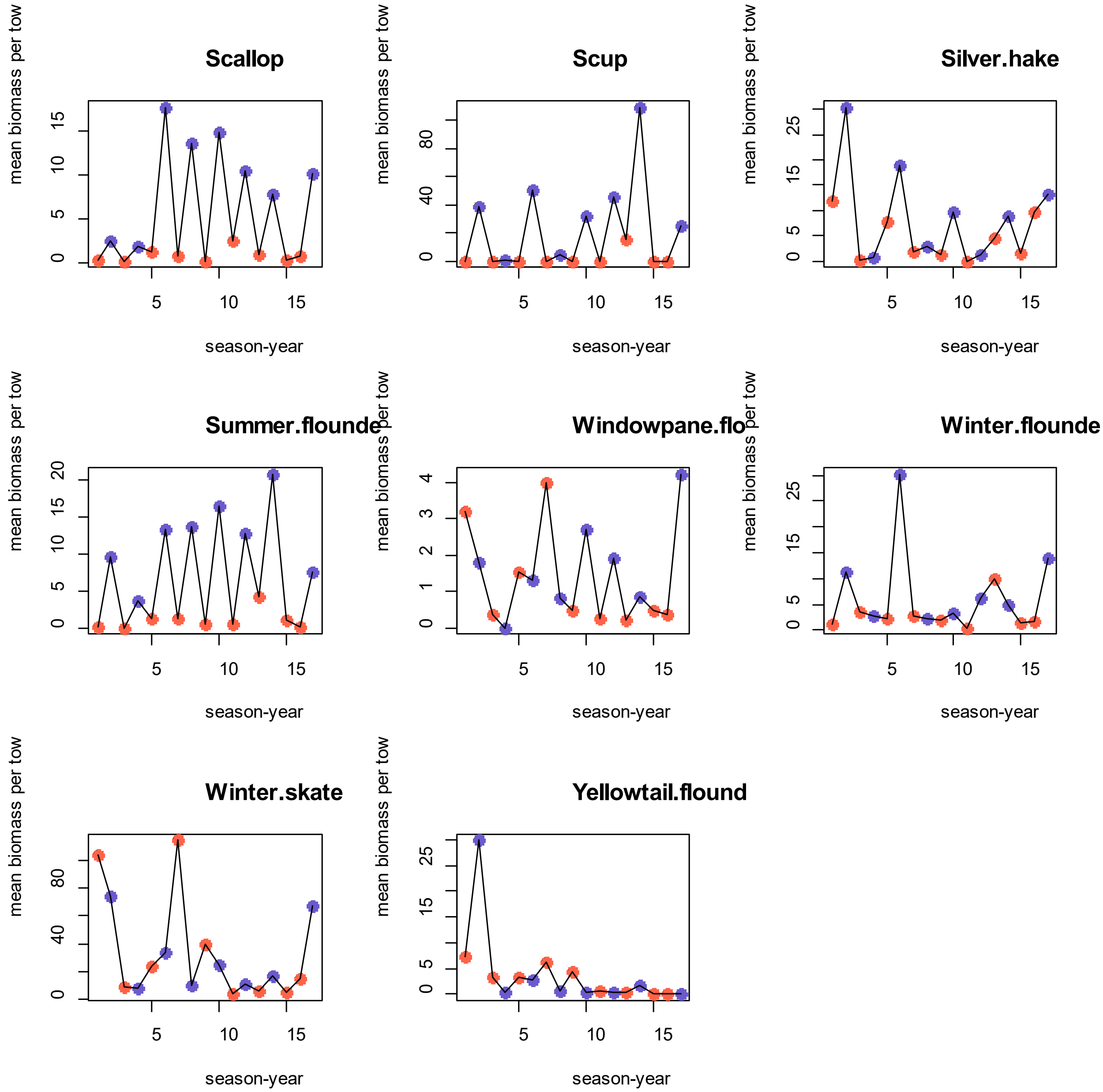

Figure 2b. Seasonal catch per tow (kg) across season and year, for selected species (Scallop to Yellowtail flounder) sampled in strata 1050 during the NEFSC seasonal trawl survey from 2010 through 2018. The orange dots represent spring surveys, blue dots represent fall surveys.

3.2 Block Island Wind Farm Trawl Survey Data

Intraannual variation in catch rates (kg/tow) were examined for several species from the monthly trawl survey that occurred over seven years at the two reference areas used in the Block Island Wind Farm (BIWF) monitoring. The monthly BIWF trawl survey data were reviewed to determine the extent to which the NEFSC trawl surveys, which are limited to spring and fall, may miss intraannual biomass peaks. The monthly means from seven years are plotted in Figure 3 (REFE area) and Figure 4 (REFS area) for the species of primary commercial and recreational interest. Monthly variation in catch rates was observed at a relatively fine spatial scale (i.e., between the two reference sites) for some species in the BIWF trawl survey, such as windowpane flounder and little skate, which illustrates the advantages that can be gained by using multiple reference sites to monitor changes in abundance over time.

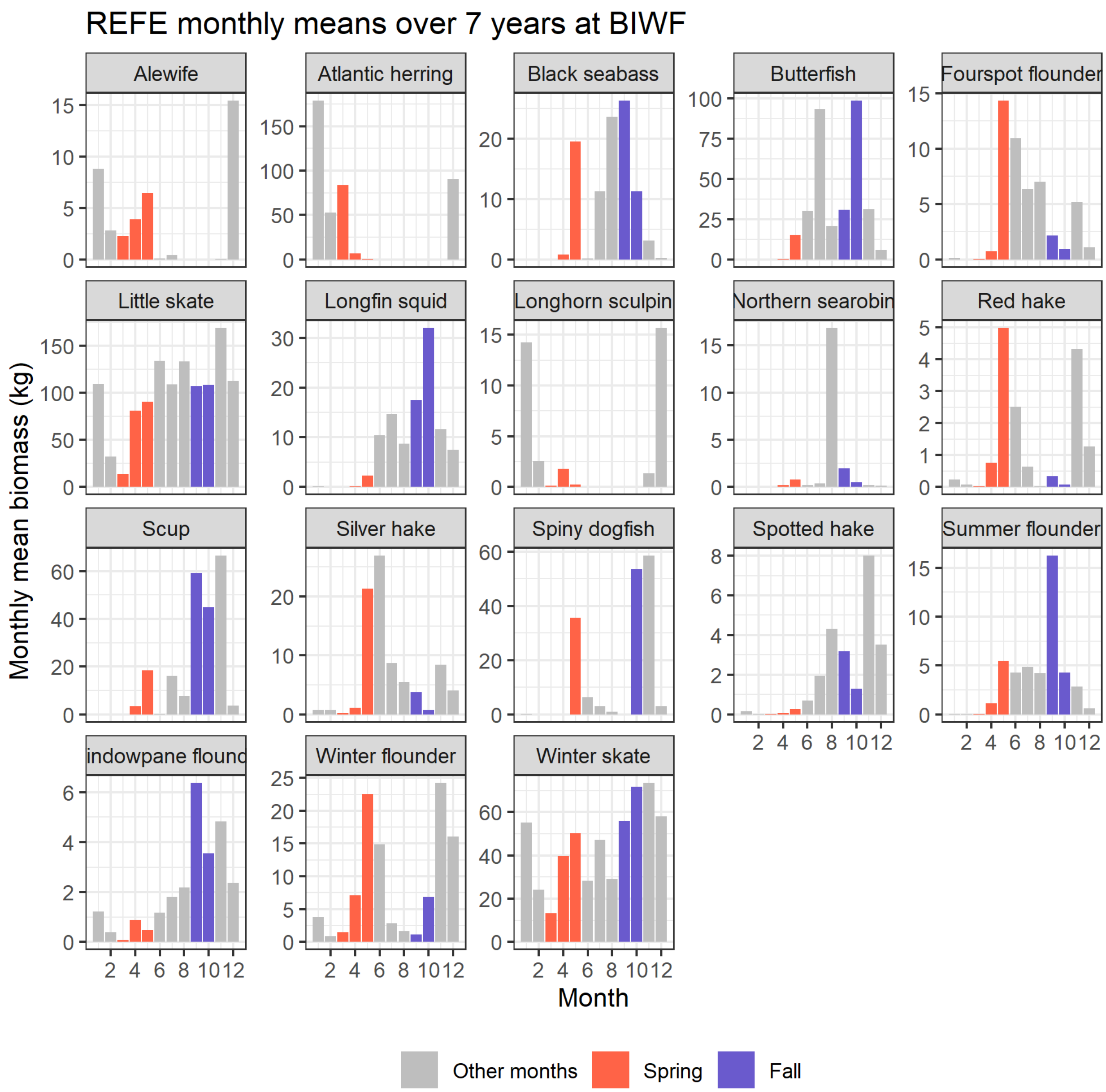

Figure 3. Monthly mean biomass (kg) averaged over seven years (from October 2012 to September 2019) for dominant species from the eastern reference area (REFE) from the BIWF trawl survey monitoring. The months that were also sampled in the NEFSC trawl survey are colored orange (spring) and blue (fall).

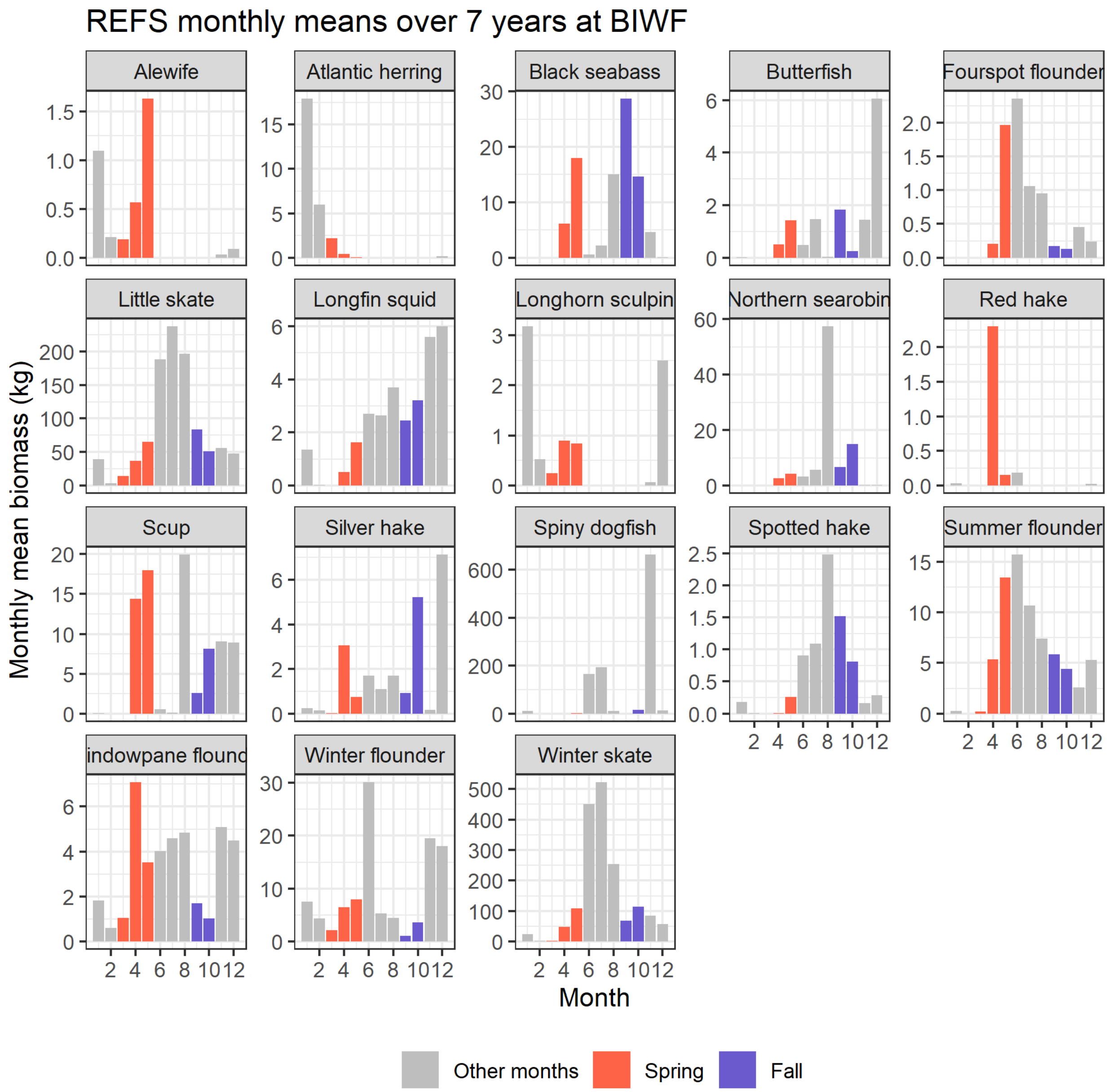

Figure 4. Monthly mean biomass from October 2012 to September 2019 (averaged over seven years) for dominant species from the southern reference area (REFS) from the BIWF trawl survey monitoring. The months that were also sampled in the NEFSC trawl survey are colored orange (spring) and blue (fall).

3.3 Reference Effect Sizes

Using the NEFSC and BIWF reference datasets, the proportional change in mean annual biomass (averaged across seasons) between subsequent 2-year time periods, was calculated as:

$$Reference\ Proportional\ Change = \left(\bar{X}_{2,3}/\bar{X}_{0,1} - 1\right) \qquad \text{[Eq. 3]}$$

where

$\bar{X}_{0,1}$ = The two year mean from all seasons in years *i* and *i+1*.

$\bar{X}_{2,3}$ = The two year mean from all seasons in years *i*+2 and *i*+3.

For [Eq. 3] note that for the NEFSC dataset, *i*= 2010 through 2014, the annual means were calculated from data from two seasons per year, and where *i* =2014, the mean from 2014 and 2015 was compared to mean from 2016 and 2018 (due to incomplete sampling in 2017). For BIWF REFE and REFS datasets, *i*= 2012 through 2015, and the annual means were calculated from data from four seasons per year (the months January, April, July, and September were subsampled from the monthly time series).

The ranges of relative percent change (proportion x 100) from these extant datasets provide context for generating realistic effect sizes (PC values) to be used in the power calculations. Results are summarized for the NEFSC dataset in Table 2 and Figure 5, and for BIWF Reference areas in Table 2 and Figure 6. The effect sizes or percent change values [derived from Eq. 3] have a natural lower bound of -100%, and an unlimited upper bound.

Table 2. Summary of effect sizes as percent change (100 x Eq. 3) by species for reference area datasets from NEFSC and BIWF (results sorted by median value).

	NEFSC (n=9)			BIWF Reference Areas (n=8)		
Species	**Minimum**	**Median**	**Maximum**	**Minimum**	**Median**	**Maximum**
Spiny dogfish		n/a		-98%	-85%	7250%
Atlantic herring	-81%	-75%	-41%	-91%	-36%	17%
Yellowtail flounder	-76%	-61%	-35%		n/a	
Longhorn sculpin		n/a		-90%	-60%	-5%
Bluefish	-67%	-39%	837%		n/a	
Winter skate	-78%	-38%	90%	-52%	-16%	105%
Silver hake	-54%	-36%	98%	-50%	812%	1690%
Little skate	-51%	-27%	58%	-46%	-29%	56%
Windowpane flounder	-42%	-23%	94%	-56%	-31%	42%
Alewife		n/a		-75%	-22%	1170%
Fourspot flounder		n/a		-56%	-20%	41%
Butterfish	-53%	-15%	663%	-89%	-1%	299%
Scallop	-32%	-11%	497%		n/a	
Goosefish	-21%	1%	165%		n/a	
Longfin squid	-26%	17%	127%	-37%	-14%	3%
Summer flounder	7%	22%	101%	-56%	-16%	73%
Red hake	-32%	33%	78%	-38%	154%	Inf
Scup	-28%	41%	362%	-23%	176%	811%
Winter flounder	-75%	89%	162%	-33%	-5%	25%
Spotted hake		n/a		-62%	175%	1590%
Black sea bass	80%	232%	258%	-71%	47%	629%
Northern sea robin		n/a		62%	334%	2360%
Atlantic mackerel	-100%	458%	Inf		n/a	
Minimum	-100%	-75%	-41%	-98%	-85%	-5%
Median	-51%	-11%	114%	-56%	-15%	105%

Maximum	80%	458%	837%	62%	812%	7250%

n/a=not available. The NEFSC summaries are presented only for those species requested by Orsted from NEFSC. The BIWF summaries are presented for species included in the RI CRMC's Ocean Special Area Management Plan (OSAMP) of recreational and commercial species of concern and/or which had sufficient catch to allow for estimation of relative effect sizes.

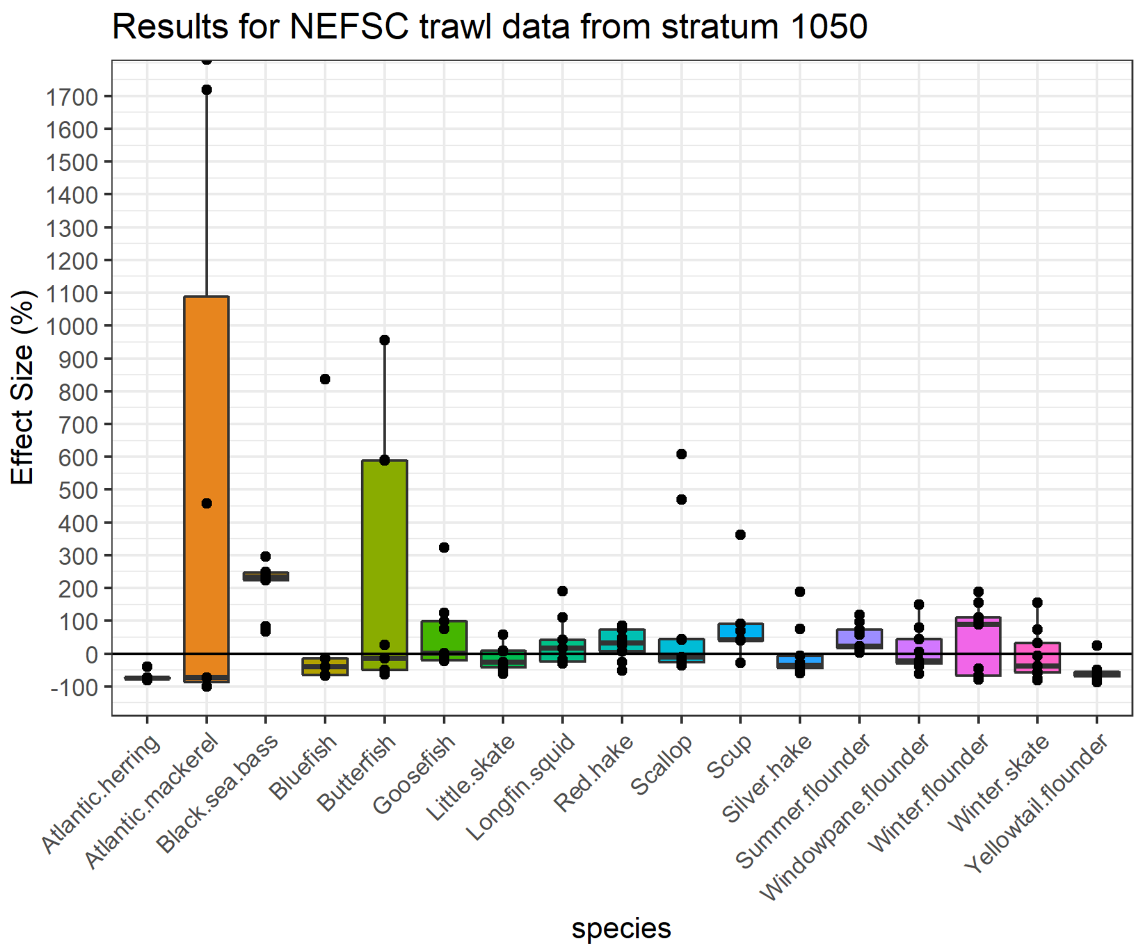

Figure 5. Boxplots showing the distribution of effect sizes as relative percent change (100 x Eq. 3) by species for NEFSC dataset (2010 – 2018). Scale of y-axis was truncated to -100% to 1700% to allow greater distinction of the values less than zero.

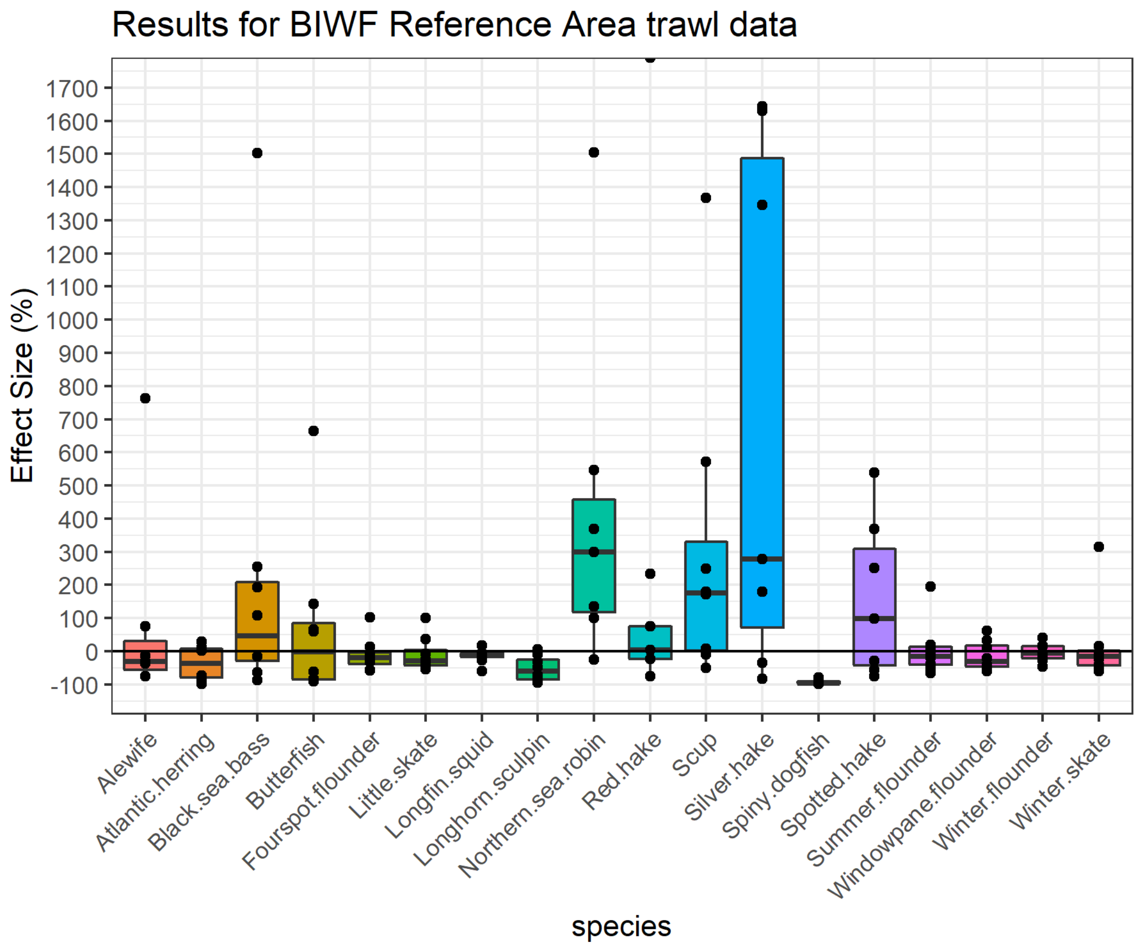

Figure 6. Boxplots showing the distribution of effect sizes as relative percent change (100 x Eq. 3) by species for BIWF reference areas (2012/2013 – 2018/2019). Scale of y-axis was truncated to -100% to 1700% to allow greater distinction of the values less than zero.

Over the nine-year period for the NEFSC dataset, nine of the 17 species had decreases in more years than increases (median values < 0) with median relative percent decreases ranging from -11% to -75%. For the BIWF Reference area dataset over the seven-year period 12 of the 18 species had decreases in more years than increases, with median relative percent decreases ranging from -1% to -85%.

The results demonstrate the substantial interannual variability that can occur for many species in the region, particularly when survey data are analyzed on a fine spatial scale (which reduces the number of observations). The data suggest that it may be reasonable to attempt to detect effect sizes on the order of 50% for some species (e.g., longfin squid), but for other species that display greater interannual variability (e.g., butterfish) detecting anything smaller than a 50% relative change may not be possible given practical constraints and the underlying natural variability in abundance and availability associated with those populations.

3.4 Coefficient of Variation

Catch (kg) per tow is naturally bounded by zero and the distribution tends to be skewed with most catches around the median value and large catches in a few tows, approximating a lognormal distribution. The NEFSC biomass data from replicate tows within a single season in Stratum 1050 were too sparse to adequately test this (n=4 to 5 per season within Strata 1050), but the data generally fit this description. For the lognormal distribution, the standard deviation (SD) is proportional to the mean and the coefficient of variation (CV = SD/mean) on the original scale is used to summarize variability in catch rates independent of the mean. A summary of the seasonal CV values for the NEFSC dataset is shown in Table 4. For conservative sample size estimates in the power analyses (Section 4.0), the observed range of median to maximum CV values across seasons, years, and species were used (0.8 to 2.2)

Table 4. Summary of seasonal variance estimates for catch (biomass, kg) for the individual fish and invertebrate species from NEFSC trawl survey (Politis et al., 2014) in Stratum 1050 that were used in this analysis.

	Seasonal Coefficients of Variation (CVs) Summarized across Seasons and Years			
Species	**Number of Seasons with Catch**	**Minimum**	**Median**	**Maximum**
Longfin squid	10	0.4	0.8	1.4
Little skate	17	0.4	0.9	1.6
Summer flounder	17	0.4	0.9	2.2
Windowpane flounder	16	0.3	1.0	1.8
Winter skate	17	0.4	1.1	1.9
Winter flounder	17	0.8	1.2	1.8
Butterfish	11	0.6	1.3	2.0
Atlantic herring	12	0.8	1.3	2.2
Black sea bass	13	0.6	1.4	2.2
Silver hake	17	0.8	1.4	2.1
Scallop	17	0.8	1.5	2.2
Yellowtail flounder	16	0.6	1.5	2.2
Scup	10	0.7	1.6	2.2
Red hake	16	0.8	1.7	2.2
Atlantic mackerel	5	1.7	1.8	2.0
Goosefish	14	0.9	1.8	2.2
Bluefish	6	1.5	2.1	2.2
Minimum	5	0.3	0.8	1.4
Median	16	0.7	1.4	2.2
Maximum	17	1.7	2.1	2.2

4.0 Power Analysis

4.1 The Study Design and Model

An asymmetrical BACI design was tested in this power analysis, with the design variables as specified in Table 5. For comparison, a symmetrical BACI (i.e., one impact and one reference area) was evaluated for power using a limited scenario (i.e., a single CV).

Table 5. Design for Revolution Wind trawl survey power simulation study

Set study design variables
• Impact Areas = 1 impact area
• Reference Areas = 2 control/reference areas
• Habitat Strata = 1
• Frequency = four seasons per year
• Number of years Before impact = 2

• Number of years After impact = 2
Variables altered in the power analysis
• Number of replicate (random) trawls per season in each area (n): 5, 10, 12, 14, 16, 20, 30, 40
• Proportional Change (PC) of Impact / Reference : -25%, -33%, -40%, -50%, -70% (Section 3.3) and 0% (for Type I error)
• CVs: 0.8, 1.0, 1.2, 1.4, 1.8, 2.2 (Section 3.4)
• A two-tailed α = 0.10

For a saturated model that estimates the mean catch (kg) for each season, year, and location, the BACI interaction contrast is described as

$$\left(\bar{X}_{Impact,Before} - \bar{X}_{Impact,After}\right) - \left(\bar{X}_{Control,Before} - \bar{X}_{Control,After}\right) \qquad \text{[Eq.42]}$$

where

$\bar{X}_{Impact,Period}$ = The two-year log-scale mean biomass per tow (kg) from the Impact area, averaged across four seasons in all years of the *Period* (Before or After).

$\bar{X}_{Control,Period}$ = The two-year log-scale mean biomass per tow (kg) averaged across the two Reference areas, and four seasons in all years of the *Period* (Before or After).

4.2 Simulation methods

The power analysis used a simulation approach to generate significance values for a range of CV estimates, effect sizes (PC values), and a range of sample sizes (Table 5). Given the substantial intraannual variability that is present amongst the fish populations in the region (Figures 2, 3, and 4), accounting for seasonality is important when estimating statistical power. Therefore, seasonality for this four season sampling design was imposed as two seasons with the same mean catch per tow μ, and the other two seasons having mean 0.25μ (a 75% decrease). Note that this is just one of several permutations that could be used to simulate the seasonal variability that is anticipated to be present in the trawl survey catch rates. The effect size (PC) was imposed on every season during the After period. Note that proportional changes on the original scale become additive changes on the log-scale; consequently, log-scale changes are a function only of the PC value and do not depend on the starting mean value. Code was written in (R Core Team 2020) to conduct the simulations; the R code is included as an addendum to this appendix.

For a given CV, PC, and sample size (n), the following steps were performed m=1000 times:

1. From a log-normal distribution with mean μ and CV, simulate *n* values of catch data for 2 seasons in each year of the Before period, for all Impact and Reference areas. Repeat with mean 0.25μ for the other 2 seasons of each year of the Before period, for all Impact and Reference areas.

2. Repeat step 1 for each year of the After period for the two Reference areas.

3. Repeat step 1 for each year of the After period for the Impact area, but with a reduced mean equal to (1+PC)μ for 2 seasons, and mean 0.25 x (1+PC)μ for the other 2 seasons.

4. Fit the saturated model to the log-transformed biomass data (i.e., a separate coefficient for every area-period-season-year).

5. Calculate the BACI interaction contrast, and save the p-value.

6. Repeat m=1000 times for 1000 simulation replicates.
7. Count the number of times out of m that the p-value was < 0.10, and store this simulated power estimate for that combination of CV, PC, and n.

Repeat Steps 1-7 for each combination of CV, PC, and n.

4.3 Results

The simulation power results for a design with one impact and two reference areas are shown in Table 6 and Figure 7. Using an asymmetrical BACI design with two reference areas increases the statistical power of the survey design when compared to a BACI approach that relies on a single reference area (Figure 8).

Table 6. Simulated power for the BACI interaction contrast within a saturated model (see text) for a range of variance (CV), effect sizes (% change), and sample sizes (n) per season per area, and using a two-tailed α = 0.10 and a design with one impact and two reference areas. The 0% change illustrates the type I error. Results with power 80% and above are shaded.

% Change	Sample Size (n)	CV=0.8	CV=1.0	CV=1.2	CV=1.4	CV=1.8	CV=2.2
0	5	0.10	0.10	0.13	0.12	0.12	0.09
0	10	0.09	0.11	0.10	0.11	0.10	0.10
0	20	0.10	0.11	0.10	0.11	0.09	0.09
0	30	0.11	0.11	0.10	0.09	0.10	0.10
0	40	0.09	0.10	0.09	0.10	0.11	0.09
-25%	5	0.46	0.35	0.29	0.29	0.22	0.20
-25%	10	0.66	0.53	0.49	0.41	0.33	0.31
-25%	20	0.92	0.80	0.73	0.66	0.55	0.48
-25%	30	0.98	0.94	0.86	0.80	0.69	0.62
-25%	40	1	0.96	0.94	0.89	0.79	0.73
-33%	5	0.66	0.54	0.46	0.42	0.35	0.30
-33%	10	0.91	0.80	0.72	0.66	0.54	0.47
-33%	20	1.00	0.97	0.92	0.88	0.79	0.71
-33%	30	1	1	0.90	0.97	0.92	0.86
-33%	40	1	1	1	0.99	0.97	0.94
-40%	5	0.85	0.71	0.63	0.56	0.46	0.43
-40%	10	0.98	0.92	0.88	0.81	0.72	0.63
-40%	20	1	1	0.99	0.97	0.91	0.89
-40%	30	1	1	1	1	0.99	0.96
-40%	40	1	1	1	1	1	0.99
-50%	5	0.97	0.92	0.86	0.80	0.65	0.60
-50%	10	1	1	0.99	0.96	0.91	0.85
-50%	20	1	1	1	1	0.99	0.98
-50%	30	1	1	1	1	1	1
-50%	40	1	1	1	1	1	1
-70%	5	1	1	1	0.99	0.98	0.94
-70%	10	1	1	1	1	1	1
-70%	20	1	1	1	1	1	1
-70%	30	1	1	1	1	1	1

-70%	40	1	1	1	1	1	1

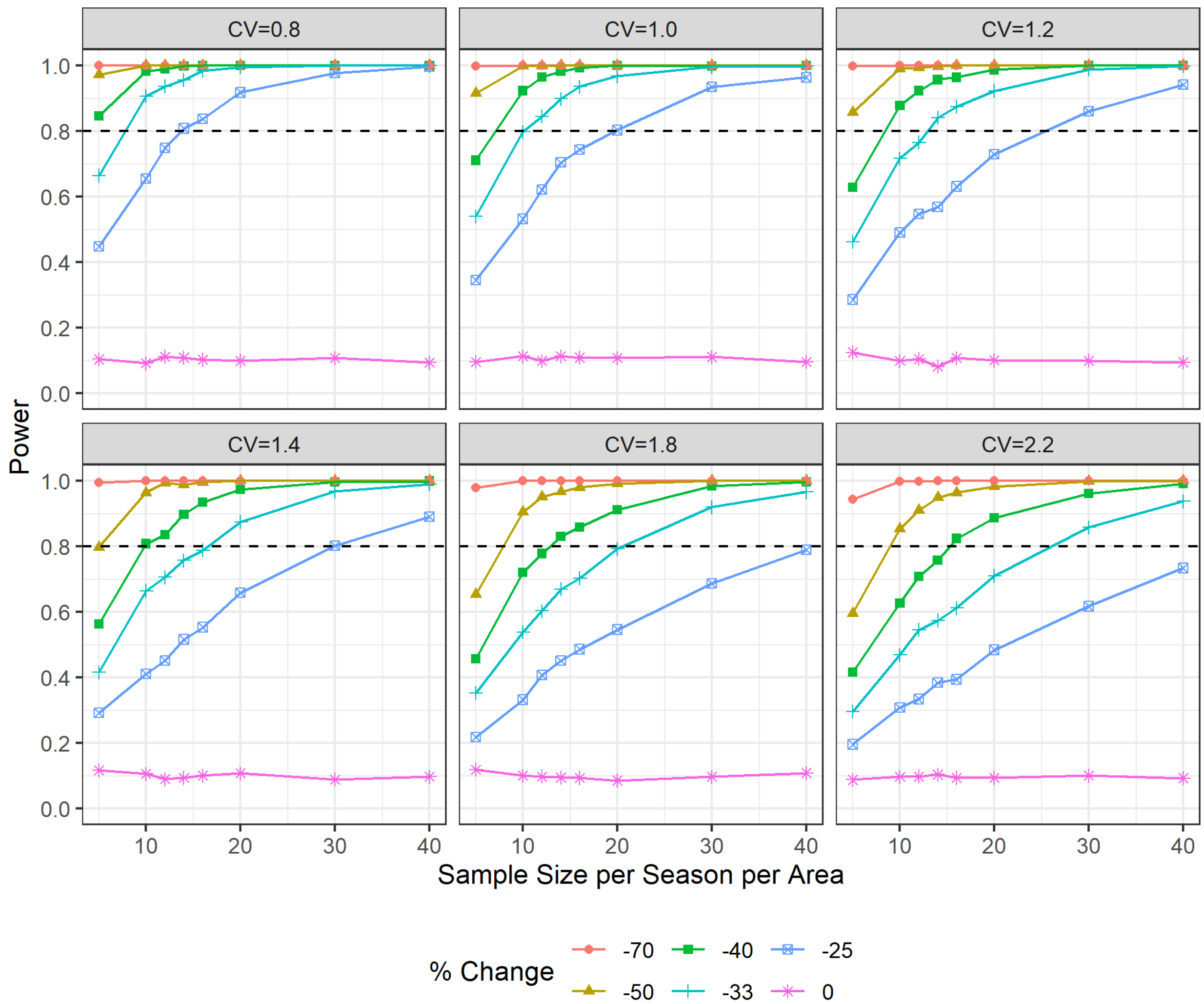

Figure 7. Power curves for the BACI interaction contrast within a saturated model (see text) for a range of variance (CV), effect sizes (negative % Change) and seasonal sample sizes in each area (n), and using a two-tailed α = 0.10. The 0% change illustrates the type I error.

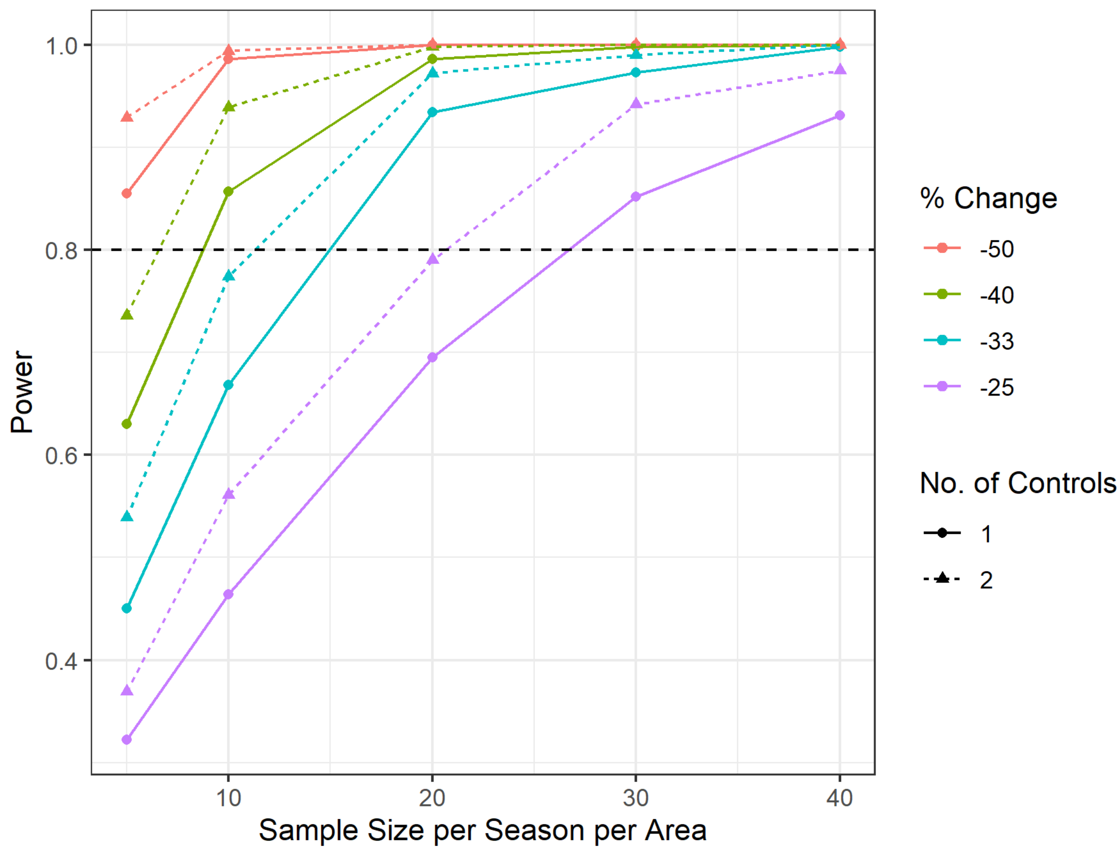

Figure 8. Power curves to illustrate the differences in power between designs with one or two reference areas for a range of effect sizes (negative % Change), and a single CV = 1.0.

5.0 Summary and Conclusions

- Data from regional trawl surveys demonstrate that fish species in the region generally exhibit moderate to high levels of natural variability (both seasonal and annual), especially when the data are analyzed on a relatively small spatial scale, which limits the number of observations.
- Given the underlying variability in catch rates that will likely be exhibited in the RWF trawl survey, it is not practicable to attempt to document a small effect size (e.g., 25% relative decrease) for fish and invertebrate species.
- For species that may be expected to demonstrate lower median CV's (e.g., 0.8-1), a seasonal sampling intensity of 10 tows/area would yield >80% power of detecting an effect size of 33% relative decrease or greater.
- For species that may be expected to demonstrate higher median CV's (e.g., 1.2 – 1.4), a seasonal sampling intensity of 10 tows/area would yield >80% power of detecting an effect size of 40% relative decrease or greater.
- For species that demonstrate higher variability in trawl survey catch rates (e.g., CVs > 1.4) a seasonal sampling intensity of 10 tows/area would only be capable of detecting larger changes in catch rates (e.g., $\geq$50% relative decrease).
- Including a second reference site improves the statistical power of the design for a given level of sampling intensity.
- This power analysis will be re-visited after the first year of the RWF trawl survey. The observed CV values will be evaluated to determine whether sampling intensity needs to be modified to achieve the desired level of statistical power.

- Simulation results indicate that taking conservatively higher sample sizes in the first year and adapting to a lower sampling effort in subsequent years (e.g., 15 tows the first year and 10 tows in subsequent years) results in a marginal increase in power (i.e., power increases from 80% to 81% for CV=1 and PC=-33%) compared to sampling 10 tows in every year. On the other hand, taking fewer samples in the first year and adapting to greater sampling effort in subsequent years (e.g., 10 tows the first year and 15 tows in subsequent years) results in a small decrease in power (i.e., power is reduced from 93% to 90% for CV=1 and PC=-33%) compared to sampling 15 tows every year.

6.0 References

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Politis PJ, Galbraith JK, Kostovick P, Brown RW. 2014. Northeast Fisheries Science Center bottom trawl survey protocols for the NOAA Ship Henry B. Bigelow. Northeast Fish Sci Cent Ref Doc. 14-06; 138 p. Online at: **https://doi.org/10.7289/V5C53HVS**

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Wilber, D., L. Read, M. Griffin, and D. Carey. 2020. *Block Island Wind Farm Demersal Fish Trawl Survey Synthesis Report – Years 1 to 6, October 2012 through September 2018.* Technical report prepared for Deepwater Wind, Providence, RI. 80 pp.

Addendum – R Script for the Statistical Power Simulation.

```
#########################################################################
## R code to simulate power for contrast-BACI approach
## libraries
	library(tidyverse)
	library(EnvStats)	#for rlnormAlt
	library(ggplot2)
	library(emmeans)

############## SIMULATE BACI DESIGN AND TEST OF COMPLEX INTERACTION (a planned contrast)
# Population means and applying percent change:
#	pop1.a and pop1.b = baseline distribution is lognormal(mean, sd); two seasons indicated by a,b
#		- applies to both impact and reference in each of the BEFORE years
#		- applies to reference in each of the AFTER years (i.e., reference remains stable over time)
#	pop2.a and pop2.b = distribution altered by the percent change (PC)
#		- mean.pop2.x = (1-PC)*mean.pop1.x
#		- applies to impact area in each of the AFTER years
# Seasonality
#		- assume 4 seasons sampled
#		- assume 2 of the seasons have mean = 0.25*mean of other 2 seasons
# Balanced design, i.e., n samples from each season, year, and area
# MODEL fit as aov(log(response) ~ grp.pd.seas.yr) [fully saturated model; most conservative]
# LINEAR CONTRAST averages the logscale differences of means using emmeans function
#
# Notes about how this formulation of the problem is more generic than it appears:
#		- applying the same mean to each year within each period is equivalent to saying that the
#		 assumed mean is the grand mean across years. Differences between years does not
#		 affect results.
#		- if the reference is not stable over time, and instead changes between the BEFORE and
#		  AFTER periods, then the % change applied to impact area is relative to the % change
#		   at reference.
########################
n.sims <- 1000
foo.num <- as.numeric(rep(NA,n.sims*6*5*6)) ## = n.sims x #effect sizes (PC) x #samp.size x #CVs
baciContr.pwrsim <- data.frame(expand.grid(PC=c(0, 0.25,0.33, 0.4, 0.5, 0.7),
	samp.size=c(5,10,20,30,40), cv=c(0.8, 1.0, 1.2, 1.4, 1.8, 2.2), mean=c(80),
	sim=1:n.sims), baci.p=foo.num)
baciContr.pwrsim <- arrange(baciContr.pwrsim, PC, samp.size, cv, mean, sim)
#set total number of seasons sampled before in each area
 b <- 4*2
#set total number of seasons sampled after in each area
 a <- 4*2
#set number of controls:
 n.c <- 2
## loop it:
my.mean <- 80			#different values were tested; did not affect results.
for (m in 1:6) {		#alternative cv values
 my.cv <- c(0.8, 1.0, 1.2, 1.4, 1.8, 2.2)[m]
 for (k in 1:6) {		#alternative effect sizes or relative % change (PC)
  PC <- c(0, 0.25,0.33, 0.4, 0.5, 0.7)[k]
```

```
 for (j in 1:5) {                    #sample sizes
  samp.size <- c(5,10,20,30,40)[j]
  #create a design matrix:
  foo.data.df <- data.frame(expand.grid(location=c("CtrlA", "CtrlB","Impact"),
        period=c("Before","After"), year=1:2, season=c("spring","summer","fall","winter"),
        rep=1:samp.size), value=as.numeric(rep(NA,samp.size*(b+a)*(n.c+1))))
  foo.data.df <- arrange(foo.data.df, location, period, year, season, rep)
  foo.data.df$grp.pd.seas.yr <- factor(with(foo.data.df,
        paste(substring(location,1,5),period,season,year)))
  for (i in 1:n.sims){               #simulate data
   foo.data.df$value[foo.data.df$period=="Before" & (foo.data.df$season == "fall" |
        foo.data.df$season=="summer")] <-
        rlnormAlt((n.c+1)*(b/2)*samp.size, mean=my.mean, cv=my.cv)
   foo.data.df$value[foo.data.df$period=="Before" & (foo.data.df$season == "winter" |
        foo.data.df$season=="spring")] <-
        rlnormAlt((n.c+1)*(b/2)*samp.size, mean=0.25*my.mean, cv=my.cv)
   foo.data.df$value[foo.data.df$period=="After" & (foo.data.df$location=="CtrlA" |
        foo.data.df$location =="CtrlB") & (foo.data.df$season == "fall" |
        foo.data.df$season=="summer")] <-
        rlnormAlt(n.c*(a/2)*samp.size, mean=my.mean, cv=my.cv)
   foo.data.df$value[foo.data.df$period=="After" & (foo.data.df$location=="CtrlA" |
        foo.data.df$location=="CtrlB") & (foo.data.df$season == "winter" |
        foo.data.df$season=="spring")] <-
        rlnormAlt(n.c*(a/2)*samp.size, mean=0.25*my.mean, cv=my.cv)
   foo.data.df$value[foo.data.df$period=="After" & foo.data.df$location=="Impact" &
        (foo.data.df$season == "fall" | foo.data.df$season=="summer")] <-
        rlnormAlt((a/2)*samp.size, mean=my.mean*(1-PC), cv=my.cv)
   foo.data.df$value[foo.data.df$period=="After" & foo.data.df$location=="Impact" &
        (foo.data.df$season == "winter" | foo.data.df$season=="spring")] <-
        rlnormAlt((a/2)*samp.size, mean=0.25*my.mean*(1-PC), cv=my.cv)

 ###fit saturated linear model on log-scale
 foo.aov2 <- aov(log(value) ~ 0+grp.pd.seas.yr, data=foo.data.df)
 foo.t2 <- emmeans(foo.aov2, ~ grp.pd.seas.yr)
 foo.contr <- contrast(foo.t2, list(baci.contrast=c(rep(c(rep(1/n.c,a), rep(-1/n.c,b)), n.c), rep(-1,a),
        rep(1,b))))
  ###test the BACI interaction contrast and save p-value:
  baciContr.pwrsim$baci.p[baciContr.pwrsim$mean == my.mean & baciContr.pwrsim$cv == my.cv &
        baciContr.pwrsim$PC == PC & baciContr.pwrsim$samp.size == samp.size &
        baciContr.pwrsim$sim==i] <- as.data.frame(foo.contr)$p.value
}}}}

#summarize simulated power (with alpha = 0.10)
my.alpha <- 0.1
baciContr.pwrsim.All.10.summ <- baciContr.pwrsim.All %>% group_by(mean, cv, PC, samp.size) %>%
 filter(baci.p <= my.alpha) %>% count(mean, cv, PC, samp.size, name="Power")
 #turn counts into proportion
 baciContr.pwrsim.All.10.summ$Power <- baciContr.pwrsim.All.10.summ$Power/n.sims
 #separate factor variable for the facet labels (mean.cv):
 baciContr.pwrsim.All.10.summ$cv.factor <- factor(baciContr.pwrsim.All.10.summ$cv,
```

```
        levels=c(0.30, 0.60, 0.75, 1.00, 1.25, 1.50, 1.75, 2.00),
        labels=c("CV=0.3", "CV=0.6", "CV=0.75", "CV=1.0", "CV=1.25", "CV=1.5", "CV=1.75", "CV=2.0"))
## PLOT:
 ggplot(subset(baciContr.pwrsim.All.10.summ, mean==80), aes(x=samp.size, y=Power,
        colour=factor(PC*100), shape=factor(PC*100)), facets=~cv.factor) +
  facet_wrap(~cv.factor)+
  geom_point() + geom_line() +
  geom_hline(yintercept=0.8, colour="black",linetype="dashed")+
  theme_bw() + theme(legend.position="bottom") +
  labs(colour="% Change", shape="% Change", x="Sample Size per Season per Area") +
  ggtitle("Power for saturated model: log(biomass) ~ Location.Pd.Season.Year [alpha=0.1]\nDesign: 4
        seasons x 2 yrs before and after; 2 controls and 1 impact")
 ggsave("power curves.png", width=7, height=6, units="in")
#####################################################
```

APPENDIX 3: Power Analysis for Lobster and Crab Ventless Trap Survey – Revolution Wind Farm

Prepared by: Lorraine Brown Read
Exa Data and Mapping

Introduction

For the ventless trap survey, a BACI design is planned to sample lobsters, Jonah crabs and rock crabs within the Revolution Windfarm (RWF) Project Area and two selected reference areas. For this 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) and 2018 (personal communication from Michael Long to Greg DeCelles) were queried to assess the residual variance estimates of lobster, Jonah crab and rock crab catch for use in this power analysis. The relationships between effect size (or magnitude of change) and statistical power for the specific BACI contrast of interest was estimated under several alternative hypotheses about changes in abundance in the Project Area relative to the reference areas, a single two-tailed alpha of 0.10, and three different design alternatives were considered (i.e., two, three, or four years post-construction).

Data and Assumptions

The survey design employed in the Project Area (also referred to as Impact area) will utilize 10-trap trawls configured identical to the trawls used in the SNECVT survey (Collie and King 2016), and the trawls planned for monitoring at South Fork Wind (SFW). The SNECVT survey in 2014 and 2015 sampled three times per month over 6 months (May – October) each year; in 2018 they sampled two times per month over 7 months (May – November). The RWF ventless trap survey will sample similar to the 2018 design of twice per month over 7 months (May – November). In these power calculations, it was assumed that the RWF survey design will be balanced with an equal number of trawls in each of the project and reference areas in each year. If the design is altered to have a different number of trawls at the reference areas than in the Project Area, the effect on power is minor as long as the imbalance is mild to moderate. The design will randomly set trawl locations during the first sampling event of each year and hold those locations fixed throughout the year, with locations re-randomized the following year. The response variable in this design is annual average catch, expressed in this appendix as catch per trap (CPUE).

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 RWF survey will be identical.
- Aliquot represents the random station location within each lease block where a 10-trap trawl was set. The same locations were fished throughout the year, and new locations were randomly selected the next year. A similar approach will be used in the RWF 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 RWF survey will use the same trawl configuration as the SNECVT 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 SNECVTS study area; the RWF footprint spans the entire SNECVTS study area excluding the five aliquots that constitute the SFW project area; the RWF Ventless Trap Survey Impact Area spans only the eastern portion of the SNECVTS study area (those collected by the F/V Happy Hours) as summarized below:

RWF (n=19 per year):	All aliquots EXCEPT: 2014: 14, 15, 20, 21, and 22 2015: 38, 39, 44, 45, and 46 2018: 62, 63, 68, 69, and 70
RWF Ventless Trap Survey Impact Area: (n=8 per year)	Only these aliquots: 2014: 10,11,16,17, 18,19, 23, 24 2015: 34,35,40,41, 42,43, 47,48 2018: 58,59, 64,65,66,67, 71,72

In the SNECVTS study, each aliquot was fished three times per month over 6 months (May-October) during 2014 and 2015, and twice per month over 7 months (May-November) during 2018. For this analysis, annualized average catch per trap was calculated for 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 by year for the entire SNECVT survey area, and for the subset of aliquots present within the RWF in its entirety, and the RWF Ventless Trap Survey Impact Area footprint (Table 1). The CPUE data followed a lognormal distribution both for the SNECVTS dataset and the BIWF ventless trap dataset (2013-2018; Wilber et al., 2020), so this power analysis assumes a lognormal distribution for the data, and uses the coefficient of variation (CV on the original scale) as the estimate of variability.

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

		Lobster			Jonah Crab			Rock Crab		
Group	**Summary Statistic**	**2014**	**2015**	**2018**	**2014**	**2015**	**2018**	**2014**	**2015**	**2018**
All (n=24)	Mean	2.49	2.10	1.98	7.29	4.91	12.8	3.57	4.34	3.05
	Std Dev	1.60	0.83	0.95	3.27	1.84	5.39	3.59	4.11	2.46
	CV	64%	40%	48%	45%	37%	42%	100%	95%	80%
RWF (n=19)	Mean	2.76	2.19	2.20	6.70	4.93	13.5	3.96	4.56	3.52
	Std Dev	1.68	0.88	0.92	2.31	2.07	5.85	3.94	4.59	2.56
	CV	61%	40%	42%	35%	42%	43%	100%	101%	73%
RWF Project Area (n=8)	Mean	3.42	2.49	2.74	5.65	4.10	10.10	4.40	6.63	3.89
	Std Dev	2.31	1.2	1.17	1.78	2.37	4.57	5.85	6.62	2.22
	CV	68%	48%	43%	32%	58%	45%	133%	100%	57%

The RWF ventless trap survey is designed to sample twice per month for 7 months. Bootstrapping from the SNECVTS dataset was used to estimate the CV for a bimonthly survey design, as well as to demonstrate how the CV is affected by increasing sample size (number of trawls). The temporal patterns of catch in both the SNECVT 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 because a longer sampling period will ensure that estimates of the annual average is complete for all trawls. The bootstrap estimates from the SNECVTS database used the following approach:

- Sample two dates per month (without replacement) to reflect the design planned for RWF and estimate an annual mean per trawl. Note: for 2014-2015 the means represent catch between May and October; for 2018, the means represent catch between May and November.
- Sample k=5 trawls (with replacement) for each year from the entire SNECVTS study area (n=24) and from the RWF area (n=19) or RWF Ventless Trap Survey Impact Area (n=8). Repeat for k=5, 6, 7, 8 trawls.
- Calculate the CV from the bootstrapped dataset for the entire SNECVTS study area, the RWF, and the RWF Ventless Trap Survey Impact Area.
- Repeat process 5000 times. The 50TH (median), 75th and 90th percentiles (Table 2) represent moderate to conservative (high) CV values for subsequent power analysis.

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

	SNECVTS study area (n=24)			RWF (n=19)			RWF Ventless Trap Survey Impact Area (n=8)		
	Percentile			Percentile			Percentile		
Trawl Count	**50th**	**75th**	**90th**	**50th**	**75th**	**90th**	**50th**	**75th**	**90th**
Lobsters									
5 Trawls	0.43	0.50	0.57	0.41	0.48	0.54	0.47	0.54	0.60
6 Trawls	0.44	0.51	0.57	0.42	0.48	0.54	0.48	0.54	0.60
7 Trawls	0.45	0.51	0.57	0.42	0.48	0.53	0.48	0.54	0.59
8 Trawls	0.46	0.51	0.57	0.43	0.48	0.53	0.49	0.54	0.58
Jonah crabs									
5 Trawls	0.39	0.44	0.49	0.39	0.45	0.49	0.40	0.46	0.50
6 Trawls	0.39	0.44	0.49	0.40	0.44	0.48	0.41	0.46	0.50
7 Trawls	0.40	0.44	0.49	0.40	0.44	0.48	0.41	0.46	0.49
8 Trawls	0.40	0.44	0.48	0.40	0.44	0.47	0.42	0.45	0.49
Rock crabs									
5 Trawls	0.61	0.75	0.88	0.62	0.76	0.89	0.69	0.82	0.95
6 Trawls	0.63	0.78	0.90	0.64	0.78	0.91	0.72	0.86	0.98
7 Trawls	0.65	0.80	0.92	0.67	0.81	0.93	0.74	0.89	0.99
8 Trawls	0.68	0.82	0.94	0.69	0.82	0.94	0.77	0.91	1.00

For all species, the median values for the RWF Project Area changed very little when the number of trawls increased from 5 to 8. The 90th percentile CV values for the lobster and Jonah crabs had increases of 0.13 or less from the median values, indicating stability in the bootstrap estimates due to consistency in the underlying dataset. The rock crab results showed more variability between the median and 90th percentile CV values, with increases in CV values as the sample size increased, likely due to the influence of a single high catch in the 2014 and 2015 (Figure 1). Across all three species, the range of median to 90th percentile values of CVs in the RWF Project Area is [0.40, 1.00], with Jonah crabs having smaller observed CV and rock crabs greater CV, relative to lobsters.

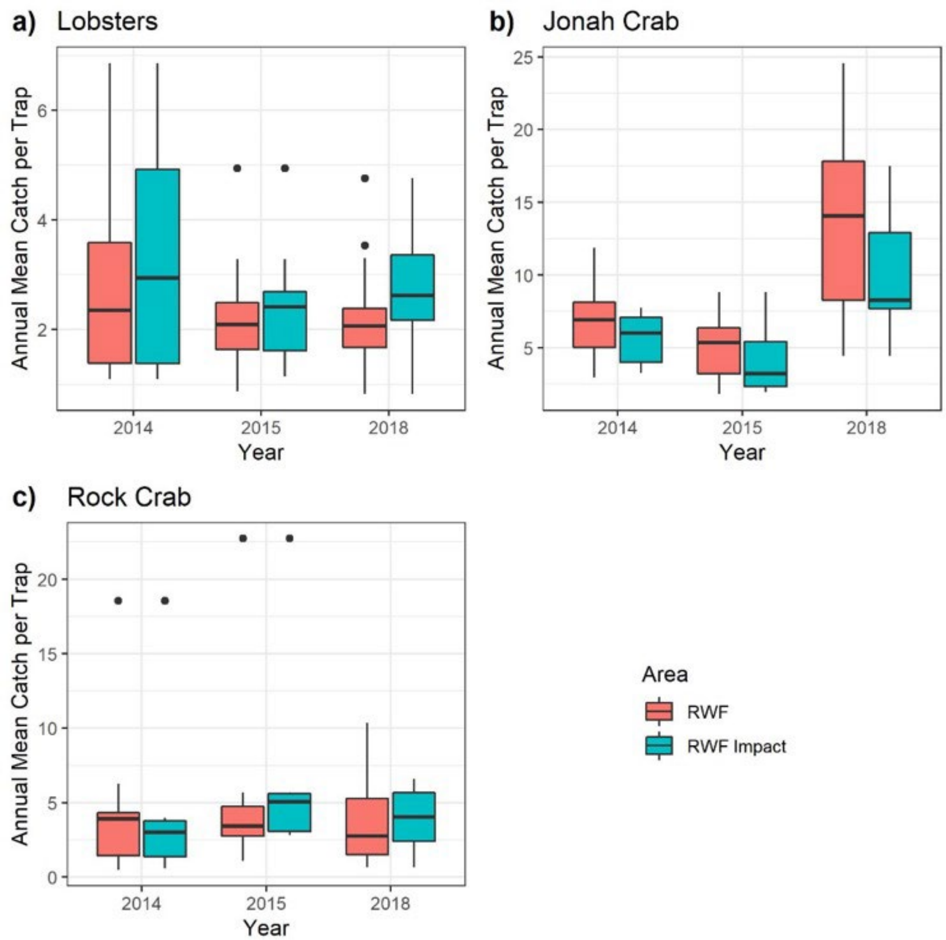

Figure 1. Distribution of the annual mean catch per trap (CPUE) for the SNECVTS data within the entire RWF (n=19 aliquots) and the RWF Ventless Trap Survey Impact Area (n=8 aliquots).

Methods

A power analysis is specific not only to study design and statistical model, but also the hypothesis of interest. The interaction null and two-tailed alternative hypotheses of primary interest associated with the ventless trap survey are as follows:

$H_{Ø}$: Changes in CPUE between time periods (before and after) will be statistically indistinguishable between the reference and impact areas.

H_1: Changes in CPUE between time periods (before and after) will be statistically different between the reference and impact areas.

The null hypothesis equates to an interaction contrast describing the (log-scale) difference between the temporal change at the windfarm and the temporal change at the reference sites. Using linear differences on the log-scale (the scale in which the model is fit) equates to proportional change (ratios) on the original measurement scale. Representing changes in CPUE as proportional rather than linear on the measurement scale is a more meaningful way to understand changes across different groups that might have widely different Baseline values. For example, a decrease of 10 fish in the average catch is a much more substantive impact for a species with a Baseline average of 20 fish than it is for a species with a Baseline average of 100 (i.e., a 50% decrease versus a 10% decrease).

The study design has 2 years nested within each time period (before/after), and 2 reference sites and an impact site within treatment. For the purposes of this power analysis, a saturated model was fit to each simulated dataset which provides an estimate of mean CPUE for each year and location. For the primary contrast comparing the temporal changes between the windfarm and reference sites, the difference on the log-scale is expressed as

$$\Delta_1 = \delta_{Reference} - \delta_{RWF} \qquad \text{[Eq. 1]}$$

where:

$\delta_{Reference} = \bar{X}_{Reference,A} - \bar{X}_{Refernce,B}$ is the temporal difference in log-scale average catch at the reference sites (two-year average from the "After" (operation) period minus two-year average from the "Before" (baseline) period, with the two reference sites averaged within each period).

$\delta_{RWF} = \bar{X}_{RWF,A} - \bar{X}_{RWF,B}$ is the temporal difference in log-scale means at the RWF Ventless Trap Survey Impact Area (two-year average from the "After" period minus two-year average from the "Before" period).

The magnitude of change is expressed as a proportional change between periods of the mean CPUE at the RWF Ventless Trap Survey Impact Area relative to the proportional change of mean CPUE at the Reference site(s). This relative percent change is expressed as:

$$\frac{\left(\bar{X}_{Impact,After}/\bar{X}_{Impact,Before}\right)}{\left(\bar{X}_{Reference,After}/\bar{X}_{Reference,Before}\right)} \qquad \text{[Eq. 2]}$$

For example, a relative percent change of 0.67 could represent a 33% decrease in catch at the impact site (a temporal ratio of 0.67) and no change at the reference site(s) (a temporal ratio of 1) (i.e., 0.67/1 = 0.67). The same value could represent any number of ratios. This relative percent change of 0.67 could also represent a 50% decrease at the impact site and a 25% decrease at the reference site(s) (i.e., 0.5/0.75 = 0.67; or a 20% decrease at the impact site and a 20% increase at the reference site(s) (i.e., 0.8/1.2 = 0.67); or other similar combinations that yield a 67% ratio of relative change[9].

The design variables evaluated in this power analysis are specified in Table 3.

Table 3. Design for Revolution Wind ventless trap survey power simulation study

Set study design variables
• Impact Areas = 1 impact area
• Reference Areas = 2 control/reference areas
• Habitat or Distance Strata = 1
• Frequency = 2x per month for 7 months (May – November) per year
• Number of years Before impact = 2
• A two-tailed α = 0.10
Variables altered in the power analysis
• Number of years After impact = 2, 3, 4
• Number of replicate (random) trawls per year in each area (n): 6, 8, 10, 12, 14, 16, 20
• Relative Percent Change (PC): -33%, -50%, -75% and 0% (for Type I error)
• Variability as CV: 0.4, 0.5, 0.6, 1.0 (see Table 2)

The power analysis used a simulation approach to generate significance values for a range of CV estimates and effect sizes, and a range of sample sizes.

For a given CV, PC, and sample size (n), the following steps were performed m=1000 times:

1. From a log-normal distribution with mean μ and CV, simulate *n* values of catch data in the RWF Ventless Trap Survey Impact Area, both Reference areas, and in each year of the Before period.
2. Repeat step 1 (same μ and CV) for each year of the After period for the two Reference areas.
3. Repeat step 1 for each year of the After period for the RWF Ventless Trap Survey Impact Area, but with mean catch in the windfarm equal to (1+PC)μ.
4. Fit the saturated model to the log-transformed catch data (i.e., a separate coefficient for every area-period-year).
5. Calculate the BACI interaction contrast, and save the p-value.
6. Repeat m=1000 times for 1000 simulation replicates.
7. Count the number of times out of m that the p-value was < 0.10, and store this simulated power estimate for that combination of CV, PC, and n.

Repeat Steps 1-7 for each combination of CV, PC, and n.

[9] Changes are expressed as relative decreases because a decline in windfarm catch relative to reference is presumed to be the main direction of concern. Because of the asymmetry of ratios, a 33% relative decrease at the windfarm (relative percent change of 0.67) is a bigger change than a 33% relative increase (relative percent change of 1.33). For example, a 33% relative decrease in the numerator (0.67/1) is equivalent to a 50% relative increase in the denominator (1/1.5). When evaluating results, consider that power for any percentage decrease is higher than power for the same percentage increase.

Results

The simulation power results for a design with one impact and two reference areas and other design details as indicated in Table 3 are shown in Table 4 and Figure 3.

Table 4. Simulated power for the BACI interaction contrast within a saturated model (see text) for a range of variance (CV), relative percent decrease at the windfarm, and sample sizes (n) per area. All simulations summarized here use two years post-operation, and a two-tailed α = 0.10 and a design with one impact and two reference areas. The 0% change illustrates the type I error. Results with power 80% and above are shaded.

% Change	Sample Size (n)	CV=0.4	CV=0.5	CV=0.6	CV=1.0
0	6	0.10	0.09	0.09	0.09
0	8	0.09	0.12	0.11	0.10
0	10	0.11	0.10	0.11	0.10
0	12	0.10	0.10	0.10	0.08
0	14	0.09	0.11	0.09	0.10
0	16	0.11	0.10	0.10	0.09
0	20	0.10	0.10	0.12	0.10
-33%	6	0.66	0.52	0.44	0.24
-33%	8	0.77	0.66	0.50	0.29
-33%	10	0.86	0.72	0.56	0.35
-33%	12	0.90	0.77	0.65	0.39
-33%	14	0.93	0.83	0.71	0.43
-33%	16	0.96	0.86	0.75	0.46
-33%	20	0.98	0.92	0.82	0.54
-50%	6	0.97	0.90	0.78	0.47
-50%	8	0.99	0.96	0.91	0.61
-50%	10	1.00	0.98	0.94	0.68
-50%	12	1.00	0.99	0.97	0.75
-50%	14	1.00	1.00	0.99	0.79
-50%	16	1.00	1.00	0.99	0.84
-50%	20	1.00	1.00	1.00	0.91
-75%	6	1.00	1.00	1.00	0.96
-75%	8	1.00	1.00	1.00	0.98
-75%	10	1.00	1.00	1.00	1.00
-75%	12	1.00	1.00	1.00	1.00
-75%	14	1.00	1.00	1.00	1.00
-75%	16	1.00	1.00	1.00	1.00
-75%	20	1.00	1.00	1.00	1.00

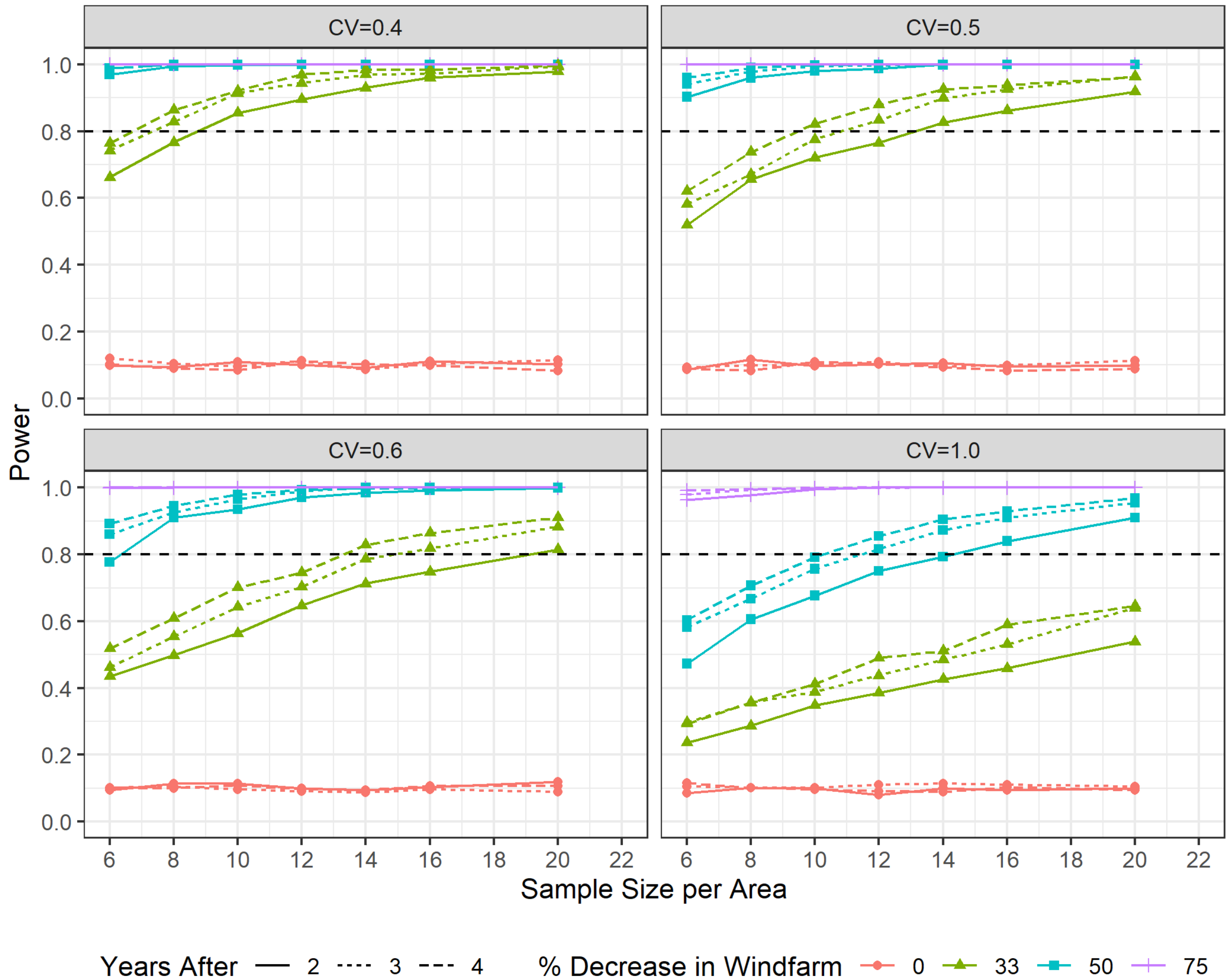

Figure 3. Power versus sample size (number of trawls) per area and year for a range of relative percent decreases and CVs (see Table 3), using a study design with single impact and two reference areas for 2 years before and 2, 3, and 4 years after operation, and a two-tailed α= 0.10.

Table 5. Power estimates contrasted between a balanced (15 trawls everywhere) and unbalanced survey design (15 trawls at the windfarm and 10 trawls at the two reference areas). Power results shown for a range of variance (CV), relative percent decrease at the windfarm (% Change). Simulations used two years before and two years post-operation, and a two-tailed α = 0.10.

% Change	Sample Size in the Two Reference Areas	Sample Size in the Wind Farm	CV=0.4	CV=0.5	CV=0.6	CV=1.0
-33%	10	15	0.92	0.80	0.68	0.39
-33%	15	15	0.95	0.85	0.74	0.44
-40%	10	15	0.99	0.94	0.77	0.54
-40%	15	15	0.99	0.96	0.76	0.63
-50%	10	15	1.00	1.00	0.84	0.76
-50%	15	15	1.00	1.00	0.90	0.86
-75%	10	15	1.00	1.00	0.98	1.00
-75%	15	15	1.00	1.00	0.99	1.00

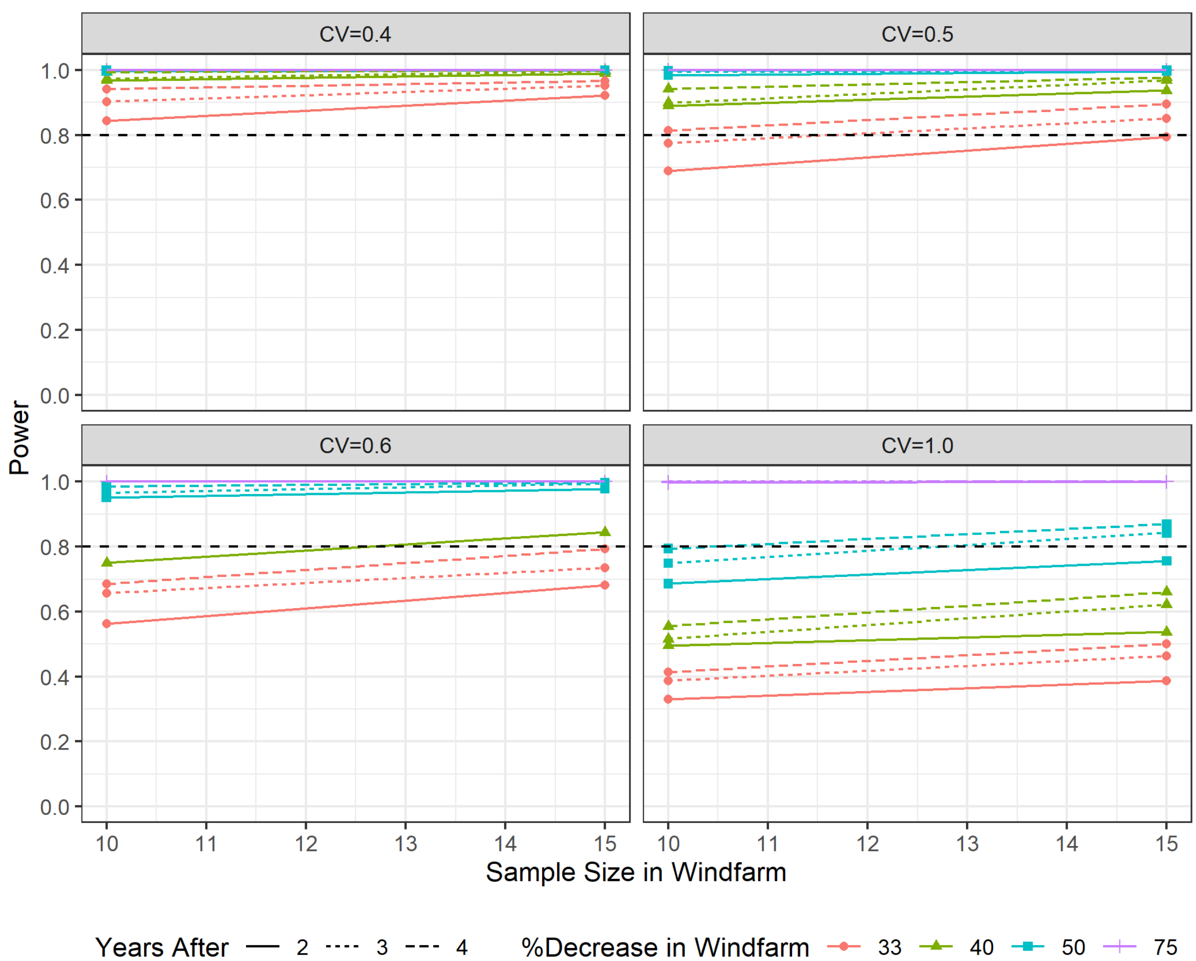

Figure 4. Power for an unbalanced design using 10 trawls in each reference area each year; and 10 or 15 trawls in the windfarm each year for a range of relative percent decreases and CVs (see Table 3), using a study design with single impact and two reference areas for 2 years before and 2, 3, and 4 years after operation, and a two-tailed α= 0.10.

Summary and Conclusions

Based on the variances observed during the SNECVT Survey, catch rates of lobsters and Jonah crabs are expected to have lower variability when compared to rock crabs (Table 2). The CV values for lobsters and Jonah crabs may be expected to have CVs between 0.4 and 0.6, while the CV values for rock crabs may be as high as 1.0. Therefore, for a given level of sampling effort, the RWF ventless trap monitoring study is anticipated to have greater power to detect changes in the relative abundance of lobsters and Jonah crabs between the reference and impact sites, and lower power for rock crabs. In other words, the study design will have the ability to detect smaller changes in relative abundance for lobsters and Jonah crabs between the reference and impact sites.

- Data from the SNECVT Survey demonstrate that Jonah crabs have lower levels of variability (0.4 to 0.5); lobsters have slightly higher levels of variability (0.5 to 0.6), and rock crabs have the greatest variability (0.7 to 1.0) (Table 2).
- For a design with two years post-operation, 14-16 trawls per area are expected to detect small effect sizes (<33% decrease) with at least 80% power when CVs are 0.5 or less; whereas slightly larger effect sizes can be detected for populations with CVs of 0.6, while the same level of sampling effort is expected to detect >50% decrease for the most variable populations (CV = 1.0; Table 4 and Figure 3).
- Each additional year post-operation is expected to increase power by approximately 5% (Figure 3) relative to a survey design with two years post-operation.
- With two years post-operation, an unbalanced design with 10 trawls per year in each of the two reference areas and 15 trawls per year in the project area is expected to decrease power by less than 5% for CVs ≤ 0.5 relative to a balanced design with 15 trawls in all three areas per year. The decrease in power for an unbalanced design relative to a balanced design is greater for larger CVs, and smaller percent change values (Table 4).

References

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APPENDIX 4: Power Analysis for Before-After-Gradient Ventless Trap Survey in Rhode Island State Waters

Performed by Julia Livermore

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Purpose

To test for an acceptable sample size at which differences can be detected between sampling groups given variances from existing RIVTS data. Multiple methods were tested and are described below. All methods focus on achieving a power level of 0.9, at a 0.1 effect size and a 0.05 significance level.

Approach 1 – Differences in Means (ventless data only)

Methods

Data Subsetting

Using R software, existing RIVTS data from 2006 to 2020 were subsetted to include only ventless lobster pots (all vented pots were omitted from further analysis). To refine the dataset to only samples collected in close proximity to the proposed cable route, a proximity analysis was conducted in ArcGIS. Sample sites within 300 m of the cable corridor over the entire time series were selected for further analysis in order to refine data and analyses of which most reflect the region proposed for sampling.

Data Simulation

All further analyses were conducted at the individual trap level in R, using lobster catch per unit effort, or CPUE (number of lobsters per pot), as the target metric.

Analysis

Differences in means between the actual catch and the two simulated catches were calculated and pooled standard deviations (square root of the average of the two group standard deviations) were created. The pwr package in R was used to calculate sample sizes for two-group independent sample t-tests.

Results

A sample size of 314 traps within groups should be sufficient to detect a 10% change in lobster CPUE with a 0.9 power level and a significance level of 0.05 (Table 1, Figures 1-2). Trap groupings could be within time periods or within distance bins; this is discussed in more detail in the conclusion. Therefore, at least 314 traps are necessary within each group, which could be configured in a variety of ways.

Table 1. Power analysis results using a t-test to evaluate difference in means of actual catch and simulated data

Power	N (within groups)	Alpha	Effect Size	Difference in Means
				1.4423
0.8	59.3	0.05	0.2	
0.9	79.1	0.05	0.2	1.4423
0.8	234.4	0.05	0.1	0.7212
0.9	313.4	0.05	0.1	0.7212

Approach 2 – Generalized Linear Model (ventless data only)

Methods

Data Subsetting and Simulation

The methods used in approach 1 were used here as well.

Analysis

The pwr package in R was used to calculate sample sizes for GLMs.

Results

Using a GLM power analysis approach, the minimum sample size within “groups” is 159 in order to achieve a power of 0.9 at an effect size of 0.1.

Table 2. Sample size needed within groups as dictated by power analysis of different GLM requirements

Power	Degrees of Freedom	Effect Size	Significance Level	N
0.8	4	0.2	0.05	65
0.9	4	0.2	0.05	82
0.8	4	0.1	0.05	125
0.9	4	0.1	0.05	159

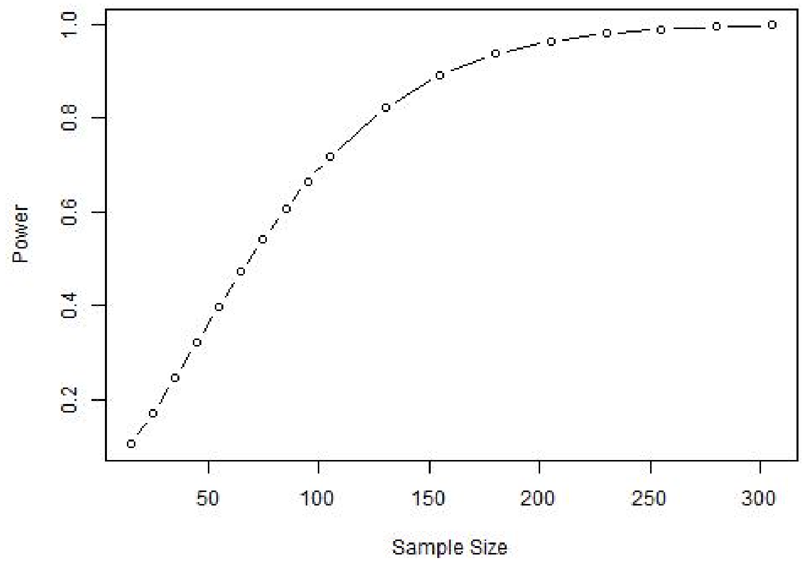

Figure 1. Power as a function of sample size with an effect size of 0.1 and a significance level of 0.05 (GLM approach)

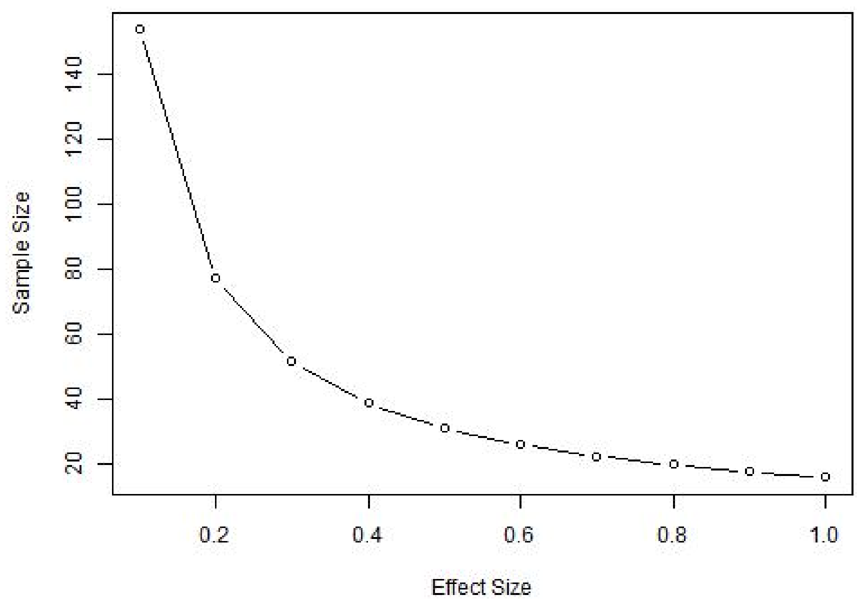

Figure 2. Sample size as a function of effect size with a power of 0.9 and a significance level of 0.05 (GLM approach)

Approach 3 – Simulated Generalized Linear Mixed Models (ventless and vented data analyzed independently)

Methods

Data Subsetting

Data were subset in the same manner as for Approach 1. However, the subsetting method was repeated for vented pots separately.

Data Simulation

Sampling with replacement (sample function in R) was used to randomly expand the spatially-subsetted RIVTS ventless pot data to exceed the maximum possible sample size for ventless posts (maximum of: 4 traps/trawl * 2 trawls/month/site * 3 distance bins * 4 stations * 12 months/year * 7 years = 8,064 traps). For further analysis, it was assumed that 4 stations would be used, each with 3 distance bins. Ten sample sizes were tested: 501, 1002, 2001, 3000, 4002, 5001, 6000, 7002, 8001, and 9000. Sample sizes needed to be divisible by three to ensure equal sampling across distance bins (i.e., a sample size of 501 equates to 167 traps per distance bin). For each sample size, 1000 model simulations were conducted; the sample size of 9000 was the exception, for which only 354 model iterations were done due to slow processing time.

For each individual simulation, a randomly stratified sample of the target sample size was pulled from the full resampled dataset; the sample was stratified by depth bins, used as a proxy for station. The data were then stratified further into three groups, one for each distance bin (a column was added to represent respective distance bin from the impact area or cable route). Finally, the catch column (lobsters/trap or CPUE) was modified for two of the distance bins. For distance bin 1 (assumed closest to the cable), catch was multiplied by 0.9 to represent a 10% reduction in catch, testing for an effect size of 0.1. Next, distance bin 2 catch was multiplied by 0.95 to represent a 5% reduction in catch. Distance bin 3 catch was unmodified.

This process was repeated using the vented data, and with different sample sizes based on the 2-vented pots per trawl design. Nine sample sizes were tested: 252, 501, 1002, 1500, 2001, 2502, 3000, 3501, and 4002.

Analysis

For each of the 1000 simulated datasets per sample size, the simulated data were analyzed using a negative binomial zero-inflated generalized linear mixed model (GLMM). Simulated catch per trap was the dependent variable (rounded down to the nearest integer) and distance bin was the independent, fixed effect variable. Sampling station, year, and month were included as random variables to account for random variability associated with seasonality, location, and year. The glmmTMB package was used to run the following model, where CatchNum refers to the simulated catch:

$$model <- glmmTMB\ (CatchNum \sim Dist\_bin + (1|Station) + (1|Year) + (1|Month),\ data = sim\_dat,\ ziformula = \sim 1,\ family = nbinom2)$$

GLMMs do not provide meaningful p-values for model covariates. As such, a likelihood ratio test was used to get a p-value associated with the distance bin covariate by testing model significance against a model without the target covariate. The p-value was exported to a table containing sample size, simulation number out of 1000, and p-values for all models conducted.

Following completion of model iterations, the proportion of significant p-values (or cases in which the null hypothesis was rejected with 95% probability; p-value <=0.05), relative to the total number of iterations per sample size was calculated. This proportion was interpreted as the statistical power as described by Johnson et al. (2015) (Figure 3).

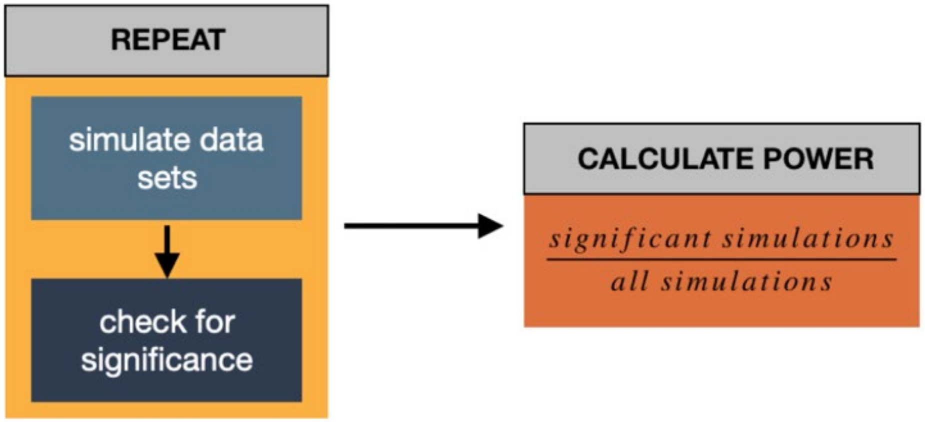

Figure 3. Shared principle of all simulation-based power analyses solutions, as described in Kumle et al. (in prep).

Results

Table 3. GLMM power analysis output for ventless pots. The proposed sample size is currently 8,064. Model runs on sample size of 9000 were halted prematurely due to extensive processing time.

Sample Size	# Significant Models	# Simulations	Power
501	336	1000	0.336
1002	660	1000	0.66
2001	925	1000	0.925
3000	988	1000	0.988
4002	1000	1000	1
5001	1000	1000	1
6000	1000	1000	1
7002	1000	1000	1
8001	1000	1000	1
9000	354	354	1

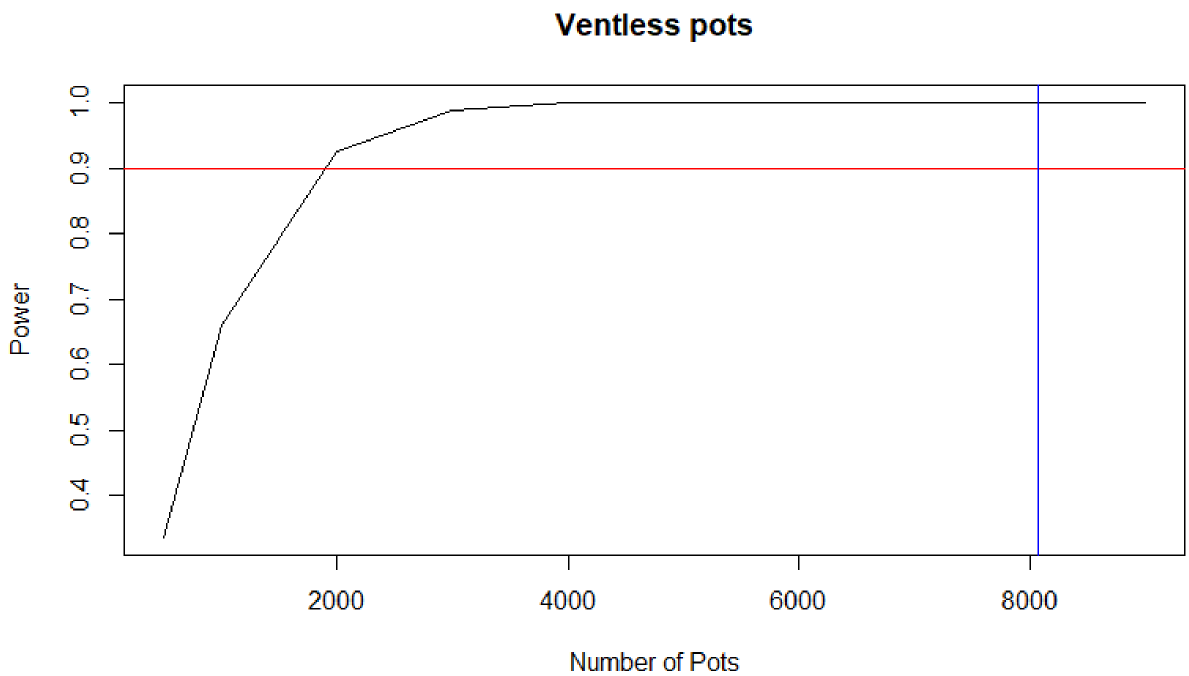

Figure 4. Power as a function of sample size for ventless pots. The red line represents the target power of 0.9. The blue line represents the proposed sample size.

Table 4. GLMM power analysis output for vented pots. The proposed sample size is currently 4,032.

Sample Size	# Significant Models	# Simulations	Power
252	187	999	0.187187187
501	337	1000	0.337
1002	668	1000	0.668
1500	828	1000	0.828
2001	940	1000	0.94
2502	975	1000	0.975
3000	994	1000	0.994
3501	997	1000	0.997
4002	999	1000	0.999

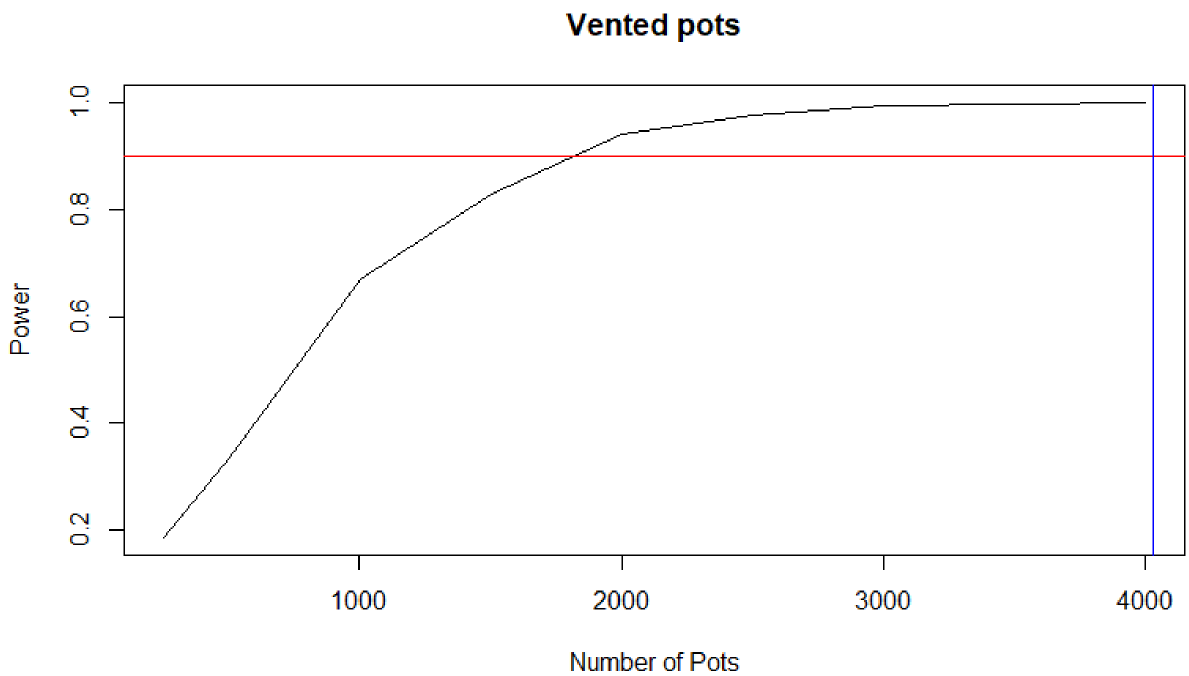

Figure 5. Power as a function of sample size for vented pots. The red line represents the target power of 0.9. The blue line represents the proposed sample size.

Conclusion

At this time, it is unknown whether EMF impacts to target species (i.e., lobster) are the same across depths, locations, and seasons. The data simulation process utilized here assumes that these impacts are equal, independent of time of year or location. Additionally, the data used to conduct the simulations are exclusively summer data (there are no fall or spring samples included). Therefore, the variance of the lobster catch data to be collected year-round may differ from that of the data used for power analyses.
For ventless pots, the first two methods utilized suggest a minimum of 314 and 159 pots within groups, respectively (either time period or distance bin). If target groups are “before” and “after” cable installation, and assuming twelve months of sampling per year and two samples per month per sampling location, then three distance bins will produce a large enough sample size to achieve target detection levels for both vented and ventless pots (Tables 4 and 5). If distance bins (distance from cables/disturbance area) are the target groups, four sampling locations will also be sufficient, as all individual groups exceed 314 (Tables 6-7).

The GLMM simulation approach assumed using 3 distance bins and 4 stations. A sample size of 2001 overall achieved a greater than 0.9 statistical power level for vented (0.94) and ventless pots (0.92), which were simulated independently. Therefore, the current design of 8,064 ventless and 4,032 vented pots (12,096 total pots) will achieve target power levels: a 10% change in catch will be detectible at greater than a 90% power level, with 95% confidence.

Table 4. Ventless traps per sampling period, assuming 4 stations and 4 traps per trawl

	Number of traps per sampling period		
Number of distance bins	Before (2 yr) + During (1 yr) = 3 yr	After (4 yr)	Total (7 yr)
3	3,456	4,608	8,064
4	4,608	6,144	10,752

Table 5. Vented traps per sampling period, assuming 4 stations and 2 traps per trawl

	Number of traps per sampling period		
Number of distance bins	Before (2 yr) + During (1 yr) = 3 yr	After (4 yr)	Total (7 yr)
3	1,728	2,304	4,032
4	2,304	3,072	5,376

Table 6. Ventless traps per station, assuming 3 distance bins and 4 traps per trawl

	Number of traps per sampling distance	
Number of stations	Annual	Total (7 yr)
4	1,152	8,064
5	1,440	10,080

Table 7. Vented traps per station, assuming 3 distance bins and 2 traps per trawl

	Number of traps per sampling distance	
Number of stations	Annual	Total (7 yr)
4	576	4,032
5	720	5,040

References

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R Code for Simulated GLMM Approach

```
options(scipen=999)
##########################
##########################
# Cable VTS Power Analysis
##########################
##########################
setwd("Folder")
load("VTS_RI_Proc_52320.RData")

require(sf)
require(simr)
require(lme4)
require(splitstackshape)
require(rgdal)
require(MASS)
require(glmmTMB)

st_layers("ExportCables_V3_Orsted_NAD832011_19N_20191203.kml")
cables<-st_read("ExportCables_V3_Orsted_NAD832011_19N_20191203.kml")
st_write(cables,dsn="ExportCables_V3_Orsted_NAD832011_19N_20191203",driver= "ESRI
Shapefile",'Cables.shp')

# Selected only cells that overlap with the buffered zone
# Exported the overlap as a new shapefile to select only trawls within those cells
cells<-readOGR(dsn ="300mCells.shp",layer="300mCells")
coordinates(Sites)<-c("Longitude","Latitude")
proj4string(Sites)<-"+proj=longlat +datum=NAD83 +no_defs +ellps=GRS80 +towgs84=0,0,0"
overlap<-Sites[cells,]
overlap<-as.data.frame(overlap)

# Merge site location data to trawls and then to traps
subTrawl<-merge(overlap,Trawls,by="SiteId")
subTraps<-merge(subTrawl,Traps,by="TrawlId")
ventless<-subset(subTraps,Trap_Type=="Ventless")
vented<-subset(subTraps,Trap_Type=="Ventless")

#############################################################################
# Conduct analysis twice: 1st for ventless pots
#############################################################################

# Create depth bins as standing for station for now (4 10m bins)
ventless$Station<-ifelse(ventless$Depth.x<10,"0-10m",ifelse(ventless$Depth.x>=10 &
ventless$Depth.x<20,"10-20m",ifelse(ventless$Depth.x>=20 & ventless$Depth.x<30,"20-
30m","30-40m")))

# Clean up data
ventless<-ventless[!names(ventless) %in%
c("TrapConfig","Exclude.y","Depth.y","Exclude.x","Groundline","NeighboringGear","Comme
nt","Latitude.y","Longitude.y","Habitat")]
Trips2<-Trips[,c("TripId","Month")]
ventless<-merge(ventless,Trips2,by="TripId")

# Characterize existing data
quart1<-quantile(ventless$CatchNum)[2]
hist(ventless$CatchNu)
# Check for over-dispersion in the data
var(ventless$CatchNum)
mean(ventless$CatchNum)
# Data overdispersed (variance larger than the mean in our dependent variable) -
likely due to all the 0s
```

```
# Use a 0-inflated negative binomial instead
# Proposed formula: formula <- CatchNum ~ Distance_Bin + Before_After + (1|Station) +
(1|Year) + (1|Month)

# Build maximum dataset
# 4 stations, 3 distance bins, 2 trawls/month, 4 traps/trawl, 12 months/year, 7 years
maxTraps<-4*3*2*4*12*7
counts<-table(ventless$Station)
probs<-counts/sum(counts)
stat1<-subset(ventless,Station=="0-10m")
stat2<-subset(ventless,Station=="10-20m")
stat3<-subset(ventless,Station=="20-30m")
stat4<-subset(ventless,Station=="30-40m")
simDat1<-stat1[sample(1:nrow(stat1),round(maxTraps*probs[1]),replace=TRUE), ]
simDat2<-stat2[sample(1:nrow(stat2),round(maxTraps*probs[2]),replace=TRUE), ]
simDat3<-stat3[sample(1:nrow(stat3),round(maxTraps*probs[3]),replace=TRUE), ]
simDat4<-stat4[sample(1:nrow(stat4),round(maxTraps*probs[4]),replace=TRUE), ]
simDat<-rbind(simDat1,simDat2)
simDat<-rbind(simDat,simDat3)
simDat<-rbind(simDat,simDat4)
remove(simDat1,simDat2,simDat3,simDat4,stat1,stat2,stat3,stat4)

# Sample sizes all divisible by three so that bins can be applied equally
sampleSizes<-c(501, 1002, 2001, 3000, 4002, 5001, 6000, 7002, 8001, 9000)

ventless_results<-data.frame()

for (num in sampleSizes){

  for (i in 1:1000){

    # Simulate data where catch decreases closer to the "cable"
    # First need to generate a random assortment of distance bins in the available
data
    newDat<-simDat[sample(1:nrow(simDat)),]
    newDat$Dist_bin<-as.factor(rep(1:3,nrow(newDat)/3))

    # 10% Reduction in closest bin and 5% reduction in middle bin; no change for
furthest bin (should be set beyond EMF signal based on BIWF data)
    newDat$Sim_Catch<-ifelse(newDat$Dist_bin ==
1,0.9*newDat$CatchNum,ifelse(newDat$Dist_bin ==
2,0.95*newDat$CatchNum,1.0*newDat$CatchNum))

    if (num>nrow(newDat)){

    }
    else {
      modDat<-stratified(newDat,"Dist_bin",num/3) # Pull stratified sample (same # of
each bin)
    }

    try({
      model<-glmmTMB(floor(Sim_Catch) ~ Dist_bin + (1|Station) + (1|Year) + (1|Month),
data=modDat, ziformula = ~1, family = nbinom2)
      outvalue<-drop1(model,test="Chisq") #Liklihood ratio test to get P-value
    },silent=T)
    ventless_results<-
rbind(ventless_results,(t(as.data.frame(c(num,outvalue$`Pr(>Chi)`[2])))))
    print(paste("Sample size ", num, "- Run ", i, " out of 1000"),sep="")

    remove(outvalue)

  }
```

```
}

ventless_results2<-ventless_results

colnames(ventless_results2)<-c("N","PVal")
ventless_results2$Sig<-ifelse(ventless_results2$PVal<=0.05,1,0)
aggDat_ventless<-aggregate(Sig~N,ventless_results2,FUN=sum)
colnames(aggDat_ventless)<-c("N","Significant")
aggDat_ventless2<-aggregate(Sig~N,ventless_results2,FUN=length)
colnames(aggDat_ventless2)<-c("N","Count")
power_ventless<-merge(aggDat_ventless,aggDat_ventless2)
power_ventless$Power<-power_ventless$Significant/power_ventless$Count

# Save outputs
write.csv(ventless_results2,"GLMM_TMB_Model_Outputs_12mon_VL.csv")
write.csv(power_ventless,"GLMM_TMB_Power_12mon_VL.csv")
pwrPlot<-plot(power_ventless$Power~power_ventless$N)
jpeg('GLMM_Pwr_Plot_12mon_VL.jpg')
plot(power_ventless$Power~power_ventless$N)
dev.off()

##############################################################################
# Repeat for vented pots
##############################################################################

# Create depth bins as standing for station for now (4 10m bins)
vented$Station<-ifelse(vented$Depth.x<10,"0-10m",ifelse(vented$Depth.x>=10 &
vented$Depth.x<20,"10-20m",ifelse(vented$Depth.x>=20 & vented$Depth.x<30,"20-30m","30-
40m")))

# Clean up data
vented<-vented[!names(vented) %in%
c("TrapConfig","Exclude.y","Depth.y","Exclude.x","Groundline","NeighboringGear","Comme
nt","Latitude.y","Longitude.y","Habitat")]
Trips2<-Trips[,c("TripId","Month")]
vented<-merge(vented,Trips2,by="TripId")

# Characterize existing data
quart1<-quantile(vented$CatchNum)[2]
hist(vented$CatchNu)
# Check for over-dispersion in the data
var(vented$CatchNum)
mean(vented$CatchNum)
# Data overdispersed (variance larger than the mean in our dependent variable) -
likely due to all the 0s
# Use a 0-inflated negative binomial instead
# Proposed formula: formula <- CatchNum ~ Distance_Bin + Before_After + (1|Station) +
(1|Year) + (1|Month)

# Build maximum dataset
# 4 stations, 3 distance bins, 2 trawls/month, 2 traps/trawl, 12 months/year, 7 years
maxTraps<-4*3*2*2*12*7
counts<-table(vented$Station)
probs<-counts/sum(counts)
stat1<-subset(vented,Station=="0-10m")
stat2<-subset(vented,Station=="10-20m")
stat3<-subset(vented,Station=="20-30m")
stat4<-subset(vented,Station=="30-40m")
simDat1<-stat1[sample(1:nrow(stat1),round(maxTraps*probs[1]),replace=TRUE), ]
simDat2<-stat2[sample(1:nrow(stat2),round(maxTraps*probs[2]),replace=TRUE), ]
simDat3<-stat3[sample(1:nrow(stat3),round(maxTraps*probs[3]),replace=TRUE), ]
simDat4<-stat4[sample(1:nrow(stat4),round(maxTraps*probs[4]),replace=TRUE), ]
simDat<-rbind(simDat1,simDat2)
```

```
simDat<-rbind(simDat,simDat3)
simDat<-rbind(simDat,simDat4)
remove(simDat1,simDat2,simDat3,simDat4,stat1,stat2,stat3,stat4)

# Sample sizes all divisible by three so that bins can be applied equally
sampleSizes<-c(252, 501, 1002, 1500, 2001, 2502, 3000, 3501, 4002)

vented_results<-data.frame()

for (num in sampleSizes){

  for (i in 1:1000){

    # Simulate data where catch decreases closer to the "cable"
    # First need to generate a random assortment of distance bins in the available
data
    newDat<-simDat[sample(1:nrow(simDat)),]
    newDat$Dist_bin<-as.factor(rep(1:3,nrow(newDat)/3))

    # 10% Reduction in closest bin and 5% reduction in middle bin; no change for
furthest bin (should be set beyond EMF signal based on BIWF data)
    newDat$Sim_Catch<-ifelse(newDat$Dist_bin ==
1,0.9*newDat$CatchNum,ifelse(newDat$Dist_bin ==
2,0.95*newDat$CatchNum,1.0*newDat$CatchNum))

    if (num>nrow(newDat)){

    }
    else {
      modDat<-stratified(newDat,"Dist_bin",num/3) # Pull stratified sample (same # of
each bin)
    }

    try({
      model<-glmmTMB(floor(Sim_Catch) ~ Dist_bin + (1|Station) + (1|Year) + (1|Month),
data=modDat, ziformula = ~1, family = nbinom2)
      outvalue<-drop1(model,test="Chisq") #Liklihood ratio test to get P-value
    },silent=T)
    vented_results<-
rbind(vented_results,(t(as.data.frame(c(num,outvalue$`Pr(>Chi)`[2])))))
    print(paste("Sample size ", num, "- Run ", i, " out of 1000"),sep="")

  }
}

vented_results2<-vented_results
colnames(vented_results2)<-c("N","PVal")
vented_results2$Sig<-ifelse(vented_results2$PVal<=0.05,1,0)
aggDat_vented<-aggregate(Sig~N,vented_results2,FUN=sum)
colnames(aggDat_vented)<-c("N","Significant")
aggDat_vented2<-aggregate(Sig~N,vented_results2,FUN=length)
colnames(aggDat_vented2)<-c("N","Count")
power_vented<-merge(aggDat_vented,aggDat_vented2)
power_vented$Power<-power_vented$Significant/power_vented$Count

# Save outputs
write.csv(vented_results2,"GLMM_TMB_Model_Outputs_12mon_vented.csv")
write.csv(power_vented,"GLMM_TMB_Power_12mon_vented.csv")
pwrPlot<-plot(power_vented$Power~power_vented$N)
jpeg('GLMM_Pwr_Plot_12mon_vented.jpg')
plot(power_vented$Power~power_vented$N)
dev.off()
```