EMPIRE WIND FISHERIES AND BENTHIC MONITORING PLAN

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September 23, 2022

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LIST OF ACRONYMS

ACCOL	Anderson Cabot Center for Ocean Life
ANOSIM	Analysis of Similarities
aRPD	apparent redox potential discontinuity
BACI	Before-After-Control-Impact
BAG	Before-After Gradient
BIWF	Block Island Wind Farm
BOEM	Bureau of Ocean Energy Management
BRUV	Baited Remote Underwater Video
CI	Confidence Interval
CPUE	Catch per Unit Effort
CTD	Conductivity Temperature Depth
CV	coefficient of variation
ECDF	Empirical cumulative distribution function
EFH	Essential fish habitat
EFP	Exempted Fishing Permit
Empire	Empire Offshore Wind LLC
EMF	Electromagnetic fields
EW1	Empire Wind 1
EW 2	Empire Wind 2
FMP/BMP	Fisheries and Benthic Research Monitoring Plan
ft	feet
GAM	Generalized Additive Model
GLM	Generalized Linear Model
GLMM	Generalized Linear Mixed Model
ha	hectare(s)
HD	High definition
HMS	Highly Migratory Species
ITIS	Integrated Taxonomy Information System
kg	kilogram(s)
km	kilometer(s)
LOA	Letter of Acknowledgement
LPIL	lowest possible taxonomic unit
m	meter(s)
mm	millimeter(s)
mi	mile(s)
nm	nautical mile(s)
NEFOP	Northeast Fisheries Observer Program
NEFSC	Northeast Fisheries Science Center

NEFSC PSB	Northeast Fisheries Science Center Protected Species Branch
NJDEP	New Jersey Department of Environmental Protection
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
NYSDEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
OCS	Outer Continental Shelf
OSS	offshore substation
PAM	passive acoustic monitoring
POI	Points of Interconnection
PV	Plan View
ROSA	Responsible Offshore Science Alliance
ROV	Remotely Operated Vehicle
SMAST	School for Marine Science and Technology
SPI	Sediment Profile Imaging
TED	Turtle Excluder Devices
µm	micron
UHD	ultra-high definition
USBL	Ultra Short Baseline
VMS	Vessel Monitoring System
VTR	Vessel Trip Report
WEA	Wind Energy Area
WTG	wind turbine generator

1.0 INTRODUCTION

Empire Offshore Wind LLC (Empire) proposes to construct and operate an offshore wind farm located in the designated Renewable Energy Lease Area OCS-A 0512 (Lease Area). The Lease Area covers approximately 79,350 acres (ac; 32,112 hectares [ha]) and is located approximately 14 statute miles (mi) (12 nautical miles [nm], 22 kilometers [km]) south of Long Island, New York and 19.5 mi (16.9 nm, 31.4 km) east of Long Branch, New Jersey (Figure 1-1). The Lease Area was awarded through the Bureau of Ocean Energy Management (BOEM) competitive renewable energy lease auction of the Wind Energy Area (WEA) offshore of New York.

Empire proposes to develop the Lease Area in two wind farms, known as Empire Wind 1 (EW 1) and Empire Wind 2 (EW 2). Monitoring efforts at both EW 1 and EW 2 will be combined and covered in this Fisheries and Benthic Monitoring Plan. EW 1 and EW 2 will be electrically isolated and independent from each other. Each wind farm will connect via offshore substations (OSS) to separate Points of Interconnection (POIs) at onshore locations by way of export cable routes and onshore substations. In this respect, the Project includes two onshore locations in New York where the renewable electricity generated will be transmitted to the electric grid.

Offshore components of the Project will consist of up to 174 wind turbines and supporting tower structures, and two offshore substations, using up to 176 foundations. In addition, there will be associated support and access structures (for the wind turbines and offshore substations) and up to 260 nm (481 km) of inter-array cable (up to 116 nm [214 km] for EW 1 and up to 144 nm [267 km] for EW 2), all of which will be located in federal waters within the Lease Area. In addition, the Project will include up to 66 nm (122 km) of submarine export cables, consisting of up to two routes to New York:

- Up to 40 nm (74 km) to the EW 1 landfall, of which 24 nm (44 km) is in federal waters and 16 nm (30 km) in state waters; and
- Up to 26 nm (48 km) to the EW 2 landfall, of which 18 nm (33 km) is in federal waters and 8 nm (15 km) is in state waters

The Project includes two onshore substation locations:

- EW 1 onshore substation in Brooklyn, New York; and
- EW 2 Onshore Substation A or EW 2 Onshore Substation B in Oceanside, New York.

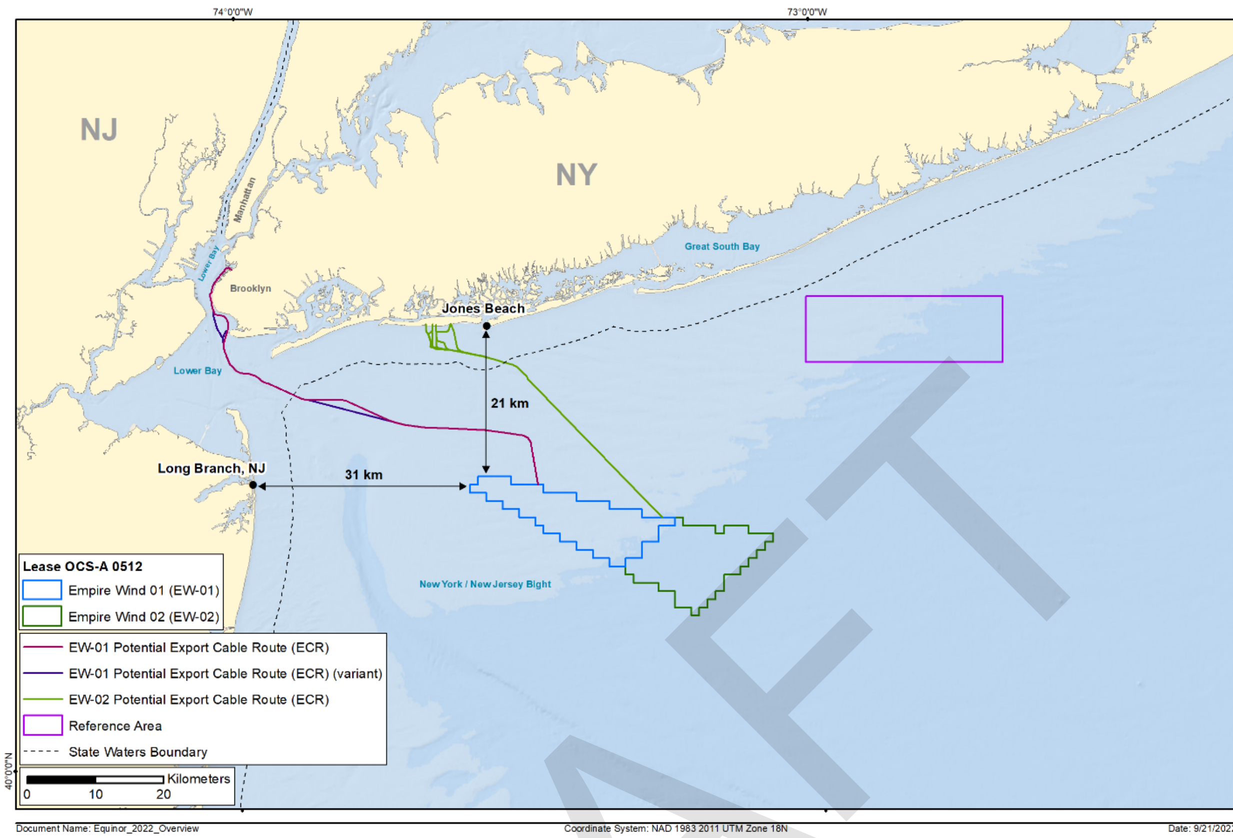

Figure 1-1. Map of the Project Area, including Export Cable routes

2.0 OVERVIEW OF FISHERIES AND BENTHIC MONITORING

This Fisheries and Benthic Research Monitoring Plan (FMP/BMP) has been developed in accordance with recommendations set forth in "Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf" (BOEM 2019), 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.

BOEM also provides guidance related to specific survey gears that can 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 fisheries 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 wind developers to review 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. Benthic monitoring that is planned for New York state waters is described in a separate monitoring plan.

Additional fisheries monitoring guidance was obtained from the Responsible Offshore Science Alliance's "Offshore Wind Project Monitoring Framework and Guidelines" (2021). These guidelines build on existing BOEM guidance, outlining the fundamental elements to include in offshore wind fisheries monitoring plans and associated studies for commercial-scale offshore wind farms and identifying the primary resources to help draft and review such plans. Based on existing BOEM guidance and best practices developed to date, this document helps to:

- Streamline project monitoring plan development and review by providing comprehensive standardized recommendations for monitoring marine resources affected by offshore wind development projects;
- Ensure project monitoring plans and supporting studies are effectively designed to provide necessary information that can be used to understand and minimize adverse impacts on marine resources from offshore wind development consistent with established BOEM, National Marine Fisheries Service (NMFS), and state guidelines, best science practices, and decision maker and developer data needs;
- Encourage the use of standardized protocols to collect and analyze biological and environmental data that can be integrated with existing survey data and other research;
- Support the integration of monitoring efforts across multiple spatial and temporal scales (site-specific to regional/ecosystem and before/after construction);
- Focus monitoring efforts on important commercial and recreational species, habitats, and other resources that may be impacted by or vulnerable to offshore wind development; and
- Encourage proactive engagement, collaboration, and involvement among state and federal agencies, research institutions, wind developers, and fishery members and representatives.

This monitoring plan will be revised through an iterative process, and survey protocols and methodologies have been and will continue to be refined and updated based on feedback received from stakeholder groups. The majority of the research described in this plan will be performed on contracted commercial and recreational fishing vessels whenever practicable. Further, the fieldwork, data analysis and interpretation, data management, and reporting described in the monitoring plan will be performed by INSPIRE Environmental unless otherwise identified.

Empire is committed to conducting research and monitoring in a responsible manner. While this plan does incorporate some traditional fisheries independent survey techniques, the majority of the proposed survey designs utilize non-extractive methodologies to reduce mortality of fish and invertebrate species, as well as minimize interactions with protected resources. Advanced technologies will be used to assess potential impacts to fish and invertebrates while limiting impacts from the monitoring itself. Where practicable, surveys have been designed to utilize protocols and methodologies from monitoring projects within other offshore wind lease areas to increase data compatibility and comparability and contribute to regional monitoring efforts.

3.0 FISHERIES MONITORING

3.1 SUMMARY OF REGIONAL FISHERIES MONITORING

Existing fishery independent and dependent data were identified and reviewed during the development of this FMP. Several established fisheries independent surveys have been conducted within the Empire Wind Lease Area, as well as in the vicinity the Export Cable Route. These surveys provide examples of on-going and recent work that help to characterize marine communities throughout the NY Bight and surrounding region. This section provides a summary of fisheries monitoring within the region, prior to construction of the Empire Wind Project.

Guida et al. (2017) compiled a regional overview of the species composition and seasonal dynamics within the NY WEA. Catches from the Northeast Fisheries Science Center (NEFSC) bottom trawl survey, conducted between 2003 and 2016, showed a seasonal shift in species composition for this region that occurs between winter and summer. During colder months, Atlantic herring, little skate, and winter skate were the numerically dominant species caught. In the warmer months, this transitioned to butterfish, little skate, longfin squid, and Atlantic sea scallop (Guida et al. 2017). Longfin squid were a core species present in August in beam trawl catches that also collected their benthic egg mops (Guida et al. 2017).

The New Jersey Department of Environmental Protection (NJDEP) and the New York State Department of Environmental Conservation (NYSDEC) have developed bottom trawl surveys that operate within NJ and NY state waters, respectively. The Ocean Stock Assessment Program samples 30-39 stations from Sandy Hook to Cape May, New Jersey, five times per year (NJDEP 2022). In New York, the Nearshore Ocean Trawl Survey is a ten-year long project that started in 2017. The survey is conducted once per season and samples from Breezy Point to Block Island Sound in water depths up to 30 meters (m) (NYSDEC 2022). In addition to traditional trawl survey sampling, the Nearshore Ocean Trawl Survey also tags striped bass during fall surveys. The top species sampled (by weight) in 2021 were winter skate, clearnose skate, smooth dogfish, little skate, scup, summer flounder, longfin squid, and Atlantic sturgeon (NYSDEC 2022).

The Fish and Fisheries Study, commissioned by the New York State Energy Research and Development Authority (NYSERDA) as part of the New York State Offshore Wind Master Plan, examined available data within an ‘Area of Analysis’ off the coast of New York and New Jersey. This area contained the majority of the Empire Wind Lease Area (Ecology and Environment Engineering, P.C. 2017). Datasets including habitat data, fishery-independent data, and fishery-dependent data were obtained from state and federal agencies, fisheries councils and commissions, universities, and non-governmental organizations. Feedback was also provided by industry stakeholders such as regulatory agencies, industry representatives and active commercial fishermen. The Fish and Fisheries Study provides a review and summary of available biological and fisheries information within the region. It also provides spatially explicit data on the geographic patterns of fishing effort and revenue in the area, based on information collected through Vessel Monitoring Systems (VMS), Vessel Trip Reports (VTR), and stakeholder input.

Recent work by Ingram et al. (2019) utilized passive acoustic monitoring (PAM) techniques as a non-extractive method to collect baseline data on Atlantic sturgeon movement through the NY WEA. From November 2016 through February 2018, 181 unique sturgeon were detected throughout the WEA. Sturgeon presence was highly variable between seasons, peaking in detections in late fall through early winter (November- January), with few detections during warmer months (July-September).

Additional data sources that characterize NY Bight regional baseline data include:

- Atlantic sea scallop resource surveys including School for Marine Science and Technology's (SMAST) drop camera surveys (Bethoney et al. 2018), dredge surveys (Hart 2015), and Coonamesset Farm Foundation (CFF) Habitat Camera (HabCam) surveys (CFF 2022).
- Northeast Area Assessment and Monitoring Program (NEAMAP) bottom trawl survey that samples annually from Cape Cod, MA to Cape Hatteras, NC, in water depths ranging from 60 to 120 feet (ft) (NEAMAP et al. 2021).
- Larval fish and lower trophic level zooplankton surveys (Thorne et al. 2020).
- Acoustic surveys, paired with bottom trawl surveys to quantify abundance and distribution of pelagic fishes and squid in the NY Bight (Thorne et al. 2020).
- Bottom trawl surveys conducted within NY state waters along the South Fork Wind Farm export cable route by Cornell Cooperative Extension (CCE) from Smith Point Inlet to Montauk Point (CCE 2022).

Regional approaches to monitoring have been suggested to better understand potential cumulative effects of offshore wind development on fisheries resources and operations. Utilizing standardized fisheries monitoring protocols will aid in understanding the spatial extent of impacts to marine resources, outside of disturbance to the individual lease areas (McCann 2012; MADMF 2018; ROSA 2021). This FMP was designed to complement existing data collection efforts, where practicable, by federal and state agencies, research institutions and other offshore wind developers as recommended by the Responsible Offshore Science Alliance (ROSA).

3.2 ESSENTIAL FISH HABITAT

The Empire Wind Project (Lease Area and cable routes) is designated Essential Fish Habitat (EFH) to 39 species with one or more life stages existing within the project area. These species include:

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

Several species without designated EFH but listed as National Oceanic and Atmospheric Administration (NOAA) Trust Resources can also be found within the project area. These species include several species of shad and river herring (alewife and blueback herring), American eel, Atlantic menhaden, Atlantic striped bass, tautog, weakfish, Jonah crab, and horseshoe crab.

3.3 FISHING ACTIVITY IN THE REGION

Commercial fishing activity within the Empire Wind Lease Area and along the Export Cable routes was characterized using several sources of publicly available information that include VMS and VTR data from the Northeast and Mid-Atlantic Ocean Data Portals (Northeast Ocean Data 2022; Mid-Atlantic Data Portal 2022) and VTR data from NOAA Fisheries (2022a). Equinor's Fisheries Liaisons have also acquired information on the fisheries that operate in the region through extensive outreach and conversations with commercial, charter, and recreational fishermen.

Recently, NOAA Fisheries (2022a) developed a public website that uses VTRs and Dealer Reports to summarize annual landings and revenue for each offshore wind project along the US East Coast. These reports help to characterize the major species harvested, gear types used, and the ports most likely to be affected by offshore wind development, for federally permitted species (NOAA 2022a). Fisheries that include VTR reporting requirements, including party/charter vessels, are represented in these summaries, whereas summaries are not provided for those fisheries without federal reporting requirements (e.g., federally permitted lobster vessels, state permitted vessels, and some HMS permitted vessels). The socioeconomic data regarding commercial fishing activity in the Empire Wind Lease Area from 2008-2019 are summarized below.

Various federally permitted fisheries conduct operations within the Empire Wind Lease Area, but the area has experienced lower levels of fishing effort in recent years. The number of commercial trips peaked in 2008, when 4,519 trips were taken in the Empire Wind Lease Area, and has been decreasing since (Table 3-1). Vessels from Point Pleasant, NJ, Freeport, NY, and Point Judith, RI conducted the greatest number of trips in the area in 2019 (Table 3-2). Point

Pleasant, NJ had the highest number of vessels conduct trips in the area in 2019 (n = 30), followed by Point Judith, RI (n = 29) and New Bedford, MA (n = 27) (Table 3-2). During the same year, the target species that accounted for the greatest number of trips to the Empire Wind Lease Area were summer flounder, black sea bass, monkfish, longfin squid, and skates (Table 3-3).

In terms of revenue, the top-five most valuable species landed from 2008 to 2019 within the Empire Wind Lease Area were the Atlantic sea scallop, longfin squid, summer flounder, Atlantic mackerel, and surf clam (Table 3-4). Atlantic herring was the species with the highest landings by weight, followed by Atlantic mackerel, longfin squid, Atlantic sea scallop, and surf clam. Additional species landed from the area include monkfish, American lobster, and black sea bass (Table 3-4).

Over the same twelve-year time-period, the scallop dredge fishery accounted for the highest revenue, followed by the bottom trawl and clam dredge fisheries (Table 3-5). VMS data for the scallop dredge fleet from 2015 to 2016 show that the fishery operated in the eastern portion of the Lease Area (Figure 3-1). The multispecies groundfish bottom trawl fleet scarcely used the eastern portion of the Lease Area (Figure 3-2), while the squid fleet operated in the middle to eastern portion of the area (Figure 3-3). The multispecies groundfish and clam dredge fisheries (from 2015 to 2016) scarcely operated within the Empire Wind Lease Area (Figure 3-4). The mid-water trawl fishery had the highest number of landings, followed by the bottom trawl and scallop dredge fisheries from 2008 to 2019 (Table 3-5). From 2015 to 2016, the mid-water trawl fishery operated mainly in the central portion of the area, with lower amounts of effort on the western and eastern boundaries (Figure 3-5). Other gear types fished in this area include lobster pots, sink gillnets, pots (other), purse seines, and handlines (Table 3-5).

Party/charter vessel usage of the Empire Wind Lease Area reached an 11-year high in 2018, when the annual revenue stemming from the area was estimated to be $155,000; a $125,000 increase when compared to the year before (Table 3-6). During the same time period, NOAA (2022a) estimates that for-hire vessels from only NY and NJ ports used the area. These vessels mainly targeted black sea bass, scup, red hake, bluefish, Atlantic cod, summer flounder, tautog, sea robins, and triggerfish (Table 3-7).

Table 3-1. The Number of Trips and the Corresponding Number of Vessels Utilizing the Empire Wind Lease Area from 2008 to 2019 (NOAA 2022a)

Year	Number of Trips	Number of Vessels
2019	1,105	180
2018	1,696	208
2017	1,796	226
2016	2,201	279
2015	2,106	276
2014	2,353	338
2013	2,260	229
2012	3,187	322
2011	3,398	384
2010	3,006	374
2009	4,300	365
2008	4,519	330

Table 3-2. The Number of Trips and the Corresponding Number of Vessels Utilizing the Empire Wind Lease Area, by Port in 2019 (NOAA 2022a)

Port	Number of Trips	Number of Vessels
Atlantic City, NJ	11	4
Beaufort, NC	17	11
Cape May, NJ	36	13
Chincoteague, VA	7	7
Freeport, NY	104	4
Hampton Bay, NY	5	3
Hampton, VA	20	11
Montauk, NY	20	7
New Bedford, MA	44	27
Newport News, VA	7	7
Point Judith, RI	64	29
Point Pleasant, NJ	336	30
Shinnecock, NY	7	3
Stonington, CT	5	3
Total	**683**	**159**

Table 3-3. The Number of Trips and Coinciding Number of Vessels by Target Species, Taken within the Empire Lease Area During 2019 (NOAA 2022a)

Species	Number of Trips	Number of Vessels
Summer Flounder	615	97
Black Sea Bass	505	89
Monkfish	451	98
Longfin Squid	434	86
Scup	401	80
Skates	381	51
Silver Hake	265	59
Red Hake	258	45
American Lobster	231	27
Bluefish	205	54
Butterfish	191	53
Atlantic Mackerel	133	40
Dogfish Smooth	109	20
Jonah Crab	102	10
Sea Scallop	87	53
Rock Crab	77	3
Dogfish Spiny	74	14
Squeteague Weakfish	67	25
Conger Eel	65	25
Tautog	57	8
Menhaden	44	5
Atlantic Herring	38	12
Sea Robins	27	12
Surf Clam	24	10
Northern Puffer	17	11
Bonito	15	7
Triggerfish	13	9
Golden Tilefish	12	5
Blueline Tilefish	9	3
King Whiting	9	7
Nk Eel	9	4
American Eel	8	4
Striped Bass	6	3
Spanish Mackerel	4	4
Amber Jack	3	3
Knobbed Whelk	3	3
Total	**4949**	**1039**

Table 3-4. The Revenue and Landings by Species, for the Empire Wind Lease Area during 2008 to 2019 (NOAA 2022a)

Species	Twelve Year Revenue	Twelve Year Landings
Sea Scallop	$5,960,000	610,000
Longfin Squid	$877,000	711,000
Summer Flounder	$343,000	110,000
Atlantic Mackerel	$166,000	719,000
Surf Clam	$112,000	156,000
Atlantic Herring	$101,000	793,000
American Lobster	$55,000	11,000
Monkfish	$53,000	23,000
Black Sea Bass	$39,000	11,000
All Others	$37,000	55,000
Total	**$7,743,000**	**3,199,000**

Table 3-5. The Revenue and Landings by Gear Type for the Empire Wind Lease Area during 2008 to 2019 (NOAA 2022a)

Gear Type	Twelve Year Revenue	Twelve Year Landings
Dredge-Scallop	$5,466,000	546,000
Trawl-Bottom	$1,948,000	1,316,000
Dredge-Clam	$290,000	346,000
Trawl-Midwater	$187,000	1,319,000
Pot-Lobster	$62,000	16,000
Gillnet-Sink	$24,000	16,000
All Others	$13,000	32,000
Pot-Other	$6,000	4,000
Seine-Purse	$2,000	14,000
Handline	$2,000	1,000
Total	**$8,000,000**	**3,610,000**

Table 3-6. The Party/Charter Vessel Estimated Revenue by Year from the Empire Wind Lease Area (NOAA 2022b)

Year	Annual Revenue
2008	$23,000
2009	$2,000
2010	$42,000
2011	$24,000
2012	$22,000
2013	$12,000
2014	$39,000
2015	$27,000
2016	$26,000
2017	$30,000
2018	$155,000
Total	**$403,000**

Table 3-7. The Estimated Catch from Party/Charter Vessel Target Species in the Empire Wind Lease Area from 2008 to 2018 (NOAA 2022b)

Species	Eleven Year Fish Count
All Others	6,980
Black Sea Bass	6,807
Scup	6,241
Red Hake	5,830
Bluefish	742
Cod	702
Summer Flounder	464
Tautog	176
Sea Robins	40
Triggerfish	17
Total	**27,999**

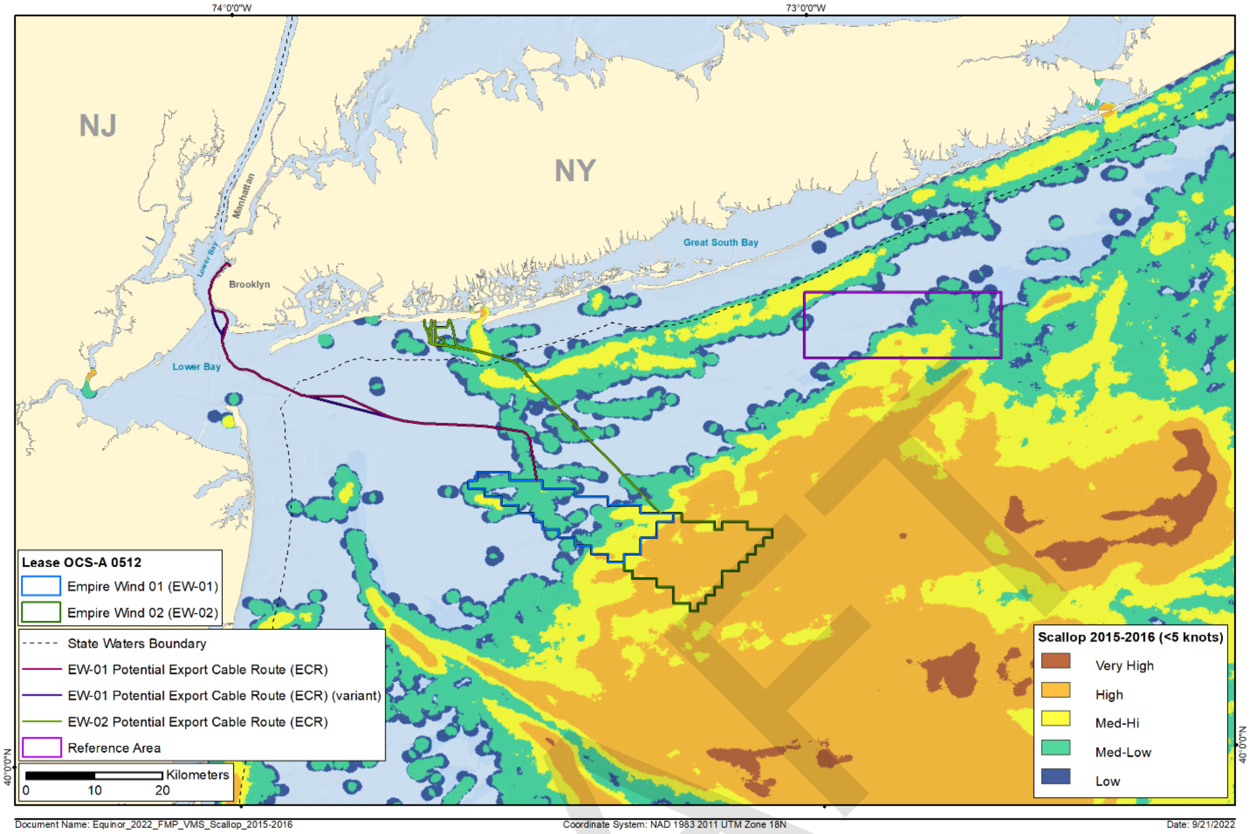

Figure 3-1. VMS data for the scallop dredge fleet from 2015 to 2016 in the Empire Wind region

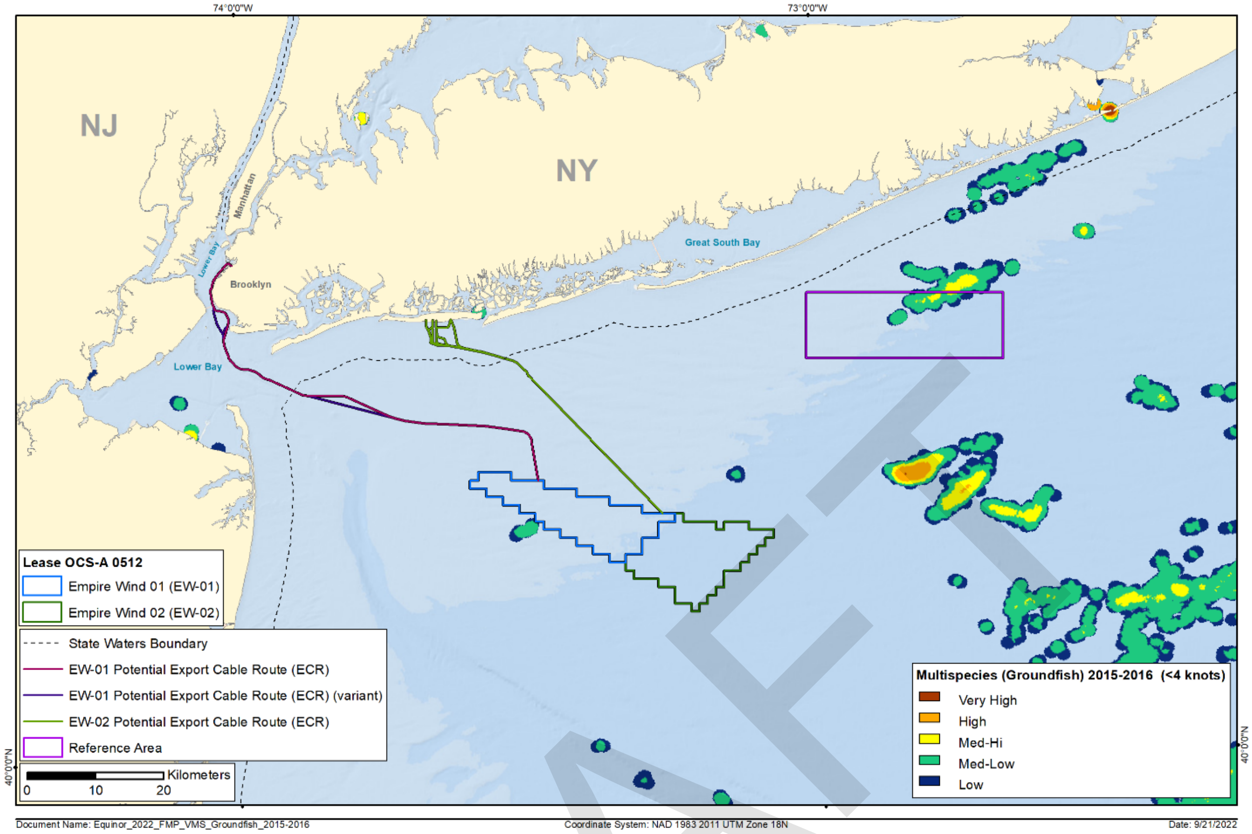

Figure 3-2. VMS data for the multispecies groundfish fishery from 2015 to 2016 in the Empire Wind region

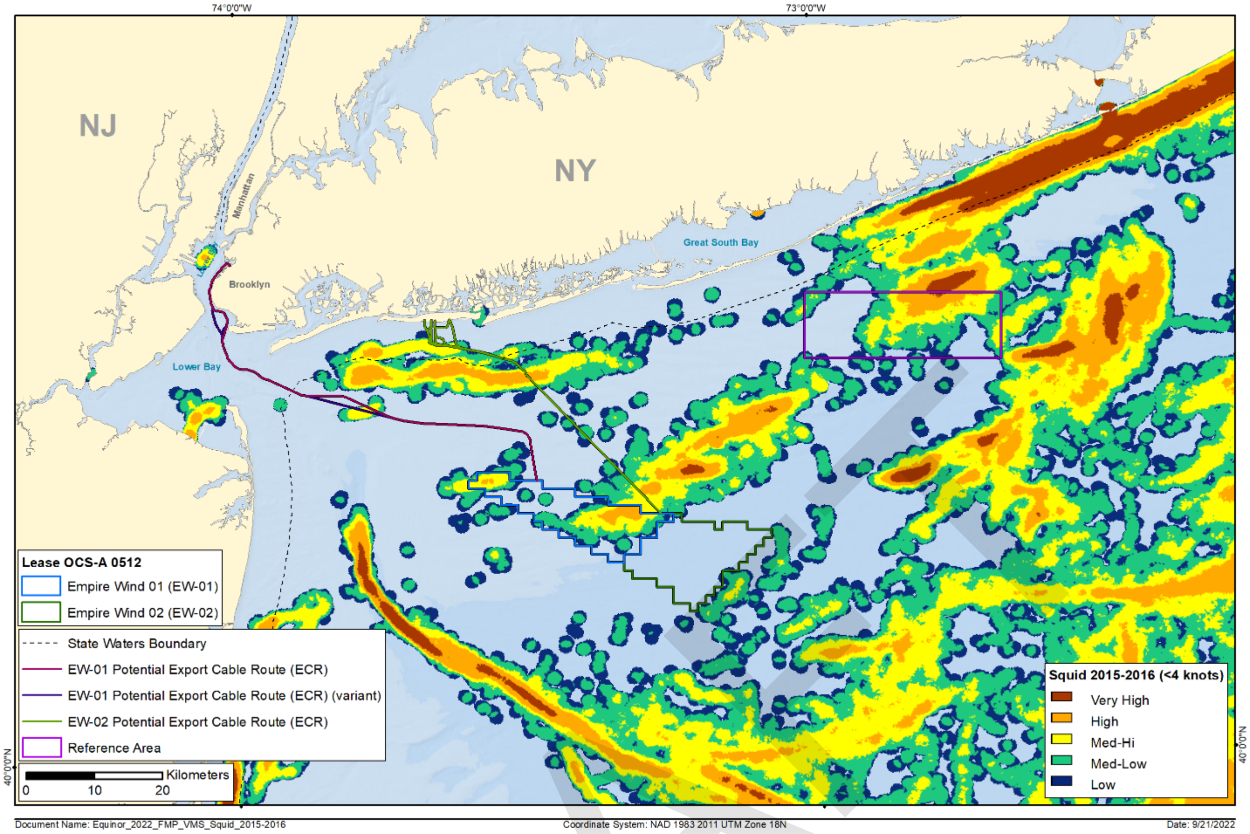

Figure 3-3. VMS data for the squid fishery from 2015 to 2016 in the Empire Wind region

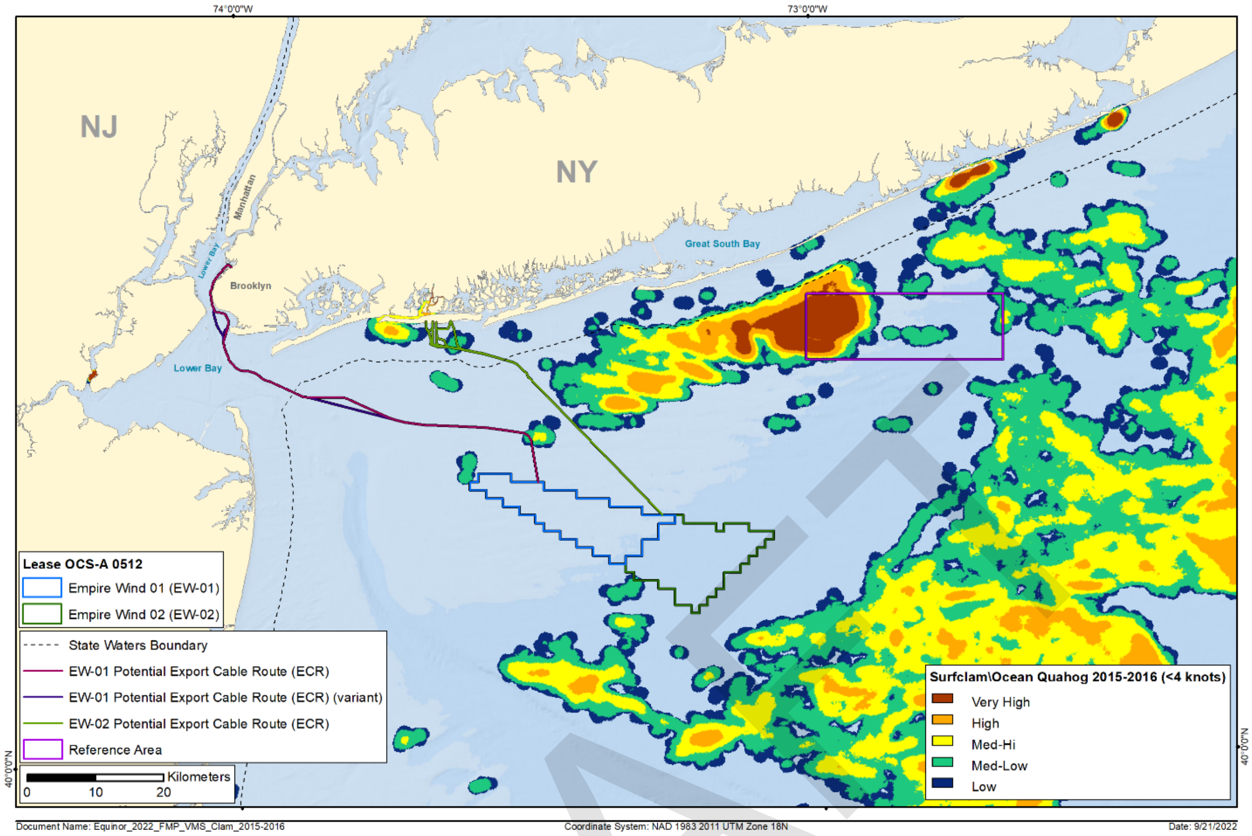

Figure 3-4. VMS data for the clam dredge fishery from 2015 to 2016 in the Empire Wind region

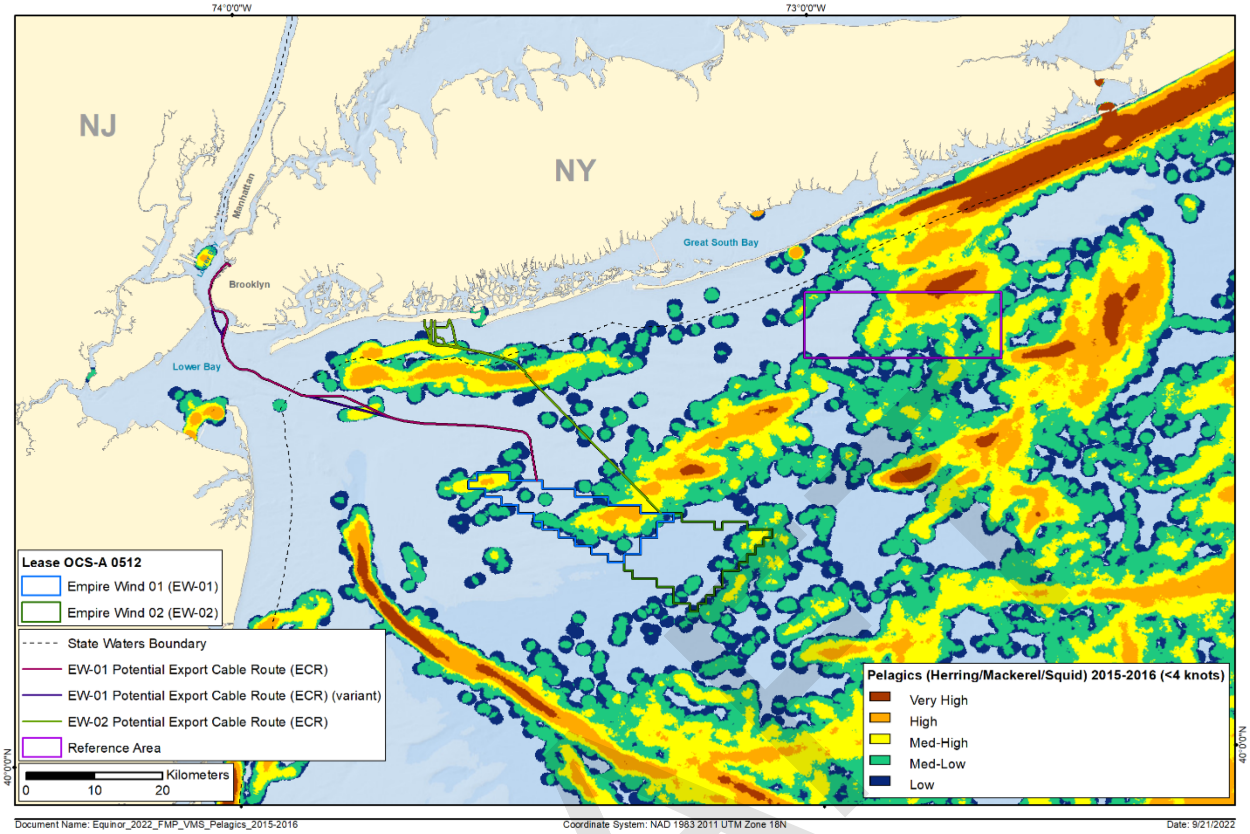

Figure 3-5. VMS data for the mid-water trawl (pelagics) fishery from 2015 to 2016 in the Empire Wind region

3.4 FISHERIES MONITORING SURVEY METHODS

Based on the review of fisheries activities and available fisheries independent data in the Empire Wind Lease Area and along the export cable routes, this FMP was designed to address several focused objectives related to impacts of the Empire Wind development on fisheries in the area. As outlined in Section 2.0, the proposed fisheries monitoring techniques focus on the use of non-extractive methodologies or propose modifications to traditional techniques to reduce mortality of fish and invertebrate species and to minimize interactions with protected species.

3.4.1 Trawl Survey

3.4.1.1 Survey Design

A trawl survey targeting longfin squid within the Lease Area will be conducted in the Fall (September and October) using a symmetrical Before-After-Control-Impact (BACI) experimental design. This trawl survey will be conducted by a contracted commercial fishing vessel with experience targeting squid in the trawl fishery and with the capability of operating the survey gear. Longfin squid are typically targeted using bottom otter trawl gear and the fishery has been active in the central portion of the Lease Area (Figure 3-3) with longfin squid constituting the third highest landings and second highest revenue over the last 12 years (Table 3-4).

The primary objective of the pre-construction monitoring survey is to investigate the biomass (kilograms [kg/tow]) of longfin squid and bycatch species in the Empire Wind Lease Area (Impact Area) relative to the reference area (Control). The trawl survey will also collect information on size structure of the target species as well as on the size structure and fish condition for bycatch species. Two years of pre-construction sampling will occur starting in the fall of 2023. Sampling will continue during the construction phase of the project and for a minimum of two years post-construction, with the duration of post-construction monitoring being informed by developing guidance from BOEM and ROSA.

The objectives of the trawl survey targeting longfin squid are as follows:

- **Objective 1** - Evaluate relative changes in the biomass of longfin squid and fish and invertebrate bycatch species between the Empire Wind Lease Area and the reference area between pre-construction, during construction, and post-construction time periods.
- **Objective 2** - Assess potential changes in the size structure of longfin squid and fish and invertebrate bycatch species between Empire Wind Lease Area and the reference area between pre-construction, during construction, and post-construction time periods.
- **Objective 3** - Investigate potential changes in the composition of fish and invertebrate species between Empire Wind Lease Area and the reference area between pre-construction, during construction, and post-construction time periods.

A BACI study design will allow for quantitative comparisons of relative biomass and size structure to be made before and after construction between the Empire Wind Lease Area and the reference area (Underwood 1992; Smith et al. 1993). Sampling replication across time and space allows for the detection of possible changes caused by construction and operation of the wind farm (Underwood 1992).

NOAA Fisheries is currently evaluating methods to reduce sea turtle bycatch within the trawl fishery south of Massachusetts (NOAA Fisheries 2022b). Nineteen percent of documented sea turtle interactions in the Northeast and Mid-Atlantic trawl fishery that occurred in the period 2000-2019 occurred on trips where longfin squid was the majority species landed. To reduce the number of sea turtle interactions in the fishery, NOAA Fisheries has conducted research on the use of Turtle Excluder Devices (TED) within trawl nets. (Dealteris and Parkins 2010; Milliken et al. 2020). With NOAA Fisheries considering the requirement of TEDs in the longfin squid fishery, the proposed trawl survey will also utilize a TED with a bottom-oriented escape outlet to reduce the likelihood of a take of protected species (sea turtles, Atlantic sturgeon) during survey operations.

The NEFSC Protected Species Branch (PSB) is currently developing a smaller TED for use with nets towed by smaller vessels typical of the inshore squid fishery off Long Island (H. Milliken, pers. comm.). The Empire Wind squid trawl survey will collaborate with PSB and utilize this smaller TED in the survey gear. Data collected as part of the survey will be shared with the PSB team to provide a comparative dataset that will assist in testing and calibration of the TED for evaluating its use in the commercial fishery.

3.4.1.2 Sampling Stations

The trawl survey will be executed using a BACI experimental design, with observations occurring within the reference area serving as a regional proxy for relative abundance of longfin squid and bycatch fish and invertebrate species away from the influence of project activities or activities associated with other offshore wind development. The reference area encompasses the same approximate area as the Empire Wind Lease Area (325 km^2), is approximately 30 km southwest of the Empire Wind Lease Area, 10 km from the Sunrise Wind export cable to the northeast, and is outside the major shipping lanes stemming from New York Harbor (Figure 1-1).

The reference area was selected to reflect similar depths and benthic habitats as the Empire Wind Lease Area. Data provided in the Northwest Atlantic Ecoregional Assessment indicate that the Empire Wind Lease Area primarily consists of fine, medium, and coarse sand (Greene et al. 2010). Additional site characterization assessments commissioned by Equinor confirm that the site is primarily comprised of sands of varying grain sizes (see Section 4.1 below; Empire Offshore Wind Construction and Operations Plan [COP] Appendix T, Benthic Resource Characterization Reports, Tetra Tech 2022). The reference area was also evaluated relative to the survey strata of the NEFSC bottom trawl survey. The NEFSC trawl survey is the only regional trawl survey that overlaps with the offshore location of the Empire Wind Lease Area. The Lease Area is mostly contained within Stratum 1010 with a small portion of the western end of the Lease Area within 3110 (Figure 3-6). Modifications to the location of the reference area may be considered based on input received from local fishing industry groups, state and federal agencies, or following discussion with the fishing industry partners that are selected to execute the trawl survey.

Both the Empire Wind Lease Area and reference area exhibit a depth range of 22-42 m. The trawl survey will be stratified by depth with the number of survey tows evenly distributed between a “shallow” depth stratum (<35 m) and a “deep” stratum (>35 m). Each survey stratum will be evenly divided into grid cells and two grid cells will be selected randomly within each stratum for sampling tows before each survey trip (Figure 3-7). The location of trawl sampling stations may be subject to change due to the presence of fixed gear (e.g., gillnets), 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 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 or other protected species 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. Empire will work with the survey scientists and captain and crew of the trawl vessel(s) to evaluate whether construction activities will impact the execution of the trawl survey.

A power analysis was conducted using trawl survey data from the Block Island Wind Farm (BIWF) and NEFSC trawl survey datasets (Attachment A) to determine sample sizes needed to achieve sufficient statistical power to detect a potential impact, given background variability in catches. NEFSC trawl survey data from 2010 through 2018 were obtained from Phil Politis (Northeast Fisheries Science Center Bottom Trawl Program Lead, personal communication), and only tows from Stratum 1010 were used to inform the power analysis. From 2010 through 2018, the NEFSC trawl survey sampled in the spring and fall. 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 factors, specifically the contrast between the temporal change at the Empire Wind Lease Area relative to the temporal change at the reference site (Equation 2 in Attachment A). 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 Empire Wind Lease site relative to the reference site), sample size (i.e., number of trawl tows per area in each season), and the number of reference sites that are sampled (Attachment A, Figures A4 and A5). When analyzing for changes in relative biomass, achieving a statistical power of at least 0.8 is intended, 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.

A sample size of 16 trawl tows per area will be targeted per sampling season in each year at the start of the survey. Based on the results of the power analysis (Attachment A, Figure A5), this level of sampling is expected to have at least 80% power to detect a 50% temporal decrease for longfin squid biomass at the Project area relative to the reference area for moderate coefficient of variation (CV) estimates (0.6-0.8). An examination of the NEFSC and BIWF trawl survey data indicates that longfin squid exhibited moderate to high levels of interannual and intraannual (e.g., seasonal or monthly) variability in catch rates (Attachment A, Figures A2 and A3 and Table A1). Given the magnitude of variability in catch rates that will likely be exhibited in the Empire trawl survey, it is not practicable to attempt to capture a small effect size (e.g., 25%) for longfin squid. This power analysis assumes that the variance in the catch rates during the Empire trawl survey will be similar to the variance observed during the BIWF and NEFSC trawl surveys. Following the collection of the first year of trawl survey data, the observed variability will be calculated for longfin squid 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 0.6 to 1.2), the sample sizes proposed for the first year of the trawl survey are robust.

3.4.1.3 Trawl Survey Methods

All survey activities will be subject to rules and regulations outlined under the Marine Mammal Protection and Endangered Species Acts. Efforts will be taken to reduce marine mammal, sea turtle, and seabird injuries and mortalities caused by incidental interactions with fishing gear. As mentioned above, deploying trawl gear will be delayed 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) 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 during September and October, when longfin squid is most abundant in the region as indicated in the BIWF and NEFSC trawl survey data (Attachment A, Figures A2 and A3). Four survey tows (two in each depth stratum) will be conducted in both the Empire Wind Lease and the reference area, twice each month (16 tows total in each area in each sampling year). Two sampling events will occur each month to distribute sampling effort and target the peak seasonal biomass. Within a sampling event, the replicate tows within the Empire Wind Lease Area and the reference area will be completed within as few days as possible, given practical constraints imposed by weather or other factors (e.g., mechanical issues with vessel). Efforts will also be made to have consistent timing between surveys (e.g., two weeks), to the extent possible.

The trawl survey will be conducted using a trawl net fitted with a TED designed by the NEFSC's PSB team (Milliken et al. 2020). The trawl net used will be typical of the local squid fishery with modifications to accommodate the TED and a bottom-oriented escape outlet. The codend will be fitted with a 2.5 cm (1 inch) knotless codend liner to sample squid and other 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. The position, heading, and speed of the vessel will be monitored throughout each tow using a software program that is integrated with a 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 other regional surveys (e.g., NEAMAP and NYSDEC Nearshore Ocean 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 of approximately 3 knots will be used. The tow will begin when the winches are locked, and an acceptable net geometry is established. 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 from each trawl tow 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. 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 and used to calculate CPUE. Length will be recorded for the dominant (i.e., most commonly encountered) 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 individually weighed. Length (e.g., total length, fork length, mantle 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 mortality.

Oceanographic data will be collected at each trawl station using a Conductivity Temperature Depth (CTD) sensor (or similar). The CTD will sample the vertical profile of the water column at each station. The CTD profile will be collected at either the start or end of each tow at the discretion of the captain and/or lead scientist. Bottom temperature information will be collected for the duration of each tow using a gear mounted temperature sensor or a temperature sensor that is included in the suite of net mensuration electronics.

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 (NEFSC 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 issued to the project; once the permit type has been specified, Empire will contact NMFS 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., Exempted Fishing Permit [EFP] or Letter of Acknowledgement [LOA]) issued to the project. Once the permit type has been specified, Empire 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 Empire health and safety assessments and plans allow.

3.4.1.4 Trawl Station Data

The following data elements 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 3.4.1.3).

3.4.1.5 Data Management and Analysis

All field data will be reviewed and verified before being entered into a relational database. Rigorous quality control audits will be performed on database tables using standardized, systematic queries to identify data and input errors. Species names (common and scientific) will be verified and tabulated for consistency with regional databases. Only audited and verified data will be exported from the relational database for use in analyses.

The pre-construction data will allow for characterization of the baseline fish and invertebrate community structure (with focus on longfin squid) in both the Project Area and reference area. 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 area to describe spatial, seasonal, and annual differences in relative abundance, species composition, and size distribution. For the dominant species in the catch, relative abundance will be compared amongst the reference and impact areas using descriptive statistics (e.g., mean, range) and length frequency data by species will be compared between areas using descriptive statistics, graphical techniques (empirical cumulative distribution function [ECDF] plots), and appropriate statistical tests (e.g., the Kolmogorov-Smirnoff test). Species composition will be compared between the impact and reference area using appropriate 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 impact), using appropriate statistical modeling. The use of a reference area will ensure that larger 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 Project Area between pre-and post-construction that did not also occur at the reference area (or the reverse) that could be attributed to either construction or operation of the wind turbines.

Once post-construction data are collected, the primary research question to be addressed will examine the magnitude of difference in the temporal changes in relative longfin squid biomass between the reference and impact areas. This research question can be framed using the following hypotheses:

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

In this symmetrical BACI design, there are multiple years of sampling in each time period (pre- and post-construction) and two depth strata within the reference area. A Generalized Linear Modeling (GLM) framework will be used to describe the data and estimate the 90% Confidence Interval (CI) on the BACI contrast. At a minimum, season and location (impact or reference site) will be evaluated as covariates in the model, but the modeling framework could be expanded to include other relevant covariates such as temperature, depth, and salinity. Multiple error distributions will be evaluated to determine the model structure that best describes the data. 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 wind farm and the average temporal change at the reference area. A statistically significant impact would be indicated by a 90% CI for the estimated interaction contrast that excludes zero. Using a 90% CI allows 95% confidence statements for the lower or upper bound (e.g., if the lower bound of the 90% CI for the mean is greater than 0, this indicates 95% confidence that the mean exceeds 0).

Length frequency data for the dominant species in the catch will be analyzed. The first goal of the length-frequency analysis will be to examine whether the size structure of these species changes over time (pre- vs. post-construction). The second goal will examine how the size structure of these species varies between areas (Project Area vs. reference area). To achieve these two goals, 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 based on the characteristics of the data.

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 of the first year of trawl survey sampling, a power analysis (e.g., Gerrodette 1987) will be conducted. The variance (e.g., Relative Standard Error [RSE]) associated with the relative abundance estimates for dominant species in the catch will be calculated. Power curves will be used to demonstrate how statistical power varies as a function of effect size and sample size (i.e., number of trawl samples per area). When analyzing changes in the relative biomass 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 a 50% decrease in longfin squid biomass at the Project Area relative to the reference area. A single two-tailed alpha (0.10) will be evaluated during the power analysis, assuming two years of pre-construction and post-construction monitoring. The results of the power analysis could 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.

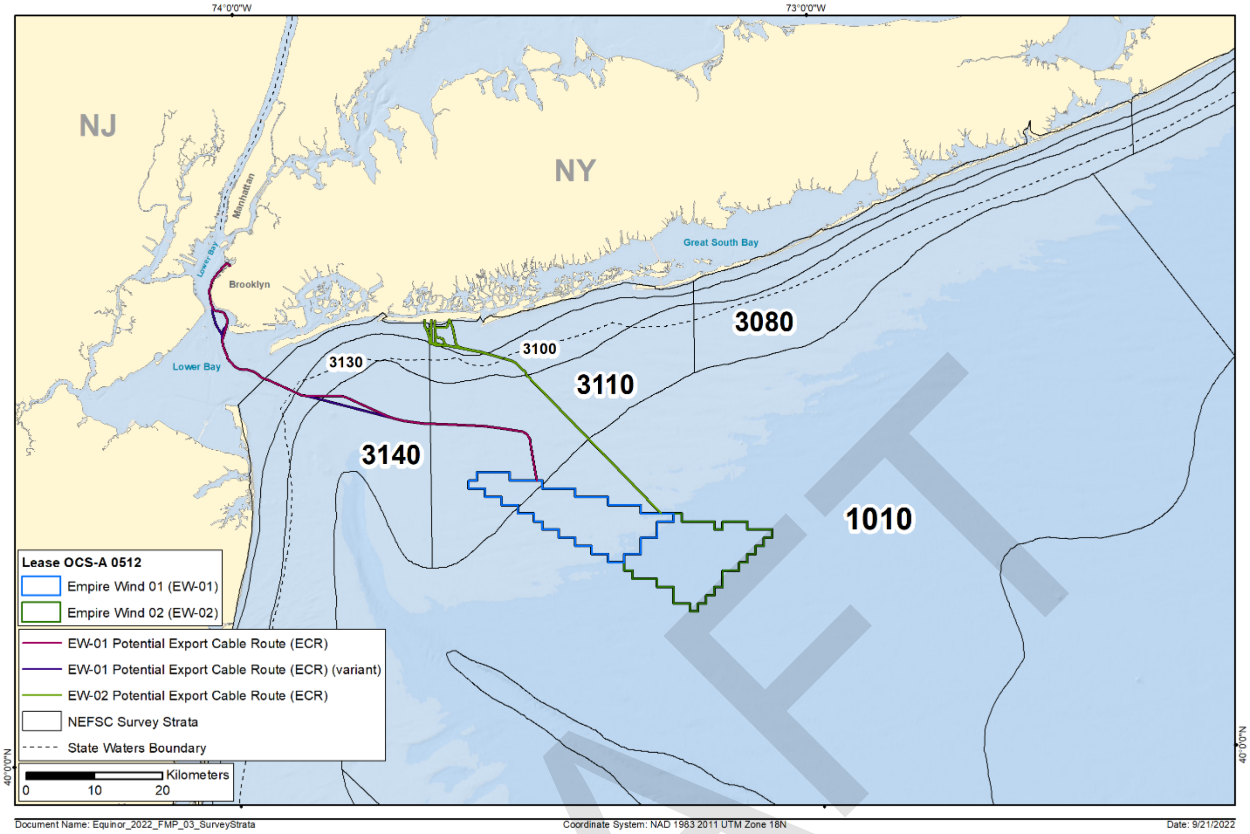

Figure 3-6. NEFSC survey strata and the Empire Wind Lease Area

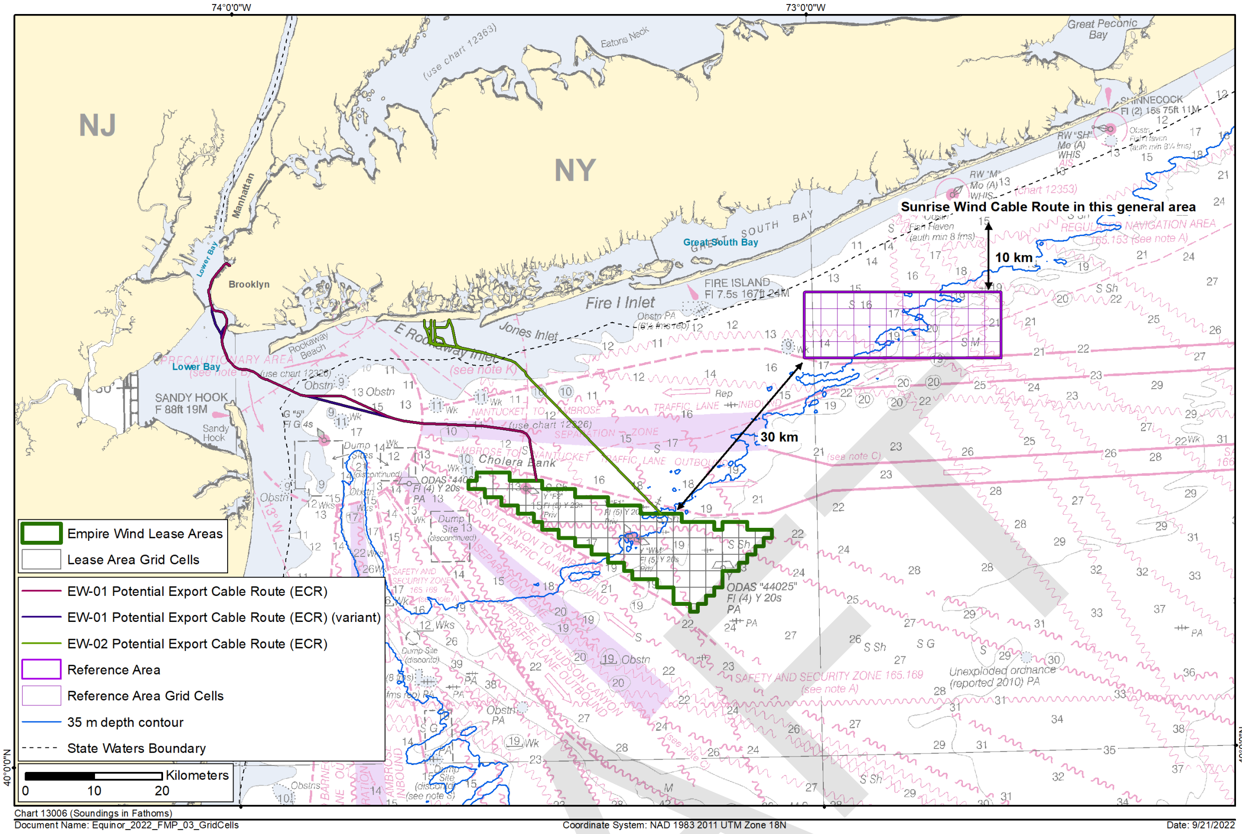

Figure 3-7. Map of the Empire Wind Lease Area and planned reference area for the trawl survey with the areas divided into grid cells and the 35 m depth contour identified

3.4.2 Baited Remote Underwater Video (BRUV) Survey

3.4.2.1 Survey Design

Empire will partner with INSPIRE Environmental to conduct a Baited Remote Underwater Video (BRUV) survey to assess the relative abundance and community composition of structure-oriented fish species within the Empire Wind Lease Area. Observations from wind farms in Europe have indicated that a community shift may occur when foundations are installed in areas that lack structured habitat, where structure-oriented species begin to inhabit these introduced turbine foundations due to a “reef effect” (Degraer et al. 2020). At Block Island Wind Farm located in Rhode Island state waters, abundances of structure-oriented species (black sea bass and Atlantic cod) increased near the wind farm after turbine installation (Wilber et al. 2022). Additionally, it is expected that structure-oriented species from more southerly regions will begin to inhabit foundations as their distributions continue to shift northward due to climate change (Hare et al. 2016). Traditional fisheries-independent survey techniques such as trawls do not sample structure-oriented species reliably as these gears are not able to survey in complex habitats (Hilborn and Waters 1992).

Traditionally, fixed-gear types are used for fisheries-independent sampling in hard bottom habitats (lobster traps, fish pots, gillnets) and these techniques are being utilized for monitoring within other offshore wind lease sites in the Northeast that contain complex bottom (South Fork Wind, LLC and INSPIRE Environmental 2022; Revolution Wind, LLC and INSPIRE Environmental 2021). These gear types often employ the use of vertical lines attached to buoys that float at the surface for use in retrieval of the gear after an extended soak time (days). With current efforts to minimize interactions of vertical lines with protected species, particularly the critically endangered North Atlantic Right Whale, non-traditional survey methods must be implemented to reduce the potential for these interactions. Additionally, these fixed-gear surveys are extractive fisheries methods that likely introduce a degree of mortality to the catch. BRUVs offer the advantages of a shorter soak time (minutes), non-extractive sampling, the ability to sample species not caught in traditional gear types, sampling a wide range of habitats, and examining video footage at a later time if needed (Langlois et al. 2020; Curry-Randall et al. 2020). Because the cameras are baited, BRUVs are particularly adept at detecting species highly attracted to bait, such as sharks (Torres et al. 2020). BRUVs have been proven to be an effective tool to monitor fish species in a variety of habitats around the world (Langlois et al. 2010; Mallet and Pelletier 2014; Harrison and Rosseau 2020; Cole et al. 2022), including structure-oriented species at wind farms in Europe (Griffin et al. 2016).

The BRUV survey will utilize a Before-After Gradient (BAG) design to assess the spatial extent of wind farm effects on adult and juvenile structure-oriented fish species. In particular, the survey will provide information on whether the abundances of structure-oriented species increase with increasing proximity to the turbines following construction. An increase in abundance would suggest a “reef effect”, whereby the addition of offshore wind foundations and scour protection creates new habitat for fish, which leads to subsequent increases in abundance in the Project Area (Anderson and Ohman 2010; Bergstrom et al. 2013). This “reef effect” has been documented in approximately half of the offshore wind farm monitoring studies that have tested for this impact (Glarou et al. 2020). The proposed survey design also eliminates the need for a Reference Area, which is required in a BACI design. Sampling effort is focused on sampling sites along a spatial gradient within the work area, rather than using a reference location that may not wholly represent conditions within the work area (Methratta 2020). This design also allows for the examination of spatial variation and does not assume homogeneity across sampling sites within the Project Area (Methratta 2020).

3.4.2.2 Sampling Stations

The Empire Wind BRUV survey is designed to occur seasonally (spring, summer, fall, winter) within the Lease Area, with monitoring targeted for two years pre-construction and two years post-construction. Monitoring is also planned during construction, provided the survey will not interfere with construction operations.

The methodologies and sampling distances employed in previous offshore wind studies were considered in the design of the BRUV survey. Bergstrom et al. (2013) used fyke nets to sample along transects that spanned a distance of 20 to 1,350 m from a turbine foundation and observed that four of the seven fish species examined demonstrated increased densities near the turbine. Griffin et al. (2016) used BRUVs to compare fish abundance and assemblage composition between locations adjacent to turbine foundations vs. 100 m distant in the Irish Sea. Stenberg et al. (2015) used gillnets to sample at three increasing distance categories from the turbine foundations (‘near’ = 0-100 m, ‘middle’ = 120-200 m, and ‘far’ = 230-330 m) and demonstrated that fish with an affinity to rocky habitats were most abundant close to the turbine foundations. In a review of European wind farm case studies, Methratta (2020) noted that the majority of direct effects associated with turbine foundations (e.g., habitat provision, attraction, food provision) are expected to occur on a local scale (i.e., 10 - 100s of meters from the turbine foundation). Currently, the South Fork Wind Farm is conducting a BAG study utilizing a 900-m string of 18 fish pots, spaced 50 m apart, deployed in a straight line away from the base of turbine foundations to examine the spatial extent of wind turbine effects on black sea bass (South Fork Wind, LLC and INSPIRE Environmental 2022).

Sampling will occur at eight randomly selected planned turbine locations. These sampling locations will remain fixed for the duration of the survey (pre- and post-construction). As with the squid trawl survey, the Lease Area with be comprised of two depth strata, where four turbine locations will be sampled in each of the “shallow” (<35 m) and “deep” (>35 m) strata. At each sampling station, four BRUV’s will be deployed at increasing distances from the planned turbine foundation location to examine the spatial extent of effects from the turbine foundation and surrounding scour protection (Figure 3-8). During the pre-construction period the first BRUV will be placed within the buffer zone around the planned turbine foundation location. Post-construction, the BRUV will be placed as close to the turbine foundation as is safely possible and that will allow for an adequate field of view around the turbine base. Three additional BRUVs will be placed at distances of 50 m, 100 m, and 200 m from the base of the turbine so that sampling occurs close to the turbine base and outside of habitat altered by turbine construction.

3.4.2.3 Survey Methods

To ensure data comparability and compatibility across wind farm projects, The BRUV survey will be conducted following best practices outlined in Birt et al. 2021 and gear designs provided by Langlois et al. 2020 (Figure 3-9) as outlined in the Ocean Wind Offshore Wind Farm Fisheries Monitoring Plan (2021). BRUVs will be rigged with a vertical line and buoy to the surface to facilitate retrieval of each BRUV. BRUVs will be deployed for approximately 60 minutes. Video will be captured using a camera with high resolution such as GoPro Hero 9 cameras or similar. The video recorded by the BRUVs will be processed by INSPIRE Environmental using computer software appropriate for video analysis (Behavioral Observation Research Interactive Software [BORIS; Friard and Gamba 2016] or similar). All fish will be identified to species when possible. The primary response variable that will be generated from the BRUV’s is MaxN, which is the moment in the video where the maximum number of individuals for a given species are observed. MaxN is the most common metric associated with BRUVs (Bicknell et al. 2019) and is considered to be a conservative estimate of relative abundance because it removes concerns that the same fish can be counted more than once (Griffin et al. 2016). Strategic design of each of the BRUVs with two video cameras can enable fish length and distance measurements to be estimated from the recordings. Measurements will only be taken for those species of greatest interest and fisheries value (e.g., black sea bass, tautog). As recommended by Langlois et al. 2020, individual fish lengths will be measured at the same time that MaxN is observed. In order to estimate fish length from the video footage the methods from previous work (e.g., Langlois et al. 2020; Birt et al. 2021; Harvey et al. 2021) will be followed. A secchi disk will be lowered from the vessel at each sampling station to assess the transparency of the water and help quantify visibility and assist with video data analysis.

3.4.2.4 Station Data

The following data elements will be collected during each sampling effort:

- Station number
- Latitude and longitude for each BRUV deployment
- Time at the start and end of the BRUV deployment
- Water depth at each BRUV location
- Wind speed
- Wave height
- Weather conditions (e.g., cloud cover, precipitation)
- Bait type used
- Oceanographic data, as collected using a CTD and a temperature logger (see Section 3.4.1.3).

3.4.2.5 Data Management and Analysis

The BAG survey design will allow for the characterization of pre-construction community structure of fish species present in the Empire Wind Lease Area and will continue sampling after construction to quantify any changes in relative abundance associated with the construction and operation of wind turbines at the site. For the pre-construction monitoring, the results presented in annual reports will focus on descriptive and quantitative comparisons of the fish metrics at increasing distances from a wind turbine foundation to describe spatial, seasonal, and annual differences in relative abundance, species composition, and size distribution. Several statistical models will be compared (e.g., GLM, Generalized Linear Mixed Model [GLMM], or Generalized Additive Model [GAM]) with distance treated as a main effect (continuous variable), and the best fitting model for each species will be used to estimate the 90% CI on the before-after change in the distance coefficient. Further, information on depth and bottom temperature collected at sea may be considered as covariates in the model to evaluate their influence on fish abundances. Habitat data collected during the benthic SPI/PV surveys (Section 4.0) and from Equinor geophysical surveys can also be considered as covariates in the model to evaluate the influence of habitat on fish abundance. Species composition will be compared before and after construction using a Bray-Curtis Index and multivariate techniques (e.g., ANOSIM). Graphical methods and descriptive statistics will be used to assess changes in the fish assemblage over time, as a function of distance from the turbines. These graphical techniques may help to elucidate the spatial scale at which relative abundance changes the most with distance from the turbine foundation. By continuing sampling during and after construction, the BRUV survey will allow quantification of any detectable changes in relative abundance, demographics, and community structure associated with proposed operations. Analyses presented in the final synthesis report will focus on identifying changes in the fish community in the Project Area between pre-and post-construction time periods at increasing distance from the turbine foundations that could be attributed to either construction or operation of the wind turbines.

The primary question to be addressed is whether fish metrics (either abundances of individual species or assemblage composition) will change relative to distance from a turbine foundation following their installation. This research question can be framed using the following hypotheses:

- $H_{\emptyset}$-Fish metrics will not change over time and will remain consistent with respect to the distance from a turbine.
- H_1-Fish metrics will change over time and will not be consistent with respect to distance from the turbine.

Species composition will be compared before and after construction using a Bray-Curtis Index and multivariate techniques (e.g., ANOSIM).

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 of the first four seasonal sampling events, a power analysis (e.g., Gerrodette 1987) will be conducted to evaluate the power of the sampling design. The variance associated with the relative abundance estimates for dominant species in the catch will be calculated. Power curves will be used to demonstrate how statistical power varies as a function of effect size and sample size (i.e., number of samples per area). A single two-tailed alpha (0.10) will be evaluated during the power analysis. 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.

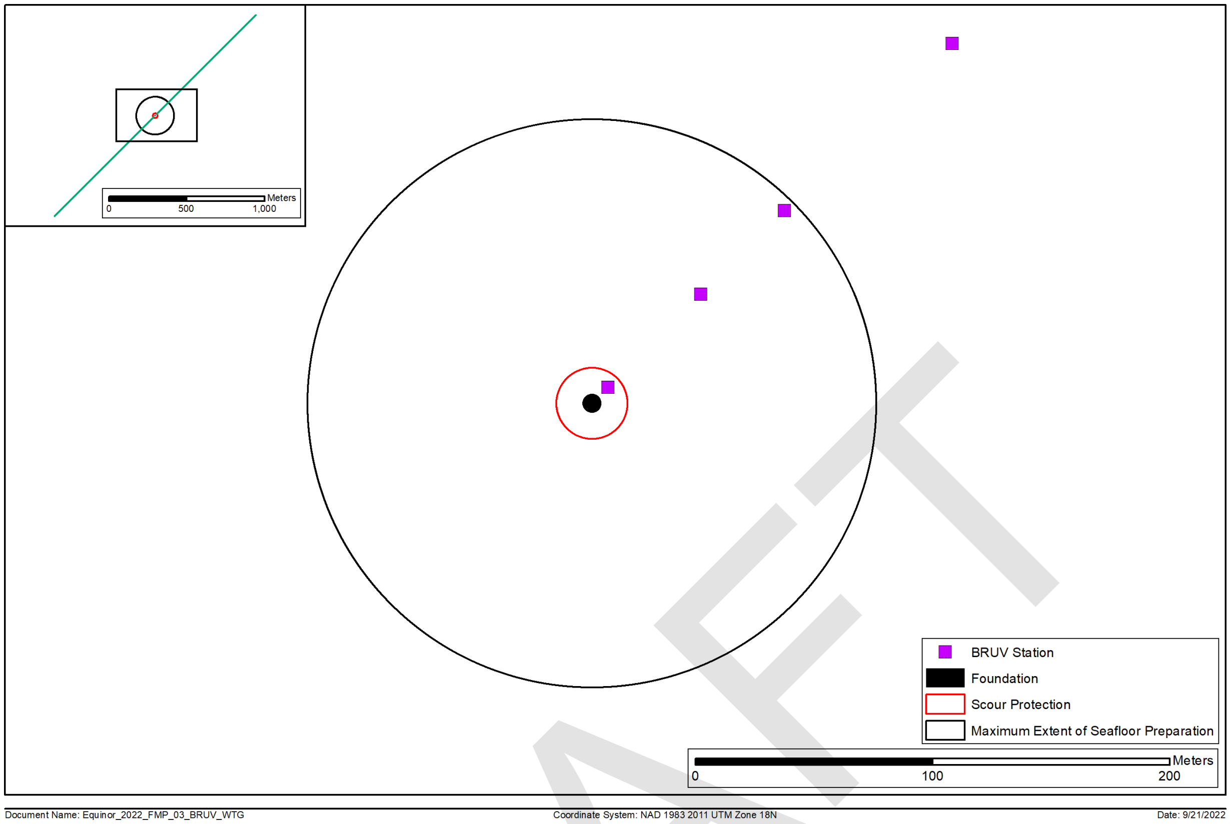

Figure 3-8. Proposed BRUV survey sampling distances

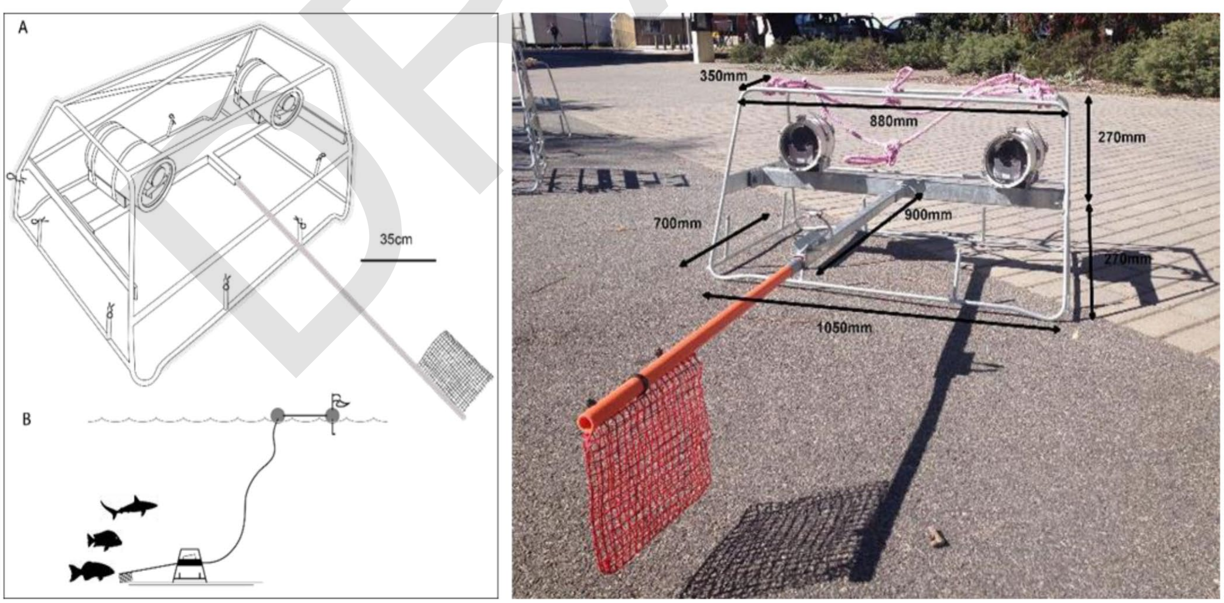

Figure 3-9. Example of BRUV (from Langlois et al. 2018) design to be adapted for use in the Empire Wind BRUV survey

3.4.3 Environmental DNA (eDNA) Sampling

Empire Wind is partnering with researchers from INSPIRE Environmental, Monmouth University, and St. Anselm's College to carry out a comprehensive eDNA survey at the Empire Wind Lease Area. The eDNA sampling will occur concurrent with the trawl and BRUV surveys, enabling a more holistic understanding of the relative abundance and composition of the species assemblage at the Empire Wind site, while ground-truthing a relatively novel, non-extractive monitoring method.

eDNA sampling can be used to collect information on species presence/absence, abundance, and biodiversity. Aquatic animals constantly shed their DNA into the surrounding water in the form of scales, damaged tissue, eggs, metabolic waste, and other biological residue. This DNA persists in the water for a short time period. During eDNA sampling, a small volume of water is collected and filtered. The sample is then analyzed, and the DNA collected in the sample is compared to a genetic reference library. Because each species has a unique complement of genes, the DNA fragments collected in the sample can be used to identify the species that were present in the area when the sample was taken.

eDNA analysis is typically conducted in one of two ways, metabarcoding or qPCR analysis. qPCR is typically used when the analysis is focused on a single species of interest, and the objective is to estimate the relative abundance of the species in the sampling area. With metabarcoding, high throughput genetic sequencing is used to sample for the presence of multiple species in order to investigate questions related to biodiversity and community composition. With metabarcoding, different genetic primers are used to assess the diversity of different taxonomic groups. A metabarcoding approach will be implemented for this monitoring effort and each sample of water will be analyzed for two primers: bony fish and cartilaginous fish, with a third primer analyzed for invertebrates from trawl survey samples.

eDNA offers several advantages over traditional fisheries sampling methods because it is non-extractive, it does not result in stress or mortality to the organisms that are identified. Unlike bottom-tending mobile sampling gear, eDNA sampling can be performed without causing any damage to the benthic habitat, and eDNA does not necessitate the use of fixed vertical lines that can lead to marine mammal entanglements. In addition, eDNA samples can be taken in areas with hard bottom benthic habitats that cannot be sampled using a trawl or other mobile bottom-tending sampling gear. eDNA can also detect a species throughout each stage of its' life cycle, thus avoiding issues associated with size/age selectivity. In the marine environment, experiments suggest that eDNA is detectable for ~48 hours (Collins et al. 2018), meaning that detections represent recent presence of a given fish species, making eDNA a valuable tool for time series. However, one drawback associated with eDNA sampling is understanding the rate at which different species shed DNA into the water column and understanding how that varies as a function of ontogeny, behavior, and abiotic factors such as temperature (Knudsen et al., 2019).

eDNA offers an exciting opportunity to investigate several questions of importance to fisheries science including; monitoring the presence/absence of rare and endangered species, estimating relative abundance, understanding community composition, detecting shifts in species distribution, monitoring the spread of invasive species, and understanding how introduced habitats affect species diversity and abundance. Improvements to DNA reference libraries are continuously occurring (e.g., Stoeckle et al. 2020a) enabling a greater variety of species to be detected through eDNA sampling.

Recent studies have completed paired sampling using eDNA and a trawl survey, and the results offer insights into the capabilities of this innovative technology to improve our understanding of the marine ecosystem (e.g., Thomsen et al. 2016; Knudsen et al. 2019; Liu et al. 2019; Salter et al. 2019; Stoeckle et al. 2020b; Afzali et al. 2021; Kirtane et al. 2021; Russo et al. 2021; Maiello et al. 2022). Stoeckle et al. (2020b) compared species diversity and relative abundance between eDNA samples and trawl catches from the NJDEP seasonal trawl survey. This study used a metabarcoding approach, and two primers were analyzed, one for bony fish, and another for cartilaginous fish. During a given month, 70-87% of the fish species detected by eDNA were also captured in the trawl, and peak seasonal abundance agreed between the two methods for 70% of the fish species. Interestingly, in all months, eDNA results indicated a greater species diversity than trawl sampling, illustrating the promise of eDNA for investigating biodiversity in the coastal ocean.

Salter et al. (2019) conducted paired sampling using eDNA and a trawl survey in the coastal waters of the Faroe Islands. This study used a qPCR approach, where the eDNA sampling was focused primarily on evaluating the distribution and abundance of Atlantic cod. In general, there was good agreement between the two sampling methods with regards to the presence and absence of cod. At the spatial scale of an individual sampling station there was generally low correlation between the biomass of cod observed in trawl catches and the concentration of cod DNA in the sample. However, when the data were aggregated and examined at a regional level, a strong correlation was found between the standardized CPUE of cod in the trawl and the concentration of cod DNA obtained in the sample.

Knudsen et al. (2019) completed paired sampling between eDNA and a trawl survey to compare the relative abundance and distribution of cod, herring, plaice, Atlantic mackerel, and European flounder in the Baltic Sea. While this study did not find significant correlations between eDNA concentrations and trawl survey catch rates, the eDNA concentrations measured for some species were associated with areas where different species were known to be most abundant. In addition, some species such as mackerel and European eel were detected using eDNA but were not present in trawl survey catches. Closek et al. (2019) used multiple methods (eDNA, trawl survey, and visual survey for marine mammals) to investigate the species composition in the Central California Current ecosystem. eDNA samples detected 48 fish taxa, and 11 species of marine mammals. Of the 48 fish taxa identified using eDNA, only 17 taxa were also collected using a trawl. On the other hand, the trawl survey observed 28 fish taxa, of which 17 taxa were also identified using eDNA. This study indicates that paired sampling using eDNA and trawl provides a more holistic understanding of species composition and biodiversity.

Stat et al. (2019) used eDNA metabarcoding and BRUV's to examine species diversity on reef and seagrass communities inside and outside a marine reserve in Western Australia. The fish community described by eDNA and BRUV's combined contained greater than 30% more generic richness than either method sampled on its own. In addition, species not detected by one method were very often detected by the other. Cole et al. (2022) also utilized eDNA and BRUV's to compare biodiversity between structured (oyster reefs) and unstructured (sand) habitats. eDNA metabarcoding detected a greater number of species than BRUV's, but both were able to resolve differences in species diversity between both habitats at fin spatial scales. Mercaldo-Allen et al. (2021) used eDNA in combination with video footage to assess fish assemblages attracted to oyster aquaculture cages and boulder habitat in Long Island Sound. Seven species were identified in the videos compared to 42 species by eDNA.

Two years of sampling are planned prior to the commencement of offshore construction. The eDNA survey will continue during the construction phase, and a minimum of two years of eDNA monitoring will be completed following offshore construction.

The primary research question associated with the eDNA survey is, does the construction and operation of the Empire Wind Project impact the community composition of fishery resources? Several metrics will be evaluated to assess the community composition, including species richness, dominant species, and relative abundance. The use of a BACI sampling design in the bottom trawl survey will allow for quantitative comparisons of community composition to be made before and after construction, and between reference and impact areas (Underwood 1992; Smith et al. 1993). The BAG design of the BRUV survey will allow for the examination of changes in community composition at increasing distance away from turbine locations. Pairing the eDNA sampling with the trawl and BRUV surveys will allow for a more holistic evaluation of community composition over time and space.

3.4.3.1 Sampling Stations

At each trawl survey sampling location in the Empire Wind Lease Area and the reference area, an eDNA sample will be collected (see Section 3.4.1.2). Therefore, during each sampling event, eight samples will be targeted for collection in the Empire Wind impact area and the trawl survey reference area, for a total of 32 samples each year. At each BRUV survey location, four samples will be taken that correspond to the sites where video data is recorded, for a total of 32 samples per seasonal sampling event, for a total of 132 samples each year. Additional surface samples will be taken at a subset of station locations (See Section 3.4.2.2).

3.4.3.2 Survey Methods

To ensure consistency with prior regional eDNA sampling efforts, samples will be collected using the procedures described in Stoeckle et al. (2020b). Briefly, water will be collected with a 1.2 L stainless steel polypropylene-lined Kemerer bottle. The bottle will be triple-rinsed with sample water before collection. At each location, water samples will be collected within 2 m of the bottom. At a subset of locations, paired surface and bottom water samples will be collected to check for differences in the community composition between the surface and the bottom. In addition, to ensure that the water samples have not been contaminated, six control samples will be collected during each survey. The final sample will be collected into a sterilized 1-liter polypropylene bottle and stored on ice or in a freezer until transferred to a laboratory for filtering. If the sample cannot be filtered within 24 hours it will be stored frozen.

Preceding the collection of water samples for eDNA analyses, water quality parameters will be measured in vertical profiles using a CTD as described in Section 3.4.1.3 (in trawl survey). To promote consistency with regional sampling efforts, the filtration and processing procedures described in Stoeckle et al. (2020b) will be followed. Collection bottles will be thawed for ~24 hours at 4°C and contents poured into a glass filter manifold attached to wall suction with a 47-mm, 0.45 µm pore size nitrocellulose filter (Millipore). Filters will be folded to cover retained material and stored in sterile 15-milliliter tubes at -80°C. As negative controls for each sampling event, several 1-liter samples of laboratory tap water will be filtered using the same equipment and procedures, and on the same day as the field samples. After filtration of contents, collection bottles will decontaminated by washing extensively with tap water, including vigorous shaking of partially filled containers with tops closed, and then air-dried and stored at room temperature-a procedure which relies on mechanical cleansing and dilution, eliminates amplifiable fish DNA from field collection bottles and filtration equipment, while avoiding possible exposure of water samples to residual bleach or other DNA destroying agents (Stoeckle et al. 2017). Frozen filters will be shipped to the Analytical Laboratory at University of MD Institute for Marine and Environmental Biotechnology for DNA extraction, library building for finfish, cartilaginous fish, and marine invertebrates, and Illumina sequencing. Products of this service will include de-multiplexed FastQ files and the extracted DNA, which will be archived in a monitored, alarmed –80°C freezer at Monmouth University.

3.4.3.3 Station Data

The following data will be collected during each sampling effort:

- Station number and sample ID
- Latitude and longitude
- Time
- Water depth
- Wind speed
- Wave height
- Weather conditions
- Oceanographic data, as collected using a CTD

3.4.3.4 Data Management and Analysis

Bioinformatics will use the DADA2 package (Callahan et al. 2016) run in R statistical computing environment according to procedures, and using the internal 12S bony / cartilaginous fish libraries, described in Stoeckle et al. (2017) and Stoeckle et al. (2020b). A 100% sequence match will be used to assign species-level taxonomic identifications. The results of bioinformatics analyses will be the number of sequence reads per taxonomic unit identified in the 12S reference sequence list. These data will be summarized in tables and graphs for each sampling event. Raw and processed data will be archived on secure servers at Monmouth University, as well as on removable media (e.g. external SDD drives).

The bioinformatics will be used to test the following hypothesis:

- $H_{\emptyset}$: Fish community composition will not differ before, during, or after construction of the Empire Wind Project
- H_1: Fish community composition will differ before, during, or after construction of the Empire Wind Project.

The following univariate metrics of the fish community composition will be evaluated in the analyses: species richness, dominant species, relative abundance, in addition to appropriate multivariate techniques (Bray-Curtis dissimilarity, non-metric Multidimensional Scaling [nMDS]) The hypothesis will be evaluated for each of the indicators using appropriate means testing techniques depending on the distribution of data collected (ANOVA or Kruskal-Wallis for parametric vs. non-parametric assessment, respectively, and analysis of similarities (ANOSIM) for the multivariate data). If significant differences are found among time periods, or among sampling areas, while controlling for seasonality, additional post-hoc testing will be performed to determine where differences were detected (e.g., before, during, after). In addition, the eDNA samples will be compared to data collected during the trawl and BRUV surveys to evaluate how information on relative abundance, presence/absence and community composition differ between the different sampling approaches. Comparisons of species richness and dominant species can be made seasonally or annually in tables or bar charts. Regression analyses can be used to examine the relationship between relative abundance determined through trawling/video vs. eDNA surveys. Specifically, relative abundance by eDNA will be computed as the number of 'reads' for a given species relative to all reads recovered for fishes in a given sample set (e.g., season), compared to relative trawl abundance (e.g., biomass/tow) of a given species relative to total mass of fish caught in a given season. Similar analyses using these relative proportions were recently published comparing trawl and eDNA assessments of fish community composition and relative biomass (Figure 8 in Stoeckle et al. 2020b). Additionally, in deep-water habitat off southwest Greenland, eDNA sequence reads from fish assemblages were correlated with biomass and abundance data obtained from trawling (Thomsen et al. 2016).

3.4.4 Acoustic Telemetry

3.4.4.1 Survey Design

Empire Wind is partnering with researchers from Monmouth University, Stony Brook University, INSPIRE Environmental, and the Anderson Cabot Center for Ocean Life (ACCOL) at the New England Aquarium to conduct acoustic telemetry monitoring at the Empire Wind Lease Area. This study will use an array of fixed station acoustic receivers to monitor the movements, presence, and persistence of several commercially and recreationally important species (e.g., black sea bass, summer flounder, winter flounder, tautog) as well as the federally endangered Atlantic sturgeon. The focal species and array design were determined based on previous work conducted by the research team within the Empire Wind Project Area (Frisk et al. 2019).

Passive acoustic telemetry can be used to monitor animal presence and movements across a range of spatial and temporal scales. Individuals tagged with an acoustic transmitter that pass within the range (tens to hundreds of meters) of an acoustic receiver provide information on an animal's presence, movements, and behavior at a fine scale within the area of interest. The use of this technology has grown over the last decade with hundreds to thousands of receivers deployed along the US. East Coast (Hussey et al. 2015; Freiss et al. 2021). By utilizing information collected across receiver arrays and shared through established data sharing networks, telemetry can also monitor animal presence and movement over a range of spatial scales (tens to hundreds of kilometers) and time scales (e.g., months to years). Therefore, passive acoustic telemetry is an ideal technology to monitor presence, residency, and movements of species within WEAs using non-lethal methods and to evaluate short and long-term impacts of wind energy projects on these movement parameters.

Acoustic telemetry has been used to investigate the behavior and movements of fish species in offshore wind areas in Europe. Reubens et al. (2013a) 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 wind farm and a nearby reference area. They concluded that sole did not exhibit avoidance of the wind farm, 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.

Several acoustic telemetry projects are ongoing or proposed at offshore wind lease sites along the US East Coast. Scientists from the Massachusetts Division of Marine Fisheries, the UMass Dartmouth School for Marine Science and Technology, Rutgers University, the Nature Conservancy, Woods Hole Oceanographic Institute, and the Northeast Fisheries Science Center are using acoustic telemetry (fixed and mobile) to monitor habitat preference and utilization of spawning Atlantic cod in and around Cox Ledge within the South Fork (South Fork Wind, LLC and INSPIRE Environmental 2022) and Revolution Wind (Revolution Wind, LLC and INSPIRE Environmental 2021) lease areas. Researchers from the ACCOL and INSPIRE Environmental are conducting a long-term acoustic telemetry project examining the presence and persistence of several HMS within the nine lease areas comprising the Southern New England Wind Energy Area. Researchers from Rutgers University and Delaware State University are using multiple acoustic methods to monitor several different species both within and around the Ocean Wind lease area off the New Jersey coast (Ocean Wind, LLC 2021). Researchers from Monmouth University, Stony Brook University, and the Cornell Cooperative extension are also using acoustic telemetry to monitor the potential effects of electromagnetic fields (EMF) and fish and invertebrate species along the export cable routes of the South Fork and Sunrise Wind Farms (South Fork Wind, LLC and INSPIRE Environmental 2022; Sunrise Wind LLC 2022).

Within the Empire Wind project area, Frisk et al. (2019) demonstrated the use of acoustic telemetry to monitor the habitat utilization of Atlantic sturgeon, winter flounder, summer flounder, black sea bass, striped bass, and several species of elasmobranch. The authors observed seasonal occupancy of the Lease Area by these species, with Atlantic sturgeon utilizing the entire Lease Area in winter. The study greatly enhanced the understanding of sturgeon movements in offshore environments where data are lacking. The current monitoring study will build on the pre-construction findings of Frisk et al. (2019) as well as continue monitoring during construction and post-construction to better understand the movements and utilization of the Project Area by these species.

3.4.4.2 Survey Methods

A receiver array comprised of 34 receivers is proposed for deployment within the Empire Wind Project Area (Figure 3-10). Vemco VR2AR-X acoustic release omnidirectional receivers will provide maximum coverage for robust and rigorous reporting. The VR2AR-X receivers can detect a tagged individual from a radius of 700 to 1,100 m from the receiver location depending on sea conditions, ambient noise, and transmitter strength. Previous ocean arrays maintained by the research team suggest an average detection radius of 1 km. Each receiver will therefore continuously monitor an area of approximately 2 to 3 km^2 over the course of the proposed study. Each receiver will be equipped with a mooring recovery system that will utilize the receiver's acoustic release mechanism to deploy a retrieval line once the receiver is recalled to allow for recovery of the mooring used to anchor the receiver in place. The receivers will be deployed year-round and receivers will be retrieved for data download twice per year.

Vemco acoustic transmitters will be deployed on several species of interest including, but not limited to, striped bass, black sea bass, summer flounder, winter flounder, and Atlantic sturgeon. Capturing of animals tagged within this study will be successfully completed through a variety of proven fishery sampling techniques (e.g., gillnet, long line, rod-and-reel) appropriate for each species. Trawling may be conducted two times per year with a three-to-one two-seam trawl (25-m headrope, 30.5-m footrope) with 12-cm stretched mesh forward netting that tapered down to 8-cm stretched mesh rear netting lined with a 6.4-mm mesh codend liner and towed with 1.5-m Thyboron brand type 11 steel trawl doors (Dunton et al. 2010; Dunton et al. 2015; Melynchuk 2017). Tows will be conducted for 5-10 minutes at speed of 3-3.5 knots. If gillnets are used to sample Atlantic sturgeon, deployed nets from 91.4 m to up to 366 m (example sample nets may be Net 1: up to 365.76 m or 4 panels 13.97 cm Stretch mesh x .90 mm 25 meshes deep; Net 2: up to 365.76 m or 4 panels 25 – 33 cm Stretch x.90 mm 12 - 15 meshes deep). Deployed nets will be continuously monitored, and the vessel will not leave the site of deployed gear. Fish may also be tagged through commercial fish trap and/or rod-and-reel.

Individuals will be surgically implanted with various Vemco acoustic transmitters depending on the size of the fish. Over the duration of the project, 325 tags will be deployed per year. Larger individuals (e.g., striped bass, Atlantic sturgeon) will be implanted with a V16 ultrasonic transmitter (69 kHz, high-power output = 158 dB re 1 μPa at 1 m, random transmitter delay = 120 s, life span = 2,435 d). Medium to small individuals (summer flounder, winter flounder, black seabass, tautog) will be tagged with either a V13 (69 kHz, high-power output = 151 dB re 1 μPa at 1 m, random transmitter delay = 180 s life span = 648 d) or a V9 (69 kHz, high-power output = 152 dB re 1 μPa at 1m, random transmitter delay = 120 s life span = 520 d). Once the transmitter has been inserted, the incision will be closed with a minimum of three absorbable interrupted sutures. The incision area will then be cleaned once more with betadine. A betadine/petroleum ointment will also be put on sutures and site of the incision site to aid in the recovery of the animals to deter bacterial infection.

3.4.4.3 Data Management and Analysis

The resulting detection data downloaded from acoustic receivers will be analyzed with the overall goal of establishing pre-construction information on species presence and persistence in the Empire Wind Lease Area. The primary question to be addressed is, what is the presence, persistence, and space utilization of the species of interest within the Empire Wind Lease Area? This research question can be framed using the following hypotheses:

- $H_{\emptyset}$-Species presence, persistence, and movements will not change between time periods (before and after).
- H_1- Species presence, persistence, and movements will change between time periods (before and after).

Short- and long-term presence, site fidelity (i.e., residency/persistence), fine- and broad-scale movement patterns, and inter-annual presence within the Lease Area (i.e., whether individuals return to the receiver array each year) will be examined. Any detection data obtained through participation in regional telemetry data sharing networks (see below) will be incorporated into analyses, particularly to examine the distribution and movements of species beyond the boundaries of the Lease Area. Analyses will include detailed detection history plots for each tagged individual that depict all detections logged for an animal over the course of a year. Summary tables and figures will be generated that describe: the number of times each fish was detected by receivers within the array, the detection history for each fish, the total number of receivers each individual was detected on, movements within the array, and monthly patterns in presence and persistence. In addition to the local-scale acoustic monitoring achieved by the proposed receiver array, broad-scale movement data will be accomplished through participation in regional telemetry data sharing programs, by obtaining detection data from our tagged animals detected within arrays deployed by other researchers in the greater Atlantic region.

All detection data of animals tagged by other researchers and recorded by the acoustic receivers in this study will be distributed to those researchers through participation in regional telemetry networks such as the Ocean Tracking Network or the Mid-Atlantic Acoustic Telemetry Network (MATOS). Detection data obtained for transmitters that are not deployed as part of this study will be disseminated to the tag owners (it is the policy of regional data sharing programs that the 'owner' of the data is the entity that purchased and deployed the transmitter, not the entity that detected it on their receiver). Inclusion of these detection data in analyses will be requested of the tag's owner (i.e., metadata on the species detected, number of detections, amount of time the animal was detected in our receiver array, etc.). Participation in data sharing networks will increase both the spatial and temporal extent of monitoring for species tagged as part of this study and allow for the collection of additional data on the presence and persistence of other marine species tagged with acoustic transmitters in and around the Empire Wind Lease Area.

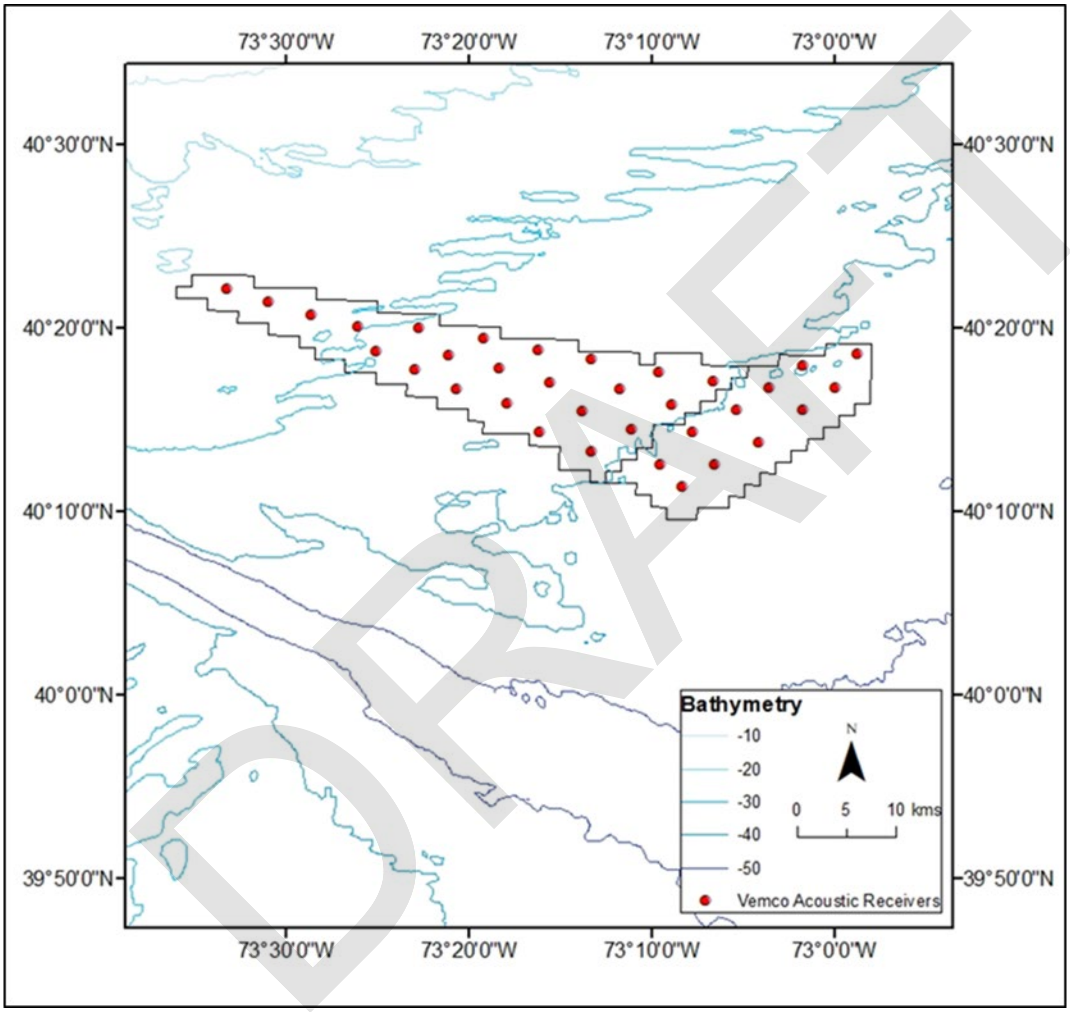

Figure 3-10. Proposed receiver locations within Empire Wind Project Area

3.4.5 Sea Scallop Plan View (PV) Camera Surveys

Sea scallops (*Placopecten magellanicus*) are an important benthic species in the area of the Empire Wind Project. The scallop population in this region support a productive and lucrative commercial fishery (Table 3-4). In particular, the eastern portion of the Lease Area is actively fished for scallops (Figure 3-1). The objective of this monitoring component is to evaluate changes in the density of sea scallops and potential shifts in the spatial distribution of sea scallops within the Empire Wind Lease Area following the construction of the Empire Wind project. These monitoring surveys will be based on seafloor imagery data collected using a plan view camera system. Several long-term fisheries independent scallop surveys utilize similar methods to assess the distribution and density of scallops in the region (UMass Dartmouth School for Marine Science and Technology [SMAST] drop-camera survey and the Habitat Mapping Camera [HabCam] Survey conducted by Coonamesset Farm Foundation). Non-extractive optical-based surveys may provide more accurate estimates of the sea scallop populations compared with dredge surveys, particularly in areas with substantial contributions of recently settled juvenile scallops that evade survey dredges (Rudders 2015).

3.4.5.1 Survey Design

Shifts in the abundance and density of sea scallops in the Empire Wind Lease Area will be assessed using a BACI study design. Similar to other fisheries-independent surveys for scallops in the area, including the UMass Dartmouth SMAST drop-camera survey and the Habitat Mapping Camera (HabCam) Survey conducted by Coonamesset Farm Foundation, this Empire Wind monitoring survey will be conducted annually every summer. Additionally, any potential temporal shifts in the spatial distribution of scallops within the lease area will be evaluated using spatial statistical analyses. Monitoring will include two years of pre-construction data collection, sampling during construction, and for at least two years after construction is completed.

Stations will be distributed systematically in a grid design across the Empire Wind lease area and reference area, which will be the same area selected for the trawl survey (see Section 3.4.1). The sequencing of surveys (trawl and scallop PV surveys) will ensure PV stations will not occur in areas that were recently trawled. A power simulation study was conducted for a BACI design and analysis contrasting scallop abundance between an impact area and reference area. A description of the components of the statistical power analysis are described in Attachment A, which, although specific to the trawl survey, the fundamental elements of the power analysis apply to this BACI designed scallop study, as well. The only major deviation from the trawl survey power analysis methods was the simulation model used. Since changes in density (i.e., scallop counts) will be assessed for the scallop surveys, a GLM with Poisson errors was used. In brief, the statistical power analysis relates the effect size (the measure of change the study design and modelling approach will be used to estimate), the power (the probability of rejecting the null hypothesis when the difference in the data exceeds a threshold effect size), alpha (the Type I error rate), and the sample size (the number of sites, replicates, and time periods sampled). Given, three of these elements, the fourth can be estimated. Thus, this power simulation study was used to explore various sample sizes within specified power and effect sizes.

Estimates of mean scallop density, standard error, coefficient of variation (CV) (%), and the number of stations sampled in 2012 within the New York Bight wind energy areas (i.e., wind energy area #4 was the Empire Wind Lease Area) were provided by Kevin Stokesbury (recently detailed in Stokesbury et al. 2022). These scallop data were collected using a drop camera approach as described in Bethoney and Stokesbury (2018), at stations located within a 5.6 km^2-grid systematic sampling design.

A symmetrical BACI design was tested in this power analysis, with the design variables, determined using Stokesbury data, specified in Table 3-8. Power curves were generated to evaluate how the power for the BACI interaction contrast within a saturated model varies as a function of the variation in scallop density (CV), the effect size (% change between Empire Wind Lease Area site relative to the reference site), the sample size (count of stations in each area during each survey time period), and using a two-tailed alpha of 0.10 (assuming two years of pre-construction and two-years of post-construction monitoring) (Figure 3-11). When analyzing for changes in relative density, achieving a statistical power of at least 0.8 is intended, 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 sample size of at most 60 stations for each area will be targeted per sampling event at the start of the monitoring. Given the lease area is 321 km^2, this sampling effort (60 stations) equates to about one station every 5.6 km (stations within a 5.6 km^2 grid). Based on the results of the power analysis (Figure 3-11), this level of sampling is expected to have at least 80% power to detect a 50% temporal and/or spatial change in scallop density for moderate coefficient of variation (CV) estimates (0.4 - 0.6). This power analysis will be re-visited after the first year of data collection at the Empire Wind Lease Area and reference area. The observed CV values will be evaluated to determine whether sampling intensity needs to be modified to achieve the desired level of statistical power. If a higher CV is observed (≥0.4) and a smaller change needs to be detected (15%-33%) then additional sampling will be required to maintain a statistical power of 0.8.

Table 3-8. Design Variables for Empire Wind Scallop Survey Power Simulation Study

Set study design variables
• Impact Areas = 1 impact area
• Reference Areas = 1 reference area
• Frequency = one season per year
• Number of years Before impact = 2 • Number of years After impact = 2
Variables used in the power analysis
• Number of station replicates (random) per season in each area (n): 20 to 110 (16 – 3 km^2 grid, for 325 km^2)
• Effect Sizes (ES): -15%, -33%, -40%, -50% and 0% (for Type I error*)
• CVs: 0.15, 0.4, 0.6, 0.8, 1.0

• A two-tailed α = 0.10

*Probability of rejecting the null hypothesis in error because the true difference is small (i.e., < Δ_M)

3.4.5.2 Sampling Methods

At each station, a plan view camera system will be deployed to capture downward facing images of the seafloor. At least eight images will be collected at each station to capture within station variability given the narrower field of view (~0.5 to 1 m^2) relative to the field of view obtained from the drop camera surveys conducted by SMAST. An Ocean Imaging® Model DSC24000 plan view underwater camera system with two Ocean Imaging® Model 400-37 Deep Sea Scaling lasers attached to a steal frame will be used to collect plan view images of the seafloor surface. The PV underwater camera system consists of a Nikon® D7100 or D7200 DSLR camera encased in a pressure housing, a 24 VDC autonomous power pack, a 500 W strobe, and a bounce trigger. A weight is attached to the bounce trigger with a stainless-steel cable so that the weight hangs below the camera frame; the scaling lasers project two red dots that were separated by a constant distance (26 cm) regardless of the field of view of the PV system. The field of view can be changed by increasing or decreasing the length of the trigger wire and, thereby, the camera height above the bottom when the picture is taken. As the PV camera system is lowered to the seafloor, the weight attached to the bounce trigger contacts the seafloor prior to the camera frame reaching the seafloor and triggers the PV camera. Obtaining a clear image of the seafloor is dependent on the water column turbidity and the length of the trigger wire. A tradeoff exists between obtaining a larger field of view by using a longer trigger wire and a highly resolved image given the turbidity conditions, which may limit the distance from the seafloor that the camera can be to obtain a clear image.

3.4.5.3 Statistical Analysis

The BACI design for this survey plan allows for the scallop density to be compared between the before and after construction periods in the two treatment types (reference and Lease Area), using appropriate statistical modeling. Additionally, the spatial distribution and potential temporal shifts in that spatial distribution will be examined using spatial statistical approaches. The use of a reference area will ensure that larger regional changes in sea scallop populations will be captured and delineated from potential effects of the proposed project.

The first two years of the scallop PV survey will be used to characterize the pre-construction sea scallop abundance, density, and spatial distribution within the Lease Area and reference area. For the pre-construction monitoring, the results presented in annual reports will focus on descriptive and quantitative comparisons of the scallop abundance and spatial distribution. An exploratory analysis of spatial temporal changes in scallop density from baseline to post-construction years will be examined to determine if the scallop distribution within the Lease Area has changed between years. A surface trend analysis will be utilized to isolate broad patterns from local patterns, spatio-temporal kriging will be used to explore the spatial and temporal structure of data at baseline and post-construction periods. Lastly, the primary spatial autocorrelative process (clustering, repulsion patterns in scallop density) will be examined.

The primary monitoring objective to be addressed with the PV image scallop survey will be to determine whether scallop density or spatial distribution shifts over time. The monitoring objectives can be framed using the following hypotheses:

- $H_{Ø}$-Changes in scallop densities and scallop spatial distributions in both the reference and impact areas will be statistically indistinguishable between time periods (before and after).
- H_1-Changes in scallop densities and scallop spatial distributions will not be the same at the reference and impact areas between time periods (before and after; two-tailed).

In this BACI design, there are multiple years within each time period and a single site within each treatment (reference and Lease Area). A GLM framework will be used to describe the data and estimate the 90% CI on the BACI contrast. At a minimum, treatment type (reference and Lease Area) will be evaluated as a covariate in the model, but the modeling framework could be expanded to include other relevant covariates such as temperature, depth, salinity, the distance to the nearest turbine foundation. 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 wind farm and the average temporal change at the reference area. A statistically significant impact would be indicated by a 90% CI for the estimated interaction contrast that excludes zero. Using a 90% CI allows 95% confidence statements for the lower or upper bound (e.g., if the lower bound of the 90% CI for the mean is greater than 0, this indicates 95% confidence that the mean exceeds 0).

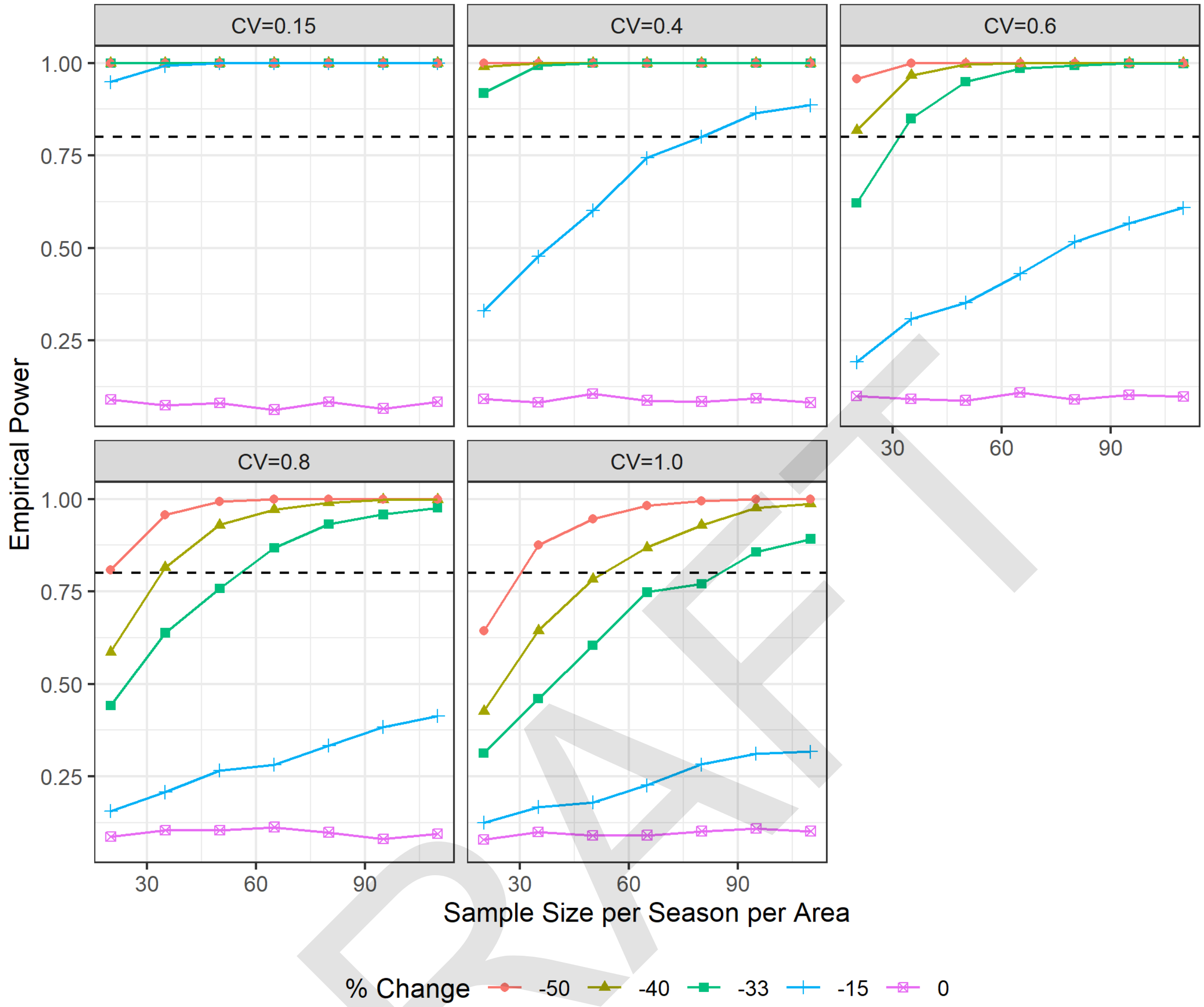

Figure 3-11. Power curves for the BACI interaction contrast within a saturated model for a range of variance (CV), effect sizes (negative % change) and sample sizes in each area per survey time point (n), and using a two-tailed alpha = 0.10. The 0% change illustrates the type I error.

4.0 BENTHIC MONITORING

4.1 EMPIRE WIND BENTHIC HABITAT OVERVIEW

The benthic habitat associated with the Empire Wind Project is described in detail in the COP (Volume 2b, Section 5.5, Equinor 2021) and COP Appendix T (Tetra Tech 2022). Several project-specific benthic and geophysical surveys have been conducted to support the benthic characterization across the Project Area including the two cable route corridors and the Lease Area. These surveys have used several sampling techniques to assess existing benthic habitat characteristics. These techniques span spatial scales, including benthic imagery and grab sampling surveys (described in the COP Appendix T, Tetra Tech 2022) and geophysical survey campaigns (synthesized in COP Appendix H, Marine Site Investigation Report, Gardline 2022).

In addition, existing regional data were compiled, synthesized, and presented in the COP (Volume 2, Section 5.5; Equinor 2021), which includes the BOEM-funded benthic resources data collection, geophysical data collection, modeling, and technical report, Battista et al. 2019, which focused on the Empire Wind Lease Area. Here we provide a summary of the data and interpretations described in detail in the references cited above.

4.1.1 Empire Wind Lease Area

The Empire Wind Lease Area seafloor is predominantly flat with low rugosity and slope (COP Appendix H, Gardline 2022; Battista et al. 2019). The water depths range from about 26 m in the western portion of the Lease Area to about 43 m in the eastern portion of the Lease Area. Generally, the Lease Area exhibits little natural variability with regards to the benthic habitat, consisting mainly of softbottom habitat. The majority of the Lease Area is characterized as rippled sand or mega-rippled sand (in the eastern portion of the Lease) with high occurrence of faunal beds (Battista et al. 2019). The sediments in the Lease Area are composed primarily of sand with shell fragments and shell hash, with some areas of sand with small gravels (i.e., pebbles) and shell fragments (COP Appendix T, Tetra Tech 2022) (Figure 4-1 top panel).

The most commonly observed benthic taxa at the Lease Area during the image-based surveys were benthic-dwelling epifauna, and specifically the common sand dollar (*Echinarachnius parma*) (Battista et al. 2019; and project-specific benthic survey, COP Appendix T, Tetra Tech 2022) (Figure 4-1 bottom panel). Sand dollars were reported to be present at 90% of the 300 stations sampled, and often in high densities, particularly in the eastern portion of the Lease Area (Battista et al. 2019). The dominance of sand dollars in this region is consistent with reports from other regional benthic studies (Malek et al. 2014; Guida et al. 2017). Aside from sand dollars (echinoderms), other benthic groups observed were annelids, molluscs (e.g., moon snails), and crustaceans (e.g, hermit crabs and amphipods) (Figure 4-1 bottom panel). The project-specific benthic characterization survey in the Lease Area also reported high-occurrences of these benthic biota (COP Appendix T, Tetra Tech 2022). The majority of the stations sampled at the Lease Area during the project-specific benthic survey were characterized as Coastal and Marine Ecological Classification Standard (CMECS) Biotic Groups Small Surface-Burrowing Fauna and Mobile Crustaceans on Soft Sediments based on the sieved infauna samples, and Sand Dollar Beds based on the seafloor imagery data (COP Appendix T, Tetra Tech 2022).

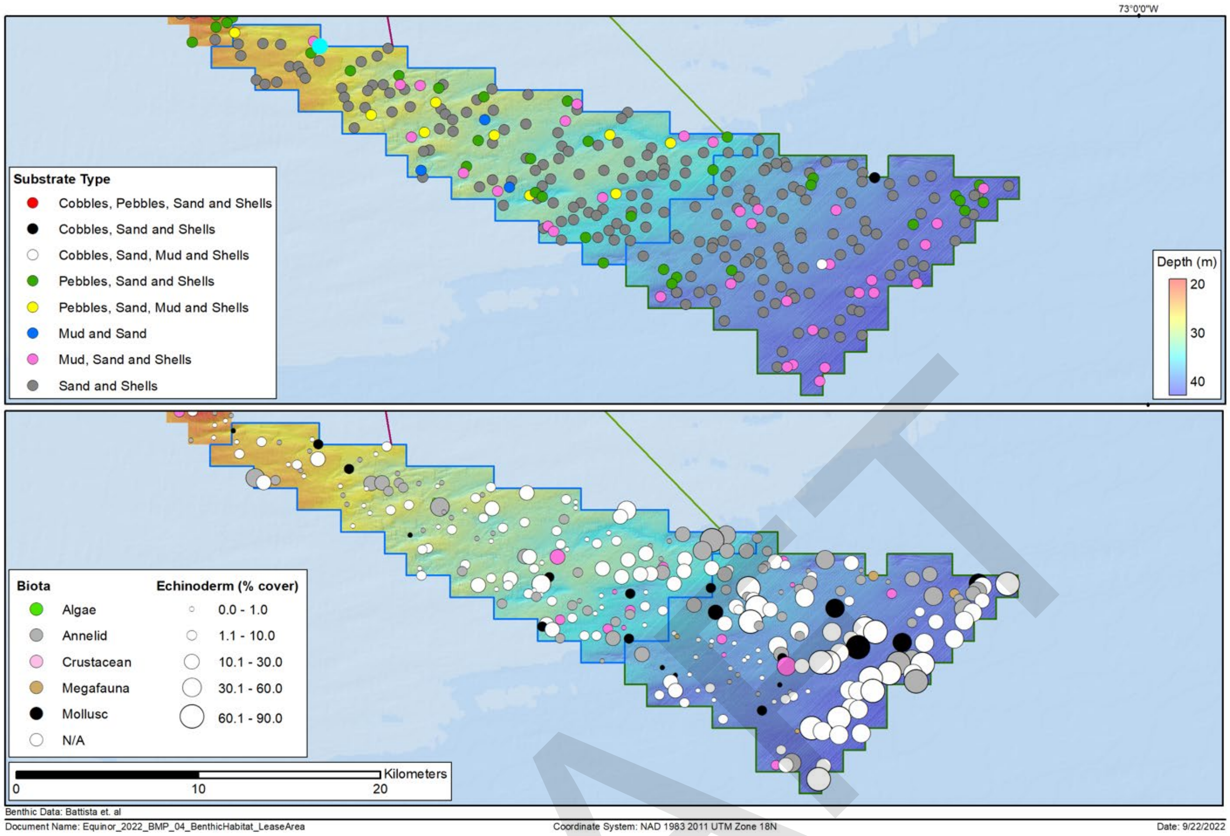

Figure 4-1. Summary of the benthic habitat at the Empire Wind Lease Area including bathymetry, substrate type (top), and biota (bottom), as originally described in Battista et al. 2019

4.1.2 Empire Wind Export Cables

The Empire Wind Project includes two separate export cables: EW 1 and EW 2 (Figure 1-1). The EW 1 export cable transits away from the Lease Area along its northeastern boundary and continues north-northwest across the Ambrose and Nantucket traffic separation schemes towards New York Harbor. The EW 1 runs parallel to the Ambrose Channel as it enters Lower New York Bay, transits through the narrows on the eastern side and makes landfall in Brooklyn, NY. The EW 2 export cable route extends away from the Lease Area at the center of northern boundary. This export cable route transits north-northwest towards Long Island, NY. There are several route alternatives currently being considered at the landfall in Oceanside, NY for the EW 2 route.

Two project-specific benthic characterization surveys were conducted along the export cable routes, which are summarized in the COP (Volume 2b, Section 5.5, Equinor 2021) and detailed results are provided in Appendix T (TetraTech, 2022 and INSPIRE 2019). Additionally high-resolution geophysical data were collected along the entirety of these two route corridors, results of which are reported in the COP (Appendix H, Marine Site Investigation Report, Gardline 2022). Here we provide a summary of the benthic conditions along both EW 1 and EW 2 cable routes (Figure 4-2).

The benthic habitat along EW 1 is generally characterized as softbottom with sediment types ranging from silt/clay to pebbles. The majority of the EW 1 within federal waters was characterized using sediment profile imagery as medium sand, fine sand, or very fine sand; fine-scale sediment layering with layers of coarser grains over finer sediments was frequently documented (Figure 4-2, left). One station located due north of the western-most corner of the Lease Area consisted of pebbles/granules over sand. The portion of the EW 1 export cable route in NY state waters transitioned from fine sand at the state waters boundary to an area of coarse and medium sand at the entrance of New York Bay. In lower New York Bay and through the narrows, the sediments along EW 1 corridor were silt/clay and very fine sand. The dominant CMECS Biotic Group observed in plan view imagery was mainly small and large tube-building fauna (Figure 4-2, right). Sand Dollar Beds, Attached Hydroids, and Mobile Crustaceans were observed in the area due north of the western-most portion of the Lease Area. Mussel Beds and Attached Mussels were observed at the stations within lower New York Bay and off Coney Island.

The benthic habitat along EW 2 is generally characterized as softbottom (Figure 4-2, left). Sediment types ranged from silt/clay to pebbles along EW 2, with fine-scale sediment layering consisting of coarser grains overlying finer grains observed in SPI imagery. High densities of sand dollar beds were observed along the offshore portion of the EW 2 (Figure 4-2, right). This benthic community transitioned to tube-building and surface burrowing infauna near shore along the EW 2 (Figure 4-2, right).

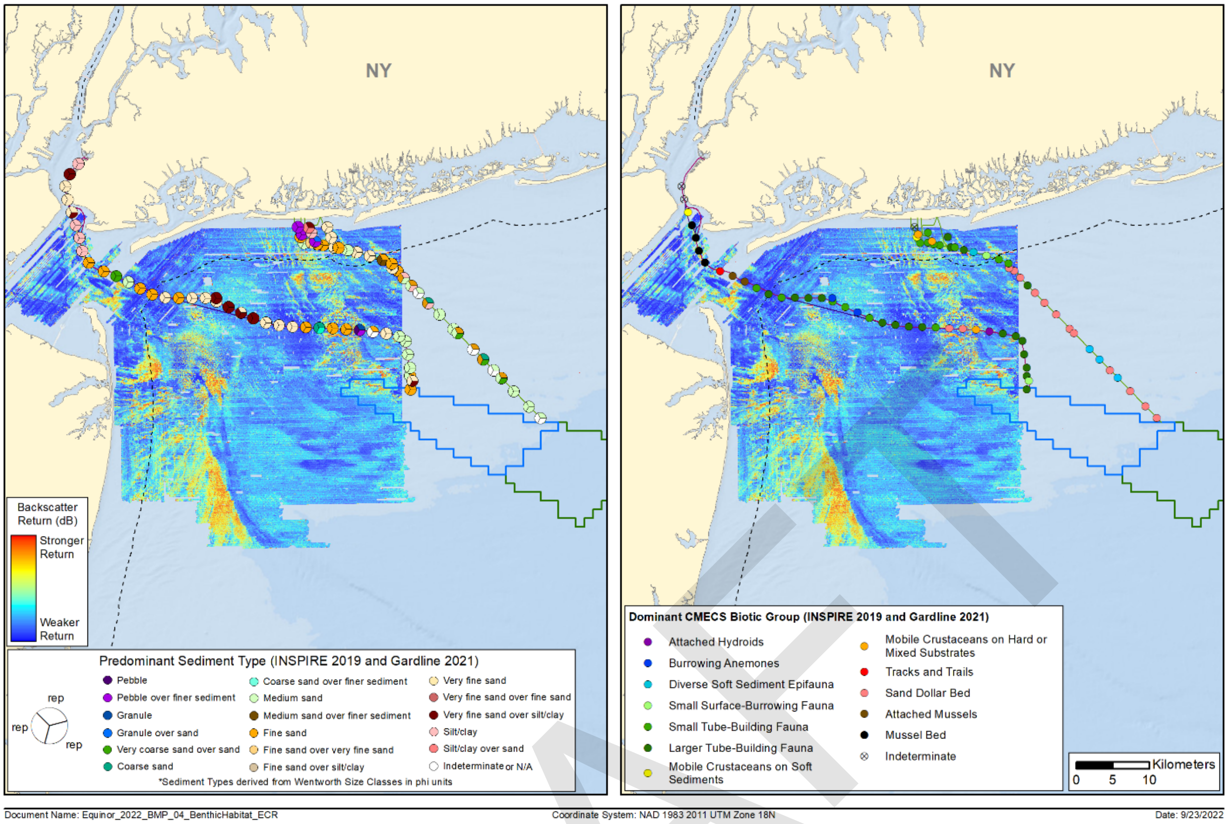

Figure 4-2. Summary of benthic habitat along the Empire Wind Export Cable corridors including sediment type (left), and CMECS Biotic Group (right), originally reported in INSPIRE 2019 and Gardline 2021 (both reports included in the COP Appendix T (TetraTech 2022)

4.2 BENTHIC MONITORING OBJECTIVES AND HYPOTHESES

Installation and operation of offshore wind projects can temporarily 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 sediments, resulting in mortality or injury of existing fauna. The introduction of novel hard substrata (wind turbine generator [WTG] foundations, scour protection layers, and cable protection layers) can lead to extensive biological growth on the introduced surfaces with complex patterns analogous to depth zonation as observed along shoreline intertidal to subtidal gradients (artificial reef effect, Petersen and Malm 2009; Reubens et al. 2013b; Degraer et al. 2020). Depending on the community composition and density, this biological epifaunal growth may lead to substantial shifts in the transfer of energy from the water column to other compartments of the ecosystem including the surrounding sediments and upper trophic levels.

Observations from existing offshore wind projects lead to three prevailing hypotheses related to benthic effects relevant to the proposed Empire Wind Project:

1. Introduction of novel surfaces (foundations, scour protection, and cable protection layers) will develop epifauna that vary with depth and change over time. *[Hard Bottom-Novel Surfaces]* (as reviewed in Langhamer 2012).

2. The artificial reef effect (epifaunal colonization) associated with the offshore wind structures will lead to enrichment (fining and higher organic content) of surrounding soft bottom habitats resulting in shifts in benthic function (increased organic matter processing). [*Structure-associated – Organic Enrichment*] (e.g., Lefaible et al. 2019; Ivanov et al. 2021).

3. Physical disturbance of soft sediments during cable installation will temporarily disrupt the function of the infaunal community, community function is expected to return to pre-disturbance conditions. [*Cable-associated – Physical Disturbance*] (e.g., Kraus and Carter 2018).

The consequences of these predicted effects may affect the role of soft and novel hard bottom habitats in providing food resources, refuge, and spawning habitat for fish and shellfish species (Reubens et al. 2014; Krone et al. 2017). The focus of the benthic monitoring will be on determining if there are unexpected changes to the benthic ecosystem associated with the development of the wind farm. Specifically, the monitoring will focus on documenting potential adverse outcomes associated with each of these three hypotheses including:

1. Dominance of non-native species relative to native species (Novel Hard Bottom Monitoring),

2. Evidence of impairment associated with organic enrichment on the seafloor surrounding the novel structures, and

3. Delayed recovery from physical disturbance along the export cable routes.

This operational monitoring plan is organized according to these three hypotheses (and potential adverse outcomes) associated with the Empire Wind Project. The plan describes the overall approach to tracking changes in both the novel hard bottom and soft bottom habitats associated with the Project development and operation. This monitoring plan is not designed to answer research questions about specific causes and effects on individual species but rather is aimed at monitoring potential changes associated with the benthic habitats of the Empire Wind Project. A comprehensive outline of the benthic monitoring plan, including the hypotheses, sampling schedule, and general approach for each monitoring component is provided in Table 4-1. The planned statistical analyses are summarized by survey type in Table 4-2.

Table 4-1. Summary of the Benthic Monitoring Plan Including Hypotheses, Approach, and Sampling Schedules for Each Component

Novel Hard Bottom

WTG/OSS Foundations, Scour and Cable Protection

Hypothesis: epifaunal community will vary with water depth (zonation with light and tide); successional development of epifaunal community over time

Approach: Use ROV/stereo camera to measure changes in % cover, identify key or dominant species, focus on documenting non-native species, estimate volume (biomass), compare across water depths

Design: stratified random selection of WTG foundations within water depth contour strata; both OSS foundations sampled [same foundations as Structure-associated Organic Enrichment Surveys]; selection of export cable protection areas to be determined following cable burial risk assessment

Y0 – late summer/early fall after construction
Y1- ROV/stereo camera late summer/early fall
Y2- ROV/stereo camera late summer/early fall
Y3- ROV/stereo camera late summer/early fall
Y5 – ROV/stereo camera late summer/early fall

Soft Bottom Habitats

Structure-associated Organic Enrichment

Hypothesis: epifaunal growth on foundations will result in sediment fining and higher organic content in surrounding soft bottom, this will support deposit feeding benthic invertebrates. Effects will decrease with increasing distance from structure foundation.

Approach: Use SPI/PV, sediment grab samples (organic matter characterization, grain size) to measure changes in benthic function over time and with distance from foundations, focus on documenting any evidence of impairment (Beggiatoa, methane, zero aRPD depth)

Design: stratified random selection of foundations within water depth contour strata [same foundations as Novel Hard Bottom surveys]; BAG design at each selected foundation:
2 radial transects at each foundation –

- 2 stations on scour protection (SPI/PV),
- 0-10m (SPI/PV + sediment samples)
- 15-25 m (SPI/PV)
- 40-50 m (SPI/PV + sediment samples)
- 90-100 m (SPI/PV)
- 190-200 m (SPI/PV)
- 900m (SPI/PV + sediment samples)

Pre seabed prep – within 6 mo prior to construction
Y0 – late summer/early fall after construction
Y1 – late summer/early fall
Y2 – late summer/early fall
Y3 – late summer/early fall
Y5 – late summer/early fall

Cable-associated Physical Disturbance

Hypothesis: After initial physical disturbance during construction, soft sediment community function is expected to return to pre-conditions; effects will decrease with increasing distance from cable

Approach: Use SPI/PV to measure changes in benthic function over time and with distance from cable centerline; focus on documenting any delayed recovery following disturbance.

Design: stratified random selection of cable segments within benthic habitat and depth strata; BAG at each selected cable segment, triplicate transects perpendicular from cable centerline – 16 stations along each transect with varying distances from cable

Pre seabed prep – within 6 mo prior to construction
Y0 – late summer/early fall after construction
Y1 – late summer/early fall
Y2 – late summer/early fall

Table 4-2. Summary of Planned Statistical Analyses for the Benthic Monitoring Surveys at Ocean Wind

Survey	Novel Hard Bottom Monitoring	Structure-associated Organic Enrichment	Cable-associated Physical Disturbance
Monitoring Plan Section	4.3	4.4	4.5
Area	Empire Wind Leases and Export Cable Segments with Cable Protection	Empire Wind Leases	Export Cable Routes
Design Type	Stratified Random	BAG	BAG
Design Overview	WTG foundations: random samples (WTGs) stratified by depth range; single season. Substation foundations will also be sampled. Segments of export cable where cable protection materials were used.	Impact only (no reference sites); stns at distances ranging from ~10 m to ~900 m from foundations; 2 directions from each foundation along prevailing current; single season	Impact only (no reference sites); stns at distances ranging from ~5 m to ~1 km from cable; ≥ 3 transects within each habitat stratum.
Number of Replicates	4 replicate WTGs per depth stratum; 2 OSS foundations; 4 replicate export cable segments with protection (locations TBD)	4 replicate WTGs per depth stratum; 2 OSS foundations;	3 replicate transects per habitat type
Sampling Effort	2 OSS jacket + [2 depth ranges x 4 WTGs] = **~10 structures** 4 segments of protected cable	~ 10 structures x 2 transects x 8 stations = **160 SPI/PV stations**	3 habitat strata x 3 transect replicates x 16 stations along each replicate transect = **144 SPI/PV stations**
Design details	**Sampling frame =** turbine foundations **Observational unit** = imaged quadrat (at systematically sampled depth intervals within frame) **Response variable** = macrobiotic cover, relative abundance of native vs non-native, presence of sensitive taxa and species of concern **Error variance** = among image quadrats at the same depth- and distance-direction (WTGs provide replication)	**Sampling frame** = turbine foundations with mobile sediment classes up/down current **Observational unit** = SPI/PV station (WTGs 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 (WTGs provide replication)	**Sampling frame** = soft bottom areas of export cable routes **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)

Survey	Novel Hard Bottom Monitoring	Structure-associated Organic Enrichment	Cable-associated Physical Disturbance
Metrics of Interest	**ROV/stereo-camera**: cover (macrobiota, relative abundance of native vs. invasive). **Photogrammetry**: Estimate of biomass/biovolume	**SPI**: aRPD, Successional Stage, penetration, methane, grain size major mode, *Beggiatoa* **PV**: cover (macrobiota, shells, cobble), presence/absence of sensitive or invasive species **Sediment Grab:** percent organic matter, total organic carbon, total nitrogen, C:N	**SPI**: aRPD, Successional Stage, penetration **PV**: cover (macrobiota, shells, cobble), presence/absence of sensitive or invasive species
Hypothesis framework	Introduction of novel surfaces will develop epifauna (specifically focused on documenting non-native species, sensitive taxa, species of concern) that vary with depth and change over time.	The artificial reef effect associated with novel structures will lead to enrichment (fining and organic matter content) of surrounding seafloor leading to shifts in benthic function (differences in aRPD depths, bioturbation depths, infaunal successional stage, grain size)	Physical disturbance during cable installation will disrupt benthic function, effects expected to decrease with distance from export cable and over time
Post-Construction Statistical Methods	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.	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.	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.

4.3 NOVEL HARD BOTTOM MONITORING – WTG FOUNDATIONS AND CABLE PROTECTION

Hypothesis 1: Introduction of novel surfaces (foundations, scour protection, and cable protection layers) will develop epifauna that vary with depth and change over time. *[Hard Bottom – Novel Surfaces]* (as reviewed in Langhamer 2012).

The hard bottom monitoring will include an examination of three types of novel surfaces: WTG foundations (including associated scour protection layers), export cable protection layers, and the OSS foundations. The primary objective of the novel hard bottom survey is to measure changes (over time and water depths) to the nature and extent of macrobiotic cover of novel hard bottom associated with the Empire Wind Project. The focus of this monitoring will be to document the potential presence and relative dominance of non-native species within the epifaunal communities. Macrofaunal percent cover, identification of species (to the lowest possible taxonomic unit [LPIL]), and the relative abundance of native and non-native organisms will be documented using a Remotely Operated Vehicle (ROV) and stereo camera surveying approach. Distinguishing non-native organisms may require physical sampling for accurate identification, which will be facilitated by a sampling arm attached to the ROV or by validation with eDNA analyzed in samples collected as part of the Fisheries Monitoring Surveys.

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 coastal rocky intertidal habitats. Previous studies in Europe and at the Block Island Wind Farm (BIWF) found biological growth led to dense accumulations of filter feeding mussels on the turbine foundations, with amphipods, tunicates, sponges and sea anemones in the deeper segments of the structures (De Mesel et al. 2015; HDR 2020; Wilber et al. 2021; Hutchison et al. 2020). Other studies have also 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 offshore wind structure, the epifaunal species composition is expected to develop successionally, with rapid opportunistic organisms pioneering the site and being replaced by more long-lived established species.

4.3.1 Technical Approach – Stereo Camera Imagery

To accomplish the objectives of the novel hard bottom monitoring, 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 novel hard surfaces (WTG foundations and scour protection layers, OSS jacket, cable protection layers). 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 focus of the UHD stereo imagery analysis will be biological features (e.g., percent cover of encrusting epifauna), identifying any non-native organisms, sensitive taxa, species of concern, presence of refuge, and quantifying the biomass of the dominant members of the epifaunal communities. The focus of the HD video will be to provide quantitative details of habitat characteristics and quality, including categorical levels for the presence of fish and decapods, and surrounding substrata (sediment type), and the percent cover of emergent fauna.

Images provide a data rich record of benthic communities. However, images flatten the landscape, which can introduce bias, limit identification, and distort quantitative analyses. By building 3D models from images, i.e., photogrammetry, we can overcome these challenges, which will allow for quantitative detection of changes at target sites (e.g., Bruno et al 2013). Photogrammetry is the process in which imagery is interpreted to provide detailed information about the physical objects observed in space. Specifically, photogrammetry generates high-resolution, photo-realistic 3D models from static images captured from multiple perspectives.

Although photogrammetry with single-camera systems cost less and integrate with low cost and free software (e.g., Agisoft Metashape and Meshromo), these systems require invasive and sometimes destructive methods including scene preparation for calibration (e.g., the placement of coded targets). Therefore, we will use a stereo-camera system. Stereo cameras do not require scene preparation because they are scaled by specific manufacturer's calibration of the two cameras with each other. Stereo-camera systems are not new. For example, Done reconstructed a habitat scale 3D model of a coral reef, using a stereo camera, over forty years ago (Done 1981). Compared to single camera systems, few researchers use stereo cameras to monitor ecological change because, until recently, commercial vendors did not offer these types of these systems for subtidal work. Now, commercial vendors manufacture stereo cameras systems and support their use in offshore, subtidal habitats to monitor equipment and environmental impacts for multiple energy industries.

We will collect UHD images at depth intervals along the turbine foundations and discrete areas of the cable protection layers will capture high-resolution images. The data will include the photographs, the calibrated 3D products, including a dense point cloud with color, a mesh, and a textured mesh. Preliminary tests yielded models with sub mm accuracy. We will use the point cloud and mesh in quantitative analysis, and we will use the textured mesh for communication.

By digitally reconstructing segments of the foundations and cable protection at predefined depth intervals, 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). Collecting imagery and constructing spatial photogrammetric models of the structures soon after construction will provide initial reference conditions that can be used to track biological changes over time following subsequent years of data collection (i.e., change analysis).

Using the 3D model, we can also evaluate the abundance of refugia by calculating rugosity. We will evaluate the presence of refugia by quantifying three-dimensional complexity in the reconstructed 3D model. We will calculate three-dimensional complexity, i.e., rugosity (f_r), as $f_r = A_t/A_g$, where A_t is the true surface area of a complex object and A_g is the geometric surface area of a 3D convex hull wrapping the complex object. Larger values indicate more refugia, and values closer to 1 indicate fewer refugia. We will calculate A_t and A_g from the reconstructed 3D models from 10 sub-sampled chunks for each each replicate area, e.g., in python or meshlab. This analysis is comparable to the traditional field methods for rugosity using a transect tape and chain, however, using a virtual 3D model, we can collect more and better data in 3D versus in 2D.

Biological data obtained through photogrammetry can 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 at the base of the novel structures. 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.

The following parameters will be measured as part of the hard bottom analysis.

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

4.3.2 Survey Design

ROV stereo camera surveys will monitor novel hard bottom habitats within subareas of the Empire Wind Project. For each selected area, we collect UHD images with a stereo camera following vendor-specific protocol. For example, we will likely collect images with auxiliary lights, with at least 50% overlap for all survey lines, with ~1 m stand-off distance, in a lawnmower pattern. Furthermore, we will render a live sparse point cloud to identify and fill gaps in the model by collecting additional images, if this service is provided by the vendor.

Replicated WTG foundations will be selected using a stratified random design, as described below. Both OSS foundations will be selected for monitoring at the same intervals as described for the WTG foundation surveys. Selection of cable protection areas for monitoring will be dependent on where cable protection is used, information that is not currently known. Segments of the export cable that is armored using cable protection material, will be selected randomly considering environmental factors including water depth, natural benthic habitat of the surrounding seafloor, and distance from shore as explanatory variables. For analysis, we will analyze select images and sections of the 3D models as described below. Segments of the export cable that is armored using cable protection material, will be selected randomly considering environmental factors including water depth, natural benthic habitat of the surrounding seafloor, and distance from shore as explanatory variables.

For the WTG foundation monitoring program, a stratified random design, with water depth ranges as strata, will be used to select the novel WTG structures that will be monitored. The same WTG foundations selected for this novel hard bottom survey will be monitored as part of the soft sediment enrichment survey (see Section 4.4). This will help facilitate synthesis between the degree of enrichment in the surrounding soft sediments and the epifaunal community composition and density colonizing the novel structures at any given time and location. The same WTG foundations selected for this novel hard bottom survey will be monitored as part of the BRUV surveys (see Section 3.4.2). This will aid in drawing inferences between epifaunal colonization with habitat use by mobile vertebrates.

The Empire Wind Project Lease Area will be divided into two strata based on depth (<35 m [shallow] and >35 m [deep]). Four replicate WTGs will be randomly selected within each of the two depth strata for sampling. These replicate WTGs will be scanned and sampled during each survey event (Table 4-1). The hard bottom monitoring will occur in late summer/early fall for each survey. The initial baseline survey will occur during the first late summer/early fall following construction (Y0). The survey will then be repeated annually for the next three years (Y1, Y2, Y3) and again five years after construction (Y5).

4.3.3 Statistical Analyses

The planned statistical analyses are summarized by survey type in Table 4-2.

For the *Novel Hard Bottom Monitoring* dataset collected at WTG foundations and scour protection layers, OSS jacket, cable 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 tubines, 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.

4.4 STRUCTURE-ASSOCIATED ORGANIC ENRICHMENT

Hypothesis 2: The artificial reef effect (epifaunal colonization) associated with the offshore wind structures will lead to enrichment (fining and higher organic content) of surrounding benthic habitats resulting in shifts in benthic function (increased organic matter processing). [*Soft Bottom – Structure-associated*] (e.g., Lefaible et al. 2019; Ivanov et al. 2021).

The *Structure-associated Organic Enrichment* monitoring will include an examination of two offshore wind components: WTG foundations and the OSS foundations. The overall objectives of this component of the benthic monitoring program are to measure potential changes in the benthic function of the benthic habitats surrounding these novel structures over time, and to assess whether benthic function changes with distance from the base of the foundations. The focus will be on monitoring for and documenting any evidence of impairment associated with organic enrichment on the seafloor surrounding the foundations (e.g., *Beggiatoa,* methane presence, zero aRPD depth [no oxygen penetrating into the sediment]).

It is expected that the epibenthic community that colonizes the novel structures will supply organic matter to the sediments below through filtration, biodeposition, and general deposition of detrital biomass. This organic material sourced from the biological activity of the epibenthic community on the novel structures will likely alter the infaunal community activity, increasing sediment oxygen demand (SOD) and promoting the activity of deep-burrowing infauna. Based on benthic monitoring results in other offshore wind farms, the effects of the foundation on the surrounding soft sediment habitat are expected to decrease with increasing distance from the foundation (as reviewed in Degraer et al. 2020 and modeled in De Borger et al. 2021).

Benthic functioning of the soft bottom habitats at the base of the novel foundations will be captured using sediment profile and plan view (SPI/PV) imagery, sediment grain size analysis, and organic matter characterization. These approaches will be employed at varying frequencies and spatial resolution as described below. The SPI/PV imagery will provide an overall integrated assessment of the physical parameters (grain size major mode) and biological factors (bioturbation depths, aRPD depths, methane production). At some stations, the SPI/PV imagery will be supplemented by sediment grab samples analyzed for grain size, percent bulk organic matter, and total organic carbon and nitrogen content, which will provide insight into shifts in the organic matter loading to the sediments and the quality of the organic matter in the sediments (carbon to nitrogen ratio).

4.4.1 Technical Approach – SPI/PV

SPI/PV will be used as the primary monitoring approach for the *Structure-associated Organic Enrichment* monitoring surveys. The SPI and PV cameras are state-of-the-art monitoring tools that capture benthic ecological functioning within the context of physical factors. The PV system captures high-resolution imagery over several meters of the seafloor, while the SPI system captures the typically unseen, sediment–water interface in the shallow seabed. Coupled SPI/PV imagery provides an integrated, multi-dimensional view of the benthic and geological condition of seafloor sediments and can be used to characterize the function of the benthic habitat, physical changes, and recovery from physical disturbance following the construction and during operation of the Empire Wind Project. Additionally, PV data will be used to characterize surficial geological and biotic (epifaunal) features of hard bottom areas within the sampling area (e.g., scour protection layers at the base of the foundations) but will not replace the dedicated novel hard bottom monitoring survey (Section 4.3).

SPI/PV imagery provides 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 that 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 offshore wind structures on soft sediment habitats (see Attachment B for more details). Taxonomic analysis of sediment grab samples provides information on the benthic community composition and infaunal abundances, but without making substantial inferences to relate presence and counts to biological activity and further ecological value or function, the sediment grab approach is severely limited in its ability to assess impacts of offshore wind development on soft sediment functioning. Further, given the inherently dynamic and patchy nature of infaunal populations, benthic species 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 offshore wind development on benthic habitats. Attachment B provides detailed justification for the use of SPI/PV imagery approach to meet these monitoring objectives and more detailed descriptions of several of the parameters that will be obtained during SPI/PV image analysis.

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 the Empire Wind Project. SPI/PV and the parameters derived from these images are standard tools for assessing the response to disturbance and enrichment (Germano et al. 2011). Seafloor geological and biogenic substrates captured in SPI/PV imagery will be described using the Coastal and Marine Ecological Classification Standard (CMECS; FGDC 2012). Triplicate images will be collected and analyzed at each station.

The following parameters will be measured during SPI and PV image analysis:

- CMECS Substrate Group and Subgroup
- gravel size measurements (predominant, minimum, maximum), where applicable
- CMECS Biotic Class and Subclass
- aRPD depth (See Attachment B)
- maximum bioturbation depth
- infaunal successional stage (See Attachment B)
- methane presence/absence
- grain size major mode
- presence, frequency, size of surficial features such as bedforms (e.g., sand ripples)
- presence of sensitive taxa (e.g., slow growing species) and ecologically valuable taxa (e.g., biogenic structure-forming taxa such as emergent fauna) (See Attachment B)

Results from the three replicate images at each station will be aggregated to provide a summary value for each metric by station. Depending on the metric type, this will include mean, maximum, or predominant (categorical variables) (e.g., predominant CMECS Substrate Subgroup, maximum infaunal successional stage, maximum and median feeding void depth, and mean aRPD depths).

4.4.2 Technical Approach – Sediment Sampling

Sediment samples will be collected and analyzed for grain size distribution and organic matter characteristics. Sediments are expected to become more organically enriched over time and closer to the foundation structures as detrital material originating from the epifaunal community activity (e.g., biodeposition) falls to the surrounding seafloor. The level of organic enrichment and organic matter loading will be assessed by analyzing sediment samples for bulk percent organic matter and total organic carbon and nitrogen content. The percent organic matter of the sediments (measured as loss-on-ignition) is expected increase over time and decrease with distance from the structure. In addition to the quantity of organic matter in the sediments, the quality of sediment organic matter is important to consider when assessing shifts in benthic function. The quality of sediment organic matter will be assessed by analyzing sediment samples for organic carbon and total nitrogen content. The organic carbon to nitrogen ratio (C:N) of sediments provides insight into the quality or lability of the organic matter (i.e., how available it is to be decomposed or consumed). Finally, it is expected that the sediment grain size will become finer over time and closer to the foundation structures. This will be measured using both SPI/PV imagery (grain size major mode) and physical sediment samples analyzed for grain size distribution.

4.4.3 Survey Design

The *Structure-associated Organic Enrichment* monitoring will be conducted using a BAG survey design to determine the spatial scale of potential impacts on benthic habitats at the Empire Wind Lease Area. The same WTG foundations selected for the Novel Hard Bottom monitoring (Section 4.3) will be selected for the *Structure-associated Organic Enrichment* monitoring. The Empire Wind Project Lease Area will be divided into two strata based on depth (<35 m [shallow] and >35 m [deep]). Four replicate WTGs will be randomly selected within each of the two depth strata for sampling. The surrounding seafloor of these replicate WTG foundations will be surveyed during each survey event (Table 4-1).

At each replicate WTG foundation and the two OSS, a BAG survey design will be used for statistical evaluation of the spatial and temporal changes in the surrounding benthic habitat (Underwood 1994; Methratta 2020). Data will be collected before and after installation and operation of Empire Wind at stations oriented along a gradient from select foundations (Figure 4-3). This BAG design is based on an understanding of the complexities of habitat distribution at Empire Wind (COP Appendix T, Tetra Tech 2022), 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).

The pre-construction benthic survey will be conducted in late summer or early fall (August to October) prior to the start of construction to document benthic habitats prior to disturbance (baseline). The next survey will occur during the first late summer/early fall following construction (Y0). The survey will then be repeated annually for the next three years (Y1, Y2, Y3) and again five years after construction (Y5). All surveys will be conducted in the same seasonal time frame, which will be during late summer or early fall to capture peak biomass and diversity of benthic organisms in alignment with previous studies (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).

Data on the mean currents near Empire Wind Lease Areas will be used to establish up current and down current transects extending from each selected WTG foundation. Two belt transects (25 m wide) of benthic stations will be established, one up current and the other down current of the selected turbine locations (Figure 4-3). Pre-construction transects will begin at the center point of the planned foundation with two stations at equal intervals up to the maximum planned extent of the scour protection area 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 (Figure 4-3). Post-construction transects will repeat this design at the same turbines and the same sampling distance intervals. These distances were chosen based on recent research indicating that effects of turbines on the benthic environment occur on a local scale (e.g., Lindeboom et al. 2011; Coates et al. 2014; Degraer et al. 2018; HDR 2019; Lefaible et al. 2019). SPI/PV imagery will be collected at every station. Physical sediment samples will be collected at the following stations beyond the scour protection layer (i.e., in soft sediments): 0-10 m, 40-50 m, and 900 m. The lower sampling effort for the physical sediment samples relative to the SPI/PV stations is due to the fact that the sediment sample data (organic matter content) will be ground truthing the information obtained from the SPI/PV imagery.

4.4.4 Statistical Analyses

The planned statistical analyses are summarized by survey type in Table 4-2.

For the *Structure-associated Organic Enrichment* dataset collected at the base of the selected WTG foundations (BAG design), 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 water depth (continuous) and direction (categorical); variability among turbines will provide site-wide random error. For individual metrics that are consistently measured across stations (e.g., aRPD depth, sediment organic matter content), 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 and sediment sample data over time and as a function of 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.

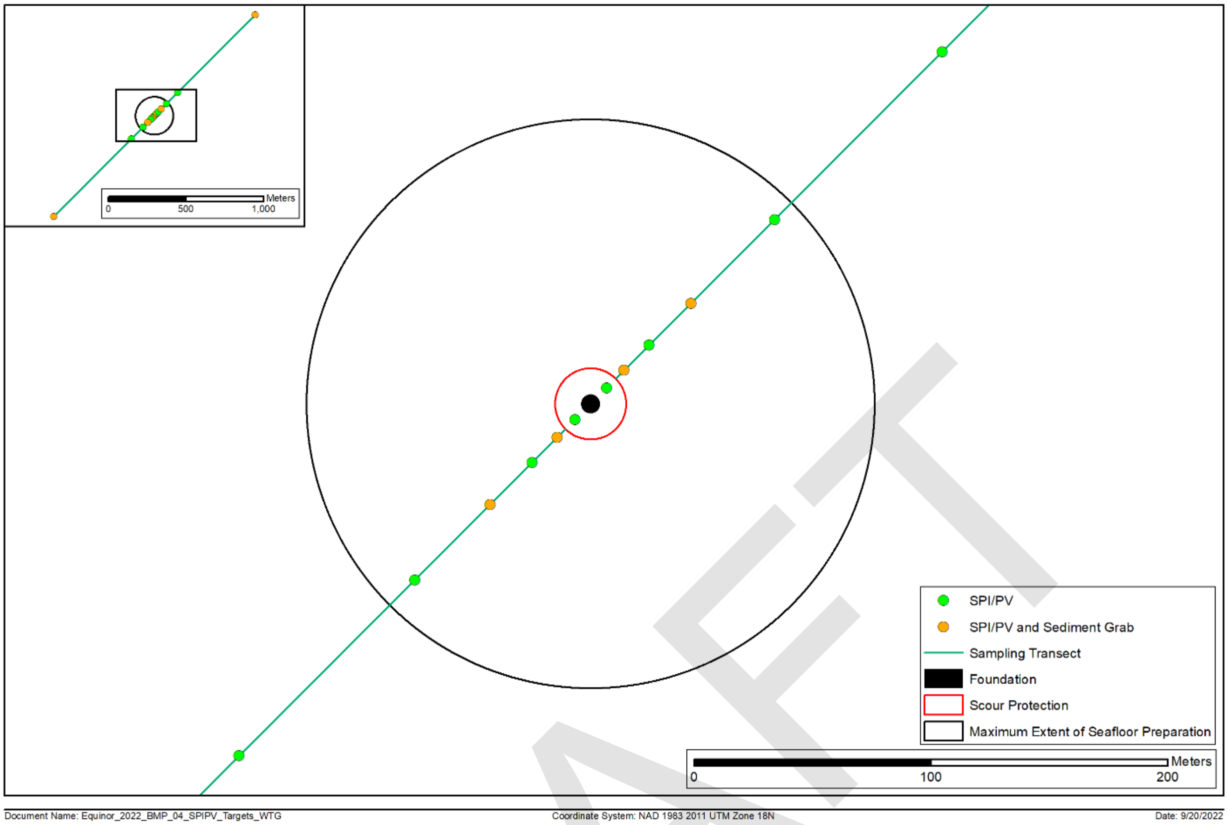

Figure 4-3. Conceptual diagram illustrating the Before-After Gradient design of the *Structure-associated Organic Enrichment* survey design, SPI/PV and sediment grab station locations on the seafloor surrounding each selected foundation. The transect orientation will be based on prevailing water currents in the area, to capture upstream and downstream effects.

4.5 CABLE-ASSOCIATED PHYSICAL DISTURBANCE – SOFT SEDIMENTS

Hypothesis 3: Physical disturbance of soft sediments from cable installation (including seafloor preparation) will temporarily disrupt the function of the infaunal community, community function is expected to return to pre-disturbance conditions. [*Soft Bottom – Cable-associated*] (e.g., Kraus and Carter 2018).

The objective for the *Cable-associated Physical Disturbance* monitoring along the Empire Wind export cables is to examine the effects of installation and operation of the export cables on the benthic habitat over time and along a spatial gradient with distance from the cable centerlines. This component of the benthic monitoring will include focused surveys along the export cable corridors. The focus of this monitoring will be on documenting any delayed recovery of the benthos following the physical disturbance associated with cable construction. Note that monitoring epifaunal growth on any cable protection material along segments of the export cables is described within the novel hard bottom component of this monitoring plan (see Section

4.3). A separate monitoring plan will be developed that focuses on the cable corridors within New York State waters.

The primary effect of cable installation is physical disturbance of the sediment resulting in sediment resuspension and temporary loss of infauna. 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. Other independent variables that may influence the benthic effects of and recovery from cable installation include levels of fishing activity (e.g., bottom trawling, clam dredging), installation methodology, and natural bottom sediment transport from tides, waves, and currents. These variables will be considered during data analysis and interpretation. 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 export cable routes. Any potential impacts of the cable on soft bottom habitats are expected to decrease over time after installation and with distance from the export cable centerline.

4.5.1 Technical Approach – SPI/PV

SPI/PV will be the primary tool used to document any changes to the small-scale physical characteristics and benthic community function following cable installation. A general summary of the rationale and value of using SPI/PV is provided in Attachment B.

4.5.2 Survey Design

A stratified random survey design will be used to select sampling frames along the export cables, stratified by habitat type. This monitoring plan provides a general overview of the design that can be adjusted when engineering and construction plans are finalized. Within each sampling frame, SPI/PV data will be collected using a BAG design, like that proposed for the seafloor surrounding the foundations (Section 4.4) (Underwood 1994; Methratta 2020). Details describing the BAG design approach and its value in evaluating potential temporal and spatial changes following construction are provided in the Section 4.4, above.

The soft bottom survey sample design will focus on sampling at representative sections of the export cables based on benthic habitat types as informed by the initial benthic characterization of the planned export cable corridors (INSPIRE 2019; COP Appendix T, Tetra Tech 2022). Sampling locations will be selected randomly, stratified by these habitats. At triplicate locations (each approximately 1 km apart) within each habitat type sampling stratum, a 25-m wide belt transect will be positioned perpendicular to the cable route (three replicate transects per habitat stratum) (Figure 4-4). Along each transect, a total of 16 stations will be sampled. At each station, triplicate SPI/PV images will be collected and analyzed. Near the centerline these stations will be distributed roughly 10 m apart and the distance intervals between stations will increase with distance from the centerline (Figure 4-4). The selected sampling locations and sampling intervals relative to the cable will remain fixed for the duration of the survey. The exact locations of the sampling frames will be selected after cable installation is completed; Figure 4-4 provides a conceptual diagram of the planned sampling design along the export cable corridors. Sampling along the export cables will occur prior to construction (within 6 months), within the first calendar year post installation (Y0), one year post-installation (Y1), and two years post-installation (Y2).

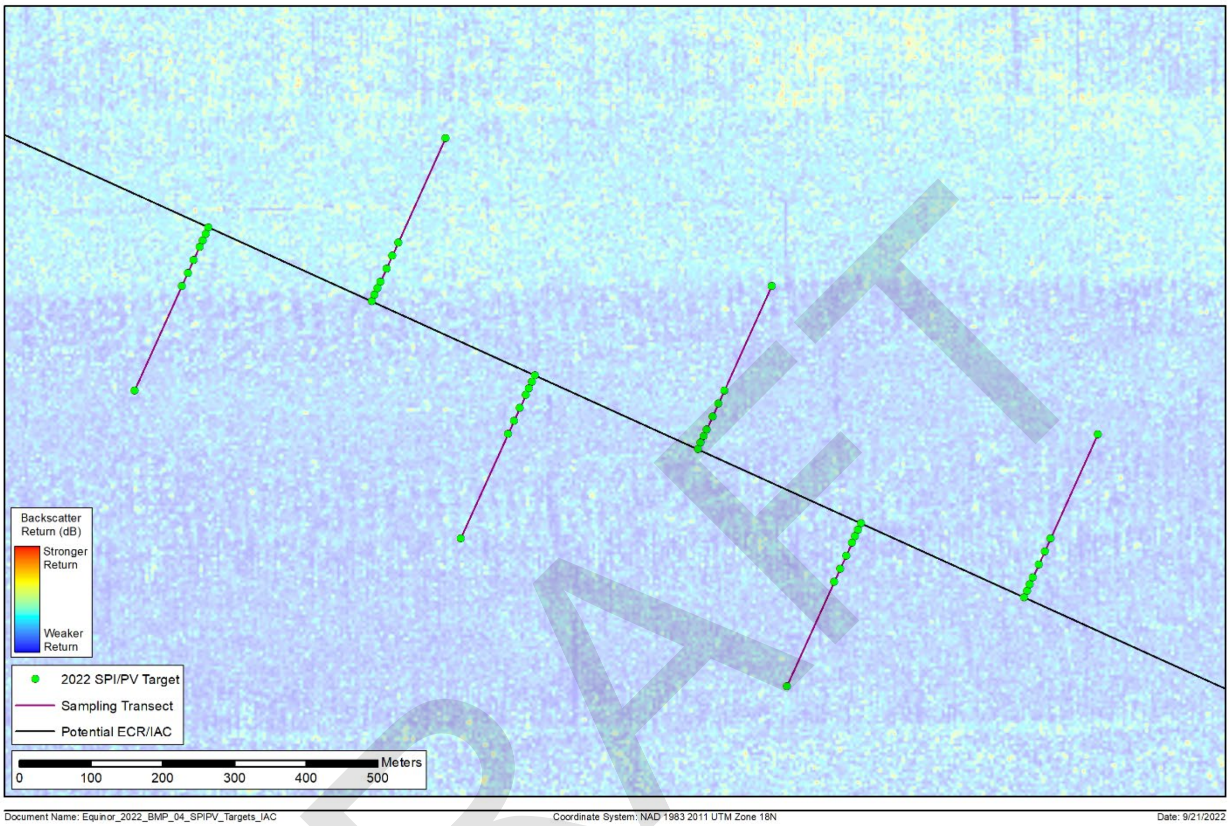

Figure 4-4. Conceptual diagram illustrating the Before-After Gradient design *of Cable-associated Physical Disturbance* survey design.

4.5.3 Statistical Analyses

The planned statistical analyses are summarized by survey type in Table 2.

For the *Cable-associated Physical Disturbance* dataset collected along the selected export cable segments (BAG design), data analysis will include exploratory multivariate approaches (e.g., nMDS) to identify patterns among responses (SPI/PV metrics, e.g., aRPD, successional stage, feeding voids, sediment grain size layering) and predictors (e.g., distance from the cable, water depth). Covariates in the model for the export cable dataset will include habitat type (categorical) and direction (categorical); variability among transects 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 export cable centerline. These graphical techniques may help to elucidate the spatial scale at which the greatest changes in benthic habitat condition occur.

5.0 DATA MANAGEMENT, REPORTING, AND DATA SHARING

The fisheries and benthic monitoring data will be managed by INSPIRE Environmental, with the exception of data described in Sections 3.3.3 and 3.3.4 which will be housed and maintained by Monmouth University. Data may be shared with state and federal agencies and other stakeholders upon request. Data will be prepared and disseminated annually and will undergo rigorous quality control and assurance audits prior to release.

Proper data management and traceability are integral to analysis and accurate interpretation and reporting. The surveys described in this monitoring plan will follow a rigorous system to inspect data throughout all stages of collection, processing, and analysis. This data management system will provide a high level of confidence in the accuracy of the data being reported. Data management will include methods for data collection, data storage and archiving, quality assurance/quality control (QA/QC) audits, distribution and dissemination protocols and best practices, and analyses. Metadata will be developed for each survey dataset which will include descriptions of data fields, data processing, QA/QC procedures, etc.

Annual reports will be prepared upon the conclusion of each year of sampling for each survey type. These reports will be shared with state and federal resource agencies. A final synthesis report will be prepared for each survey after the final year of sampling has concluded. This report will evaluate the survey findings during the pre- and post-construction survey time periods. The project team will disseminate annual results to agencies through an in-person meeting or webinar to solicit questions or feedback on the survey results, protocols, etc. The team will also host an in-person workshop to review results of monitoring efforts with members of the fishing industry.

In order to obtain data derived from this monitoring plan, stakeholders must submit a formal request to Empire Offshore Wind, LLC. A brief proposal will be required that states the purpose of the request, a description of the data requested (e.g., survey type, timeframe, species of interest), a list of collaborators and their affiliations, if applicable, and a description of the anticipated products of the work (e.g., manuscripts, fisheries stock assessments). Data access protocols will be developed to provide conditions for requesting monitoring data. Any data requested will be disseminated provided the criteria outlined in the data access protocols are met. Data will be sent to the requesting party electronically in most cases and any exceptions will be dealt with on a case-by-case basis with the party or parties seeking access. Empire Offshore Wind LLC will amend the above data sharing protocols as needed in accordance with current data sharing efforts and guidance being developed through ROSA.

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EMPIRE WIND FISHERIES AND BENTHIC MONITORING PLAN

ATTACHMENTS

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September 2022

Attachment A - Power Analysis for Trawl Survey of Longfin Squid

1.0 Introduction

For the trawl survey, a symmetric BACI design is planned for the Empire Wind (EW) project area, with one impact and one control or reference area. The EW trawl survey will use NOAA-derived survey gear and NEAMAP sampling protocols and will focus primarily on longfin squid, though it is expected to also capture other benthic and pelagic fish and invertebrate species. This power analysis addresses only longfin squid catch.

This Attachment covers two topics:

1. A review of existing trawl survey datasets in the vicinity of EW 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 inter-annual and intra-annual 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 between an impact area and control area. 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. Statistical analysis of this OSW monitoring data from the BACI design will focus on the BACI interaction contrast between period and location, and is specified as a contrast between the temporal change at the Impact site to the temporal change at the Control site, with responses averaged across seasons and years within each period. The effect size herein is expressed as a proportional change between periods of the mean catch per tow at the Impact site relative to the mean catch per tow at the Control site. For example, an effect size of –0.33 (-33%) could represent a 33% decrease in catch at the impact site and no change at the control site (0.67/1 -1); or a 50% decrease at the impact site and a 25% decrease at the control site (0.5/0.75-1); or a 20% decrease at the impact site and 20% increase at the control (0.8/1.2-1); other similar combinations that yield a 67% ratio of relative change. In the context of statistical power analysis, a threshold effect size (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 is simply 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 effect sizes for reference areas are used to establish what constitutes a meaningful threshold effect size (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 significantly different from zero when an effect of size Δ_M is operating on the data.

- **Alpha (α)** is the Type I error, or the probability of rejecting the null hypothesis in error because the true difference is small (i.e., < Δ_M). The value α is typically fixed, at 0.05 or 0.10 (95% or 90% confidence). For power estimated through simulations, α is estimated as the percent of significant outcomes when the effect size imposed on the data was 0. For this study, a target α = 0.10 was used for the two-tailed null hypothesis which allows us to say whether results are significantly greater than or less than zero (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 1 control site; 2 years of monitoring before and after construction, with sampling only in the fall of each 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 effect size, or a smaller detectable effect size 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 NEFSC (Politis et al. 2014) trawl dataset was used to establish 1) a proximate range of meaningful effect sizes that could be considered for measuring change over time, and 2) the expected distributional form for the longfin squid catch as biomass and reasonable variance estimates. The NEFSC dataset was screened to only include:

- tows from Stratum 1010, which includes the location for the EW project (Figure A1).
- Longfin squid catch.

This NEFSC survey design included seven to eight (random) 20-minute replicate tows in survey stratum 1010 in Fall (mid-September to early October) in the years 2010 to 2019, with replicate tows for each season generally occurring over two to four separate days which spanned a period of less than a week to 24 days, depending on the year. 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 8,750 km^2 stratum, and estimates of natural levels of inter-annual changes in catch. The survey planned for EW will be within a smaller area (322 km2) and limited to Fall with optimal timing informed by historical commercial landing information, examination of regional fisheries independent survey data, and stakeholder input. For comparison to the NEFSC trawl survey, monthly data from the Block Island Wind Farm (BIWF) otter trawl survey were also reviewed (Section 3.2) to determine the extent to which the seasonal NEFSC trawl survey captured intra-annual biomass peaks for longfin squid. 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 intra-annual 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 EW trawl survey. We expect the NEFSC estimates of spatial variance to be conservatively high relative to the variance expected from the EW monitoring, because the EW survey will occur over a smaller spatial area, so less spatial heterogeneity may be expected amongst replicate tows. The EW trawl survey will maintain the same spatial sampling densities within the impact and the reference area (i.e., the two areas will be the same size, and predominantly within the boundaries of Stratum 1010).

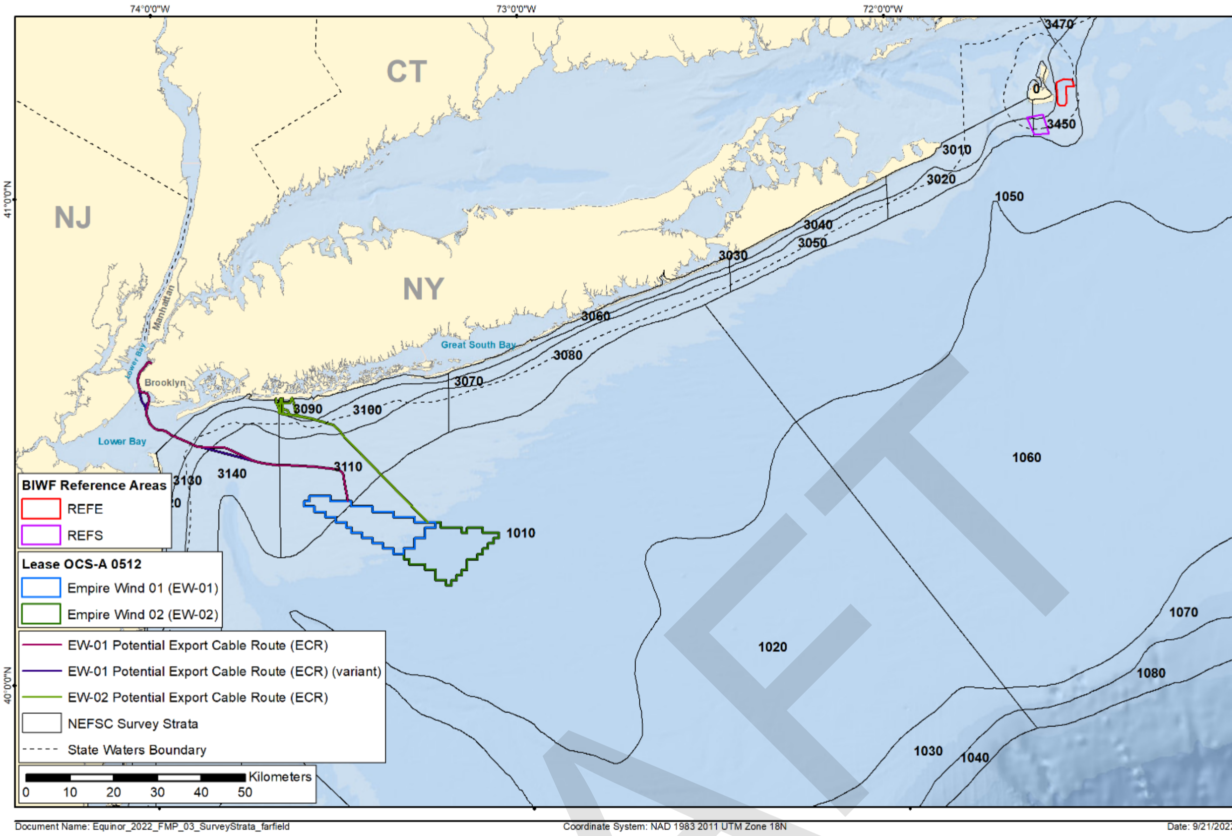

Figure A1. Map of NEFSC strata and the Empire Wind project area. Trawl survey data sampled in stratum 1010 from 2010-2019 were used in the analysis. The reference sites used in the BIWF Trawl survey (REFE and REFS) are also indicated for reference.

Table A1. Seasonal Summary by Year of Longfin Squid Catch (biomass, kg) in the NEFSC Trawl Survey (Politis et al., 2014) sampled in Stratum 1010

	Fall Survey			Spring Survey			
Year	**# of Tows**	**Mean Catch (kg/tow)**	**StDev of Catch (kg/tow)**	**# of Tows**	**Mean Catch (kg/tow)**	**StDev of Catch (kg/tow)**	**% of Annual Catch caught in Fall**
2010	8	18.6	19.0	8	0	0	100%
2011	7	4.6	4.0	7	0	0	100%
2012	7	16.6	22.9	7	3.2	2.5	84%
2013	7	3.5	2.3	7	0.02	0.03	100%
2014	7	33.7	11.2	6	0.03	0.05	100%
2015	7	17.1	10.8	7	0.01	0.04	100%
2016	7	9.9	8.0	7	1.2	1.3	89%
2017	0[1]	na	na	7	0.12	0.17	na
2018	7	7.7	9.0	5	0	0	100%
2019	7	10.9	9.3	7	0.43	0.81	96%

[1] There was no fall survey in 2017.

Fall was the dominant season for Longfin squid, both in the NEFSC survey (Table A1, Figure A2), and at BIWF (Figure A3).

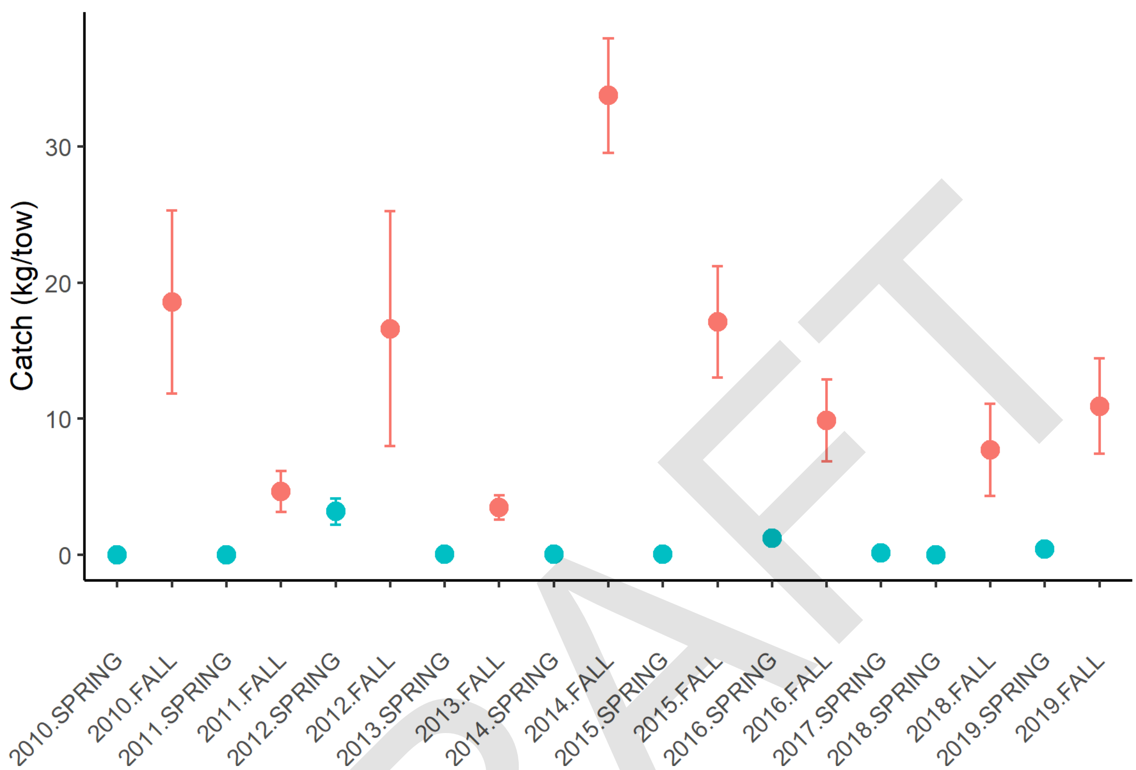

Figure A2. Mean and standard error of the seasonal longfin squid catch per tow (kg) sampled in stratum 1010 during the NEFSC seasonal trawl survey from 2010 through 2019. Blue represents spring surveys, and orange represents fall surveys.

3.2 Block Island Wind Farm Trawl Survey Data

Intra-annual variation in catch rates (kg/tow) were examined for longfin squid 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 survey data summaries, which are limited to a short window during fall, may miss intra-annual biomass peaks. The monthly mean longfin squid catch from seven years at the two reference areas are plotted in Figure A3 . September-October appeared to be the peak for REFE, while at REFS the much more muted peak occurred during November-December.

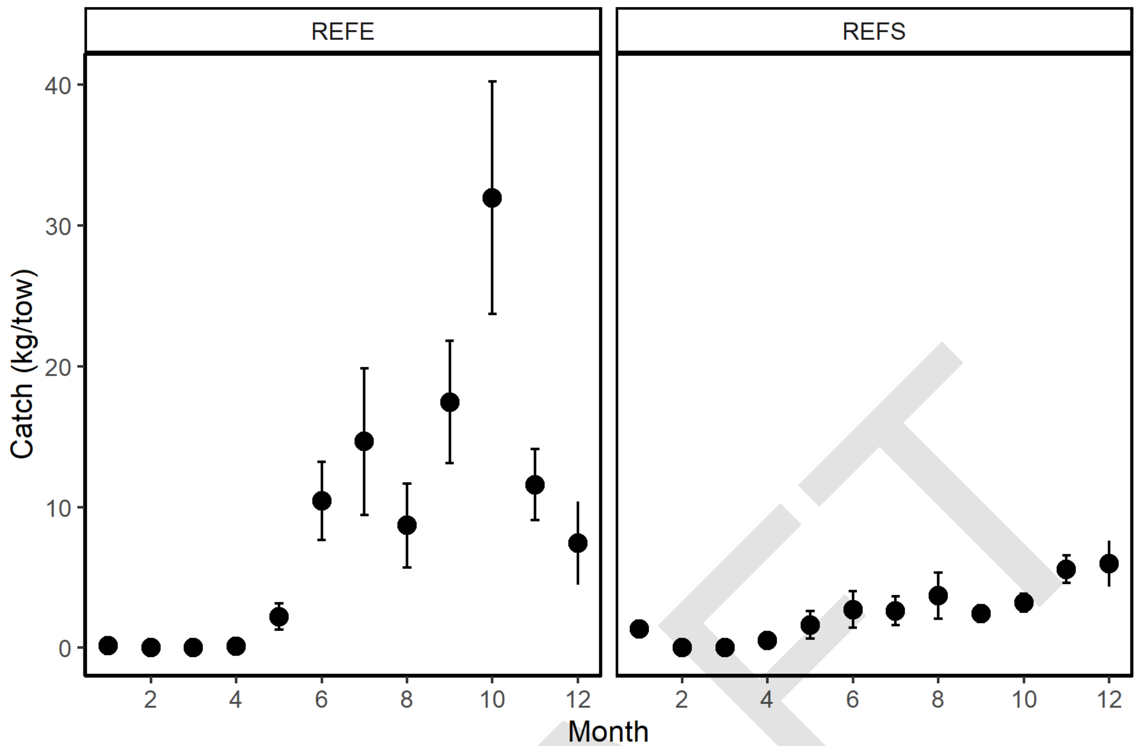

Figure A3. Monthly mean biomass (kg) averaged over seven years (from October 2012 to September 2019) for longfin squid from the eastern reference area (REFE) and southern reference area (REFS) from the BIWF trawl survey monitoring.

3.3 Effect Sizes

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

$$\%ES = \left(\bar{X}_{2,3} - \bar{X}_{0,1}\right)/\bar{X}_{0,1} \times 100 \qquad \text{[Eq. 1]}$$

where

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

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

For [Eq. 1] in the NEFSC dataset i= 2010 through 2015, and due to no fall sample results in 2017, 2014/2015 were compared to 2016/2018). This yields six contrasts of two adjacent two-year averages for fall. For the seven-year BIWF reference area datasets, the surveys run from October 2012 through September 2019. So i= (Oct) 2012 through (Sept-Oct) 2015, and the annual means were calculated from data from September and/or October within each calendar year (the months were subsampled from the continuous time series). This yields five contrasts of two adjacent two-year running averages of September-October means (with only October used in year 1 and only September used in year 7).

The ranges of relative percent change from these extant datasets provide context for generating realistic effect sizes to be used in the power calculations. Results are summarized for longfin squid in the two datasets in Table A2 and Figure A4. The effect sizes [Eq. 1] have a natural lower bound of -100%, and an unlimited upper bound.

Table A2. Summary of relative effect sizes (Eq. 1) observed for longfin squid from NEFSC dataset and BIWF Reference area dataset.

	Longfin Squid				
Data Source	**Minimum**	**1st Quartile**	**Median**	**3rd Quartile**	**Maximum**
NEFSC (n=6 contrasts)	-65%	-30%	-21%	53%	153%
BIWF REFE (n=5 contrasts)	-65%	-40%	-20%	27%	29%
BIWF REFE (n=5 contrasts)	-50%	-48%	-6%	34%	39%

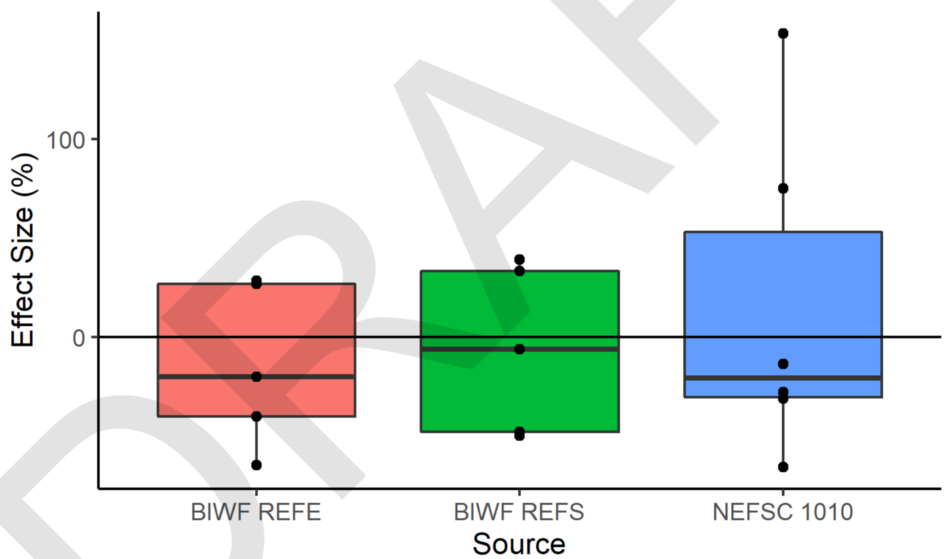

Figure A4. Boxplots showing the distribution of relative effect sizes (Eq. 1) for longfin squid for NEFSC dataset (2010 – 2018) and BIWF reference area datsets (October 2012 – September 2019).

The results shown in Figure 2 and Figure A4 demonstrate that substantial inter-annual sampling variability has occurred for longfin squid over the past 10-12 years, the sampling variability on a multi-year time scale may be larger when survey data are analyzed on a localized spatial scale due to spatial-temporal interactions. The data suggest that it may be meaningful to attempt to detect effect sizes on the order of ±40-50% or larger for longfin squid.

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 Stratum 1010 biomass data for fall catches of Longfin squid 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 A3. For conservative sample size estimates in the power analyses (Section 4.0), the CV values used captured approximately the median to maximum CV values across years (0.8 to 1.4).

Table A3. Summary of seasonal relative variance estimates for catch (biomass, kg) of longfin squid caught in the NEFSC fall trawl survey (Politis et al. 2014) in Stratum 1010 from 2010 to 2019

		Coefficients of Variation (CVs) among Fall Trawls Summarized across Years				
Source	**# of Years with Fall Catch**	**Minimum**	**1st Quartile**	**Median**	**3rd Quartile**	**Maximum**
NEFSC Stratum 1010	9	0.33	0.67	0.85	1.02	1.38

4.0 Power Analysis

4.1 The Study Design and Model

A symmetrical BACI design was tested in this power analysis, with the design variables as specified in Table A4. For a limited scenario (i.e., a single CV), power was simulated for a BACI design with one impact and one control area.

Table A4. Design for Empire Wind trawl survey power simulation study

Set study design variables
• Impact Areas = 1 impact area
• Control Areas = 1 control/reference area
• Habitat Strata = 1
• Frequency = one season per year
• Number of years Before impact = 2 • Number of years After impact = 2
Variables used in the power analysis
• Number of replicate (random) trawls per season in each area (n): 5 to 15
• Effect Sizes (ES): -33%, -40%, -50%, -70% (Section 3.3) and 0% (for Type I error)
• CVs: 0.6, 0.8, 1.0, 1.2, 1.4 (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

$$(\bar{X}_{Impact,Before} - \bar{X}_{Impact,After}) - (\bar{X}_{Control,Before} - \bar{X}_{Control,After}) \quad \text{[Eq. 2]}$$

where

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

$\bar{X}_{Control,Period}$ = The two-year log-scale mean biomass per tow (kg) from the Control area, for Fall season 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 seasonal CV estimates and effect sizes, and a range of sample sizes (Table A4). The effect size, ES, was imposed on each year 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 effect size and do not depend on the mean value. Calculations were scripted in R version 4.0.5 (R Core Team 2021), utilizing packages *dplyr* (Wickham et al. 2019), *lme4* (Bates et al, 2015), *emmeans* (Lenth 2021), and *EnvStats* (Millard 2013); figures were generated using *ggplot2* (Wickham 2016). The R code is included as an addendum to this Attachment.

For a given CV, ES, 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 each year of the Before period, for both Impact and Control areas.
2. Repeat step 1 for each year of the After period for the control area.
3. Repeat step 1 for each year of the After period for the Impact area, but with a reduced mean equal to (1+ES)μ.
4. Fit a GLM to the simulated biomass data, where the dependent variable was the catch per trawl, coefficients were estimated for 8 groups (i.e., a saturated model, one estimate for each area-year), and a Gamma error distribution with a log-link was used. Based on residual diagnostics and model fit for a small set of simulated data sets, the Gamma error distribution was found to provide the best fit.
5. Calculate the BACI interaction contrast based on multi-year means, and save the p-value.
6. Repeat Steps 1-5 for 1000 simulation replicates.

7. Count the number of simulations for which the detection outcome from step 5 had a p-value < nominal alpha. The reported power results use a nominal alpha that achieves approximately a 10% rejection rate for no effect (ES=0).

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

4.3 Results

Estimates of type I error (false positives) were calculated as the proportion of the simulated "no effect" datasets in which the BACI interaction contrast was rejected at $\alpha = 0.10$. For a nominal $\alpha = 0.10$, the empirical type I error rate had a tendency to be inflated (between 10% and 20% and 15% on average). When the empirical type I error was greater than 10%, this means that the test procedure was overly sensitive, i.e., rejecting more cases than it should. There was an inverse relationship between magnitude of CV and empirical type I error, with higher type I error rates occurring when relative variance of simulated data was lower. This may reflect a poorly specified model (e.g., inappropriate error distribution) for the simulated data sets with higher variance. For this approximation of power, the nominal alpha was adjusted to achieve an empirical type I error rate of approximately 10%, and this alpha level was applied to all test results to estimate both the type I error and the empirical power (Table A5, Figure A5).

Table A5. Simulated power for the BACI interaction contrast within a saturated GLM (see text) for a range of variance (CV), effect sizes (% change), and sample sizes (n) per area per year, using a design with one impact and one control area. Empirical power results are based on nominal two-tailed α levels which achieved an empirical type I error of approximately 10%. Results with power 80% and above are shaded.

% Change	Sample Size (n)	CV=0.6	CV=0.8	CV=1.0	CV=1.2	CV=1.4
Nominal alpha:		*0.08*	*0.07*	*0.06*	*0.05*	*0.04*
0	5	10%	11%	11%	10%	12%
0	7	11%	10%	11%	10%	11%
0	9	9%	12%	9%	11%	10%
0	11	10%	9%	10%	9%	8%
0	13	11%	10%	10%	7%	9%
0	15	9%	8%	7%	9%	8%
-33%	5	31%	23%	21%	20%	14%
-33%	7	36%	28%	22%	19%	17%
-33%	9	41%	30%	22%	20%	16%
-33%	11	46%	34%	23%	19%	18%
-33%	13	51%	36%	26%	23%	18%
-33%	15	56%	39%	29%	23%	20%
-40%	5	42%	31%	27%	21%	21%
-40%	7	48%	38%	29%	23%	20%
-40%	9	56%	42%	31%	24%	23%
-40%	11	65%	45%	33%	28%	22%
-40%	13	71%	50%	38%	29%	22%
-40%	15	75%	53%	40%	32%	24%
-50%	5	58%	46%	36%	28%	28%
-50%	7	73%	54%	39%	34%	29%
-50%	9	81%	58%	44%	37%	33%
-50%	11	83%	67%	51%	39%	34%
-50%	13	90%	71%	54%	45%	34%
-50%	15	94%	76%	58%	49%	38%
-70%	5	94%	81%	70%	59%	52%
-70%	7	98%	90%	78%	64%	59%
-70%	9	100%	95%	85%	75%	62%
-70%	11	100%	96%	89%	79%	68%
-70%	13	100%	99%	94%	83%	74%
-70%	15	100%	99%	95%	89%	79%

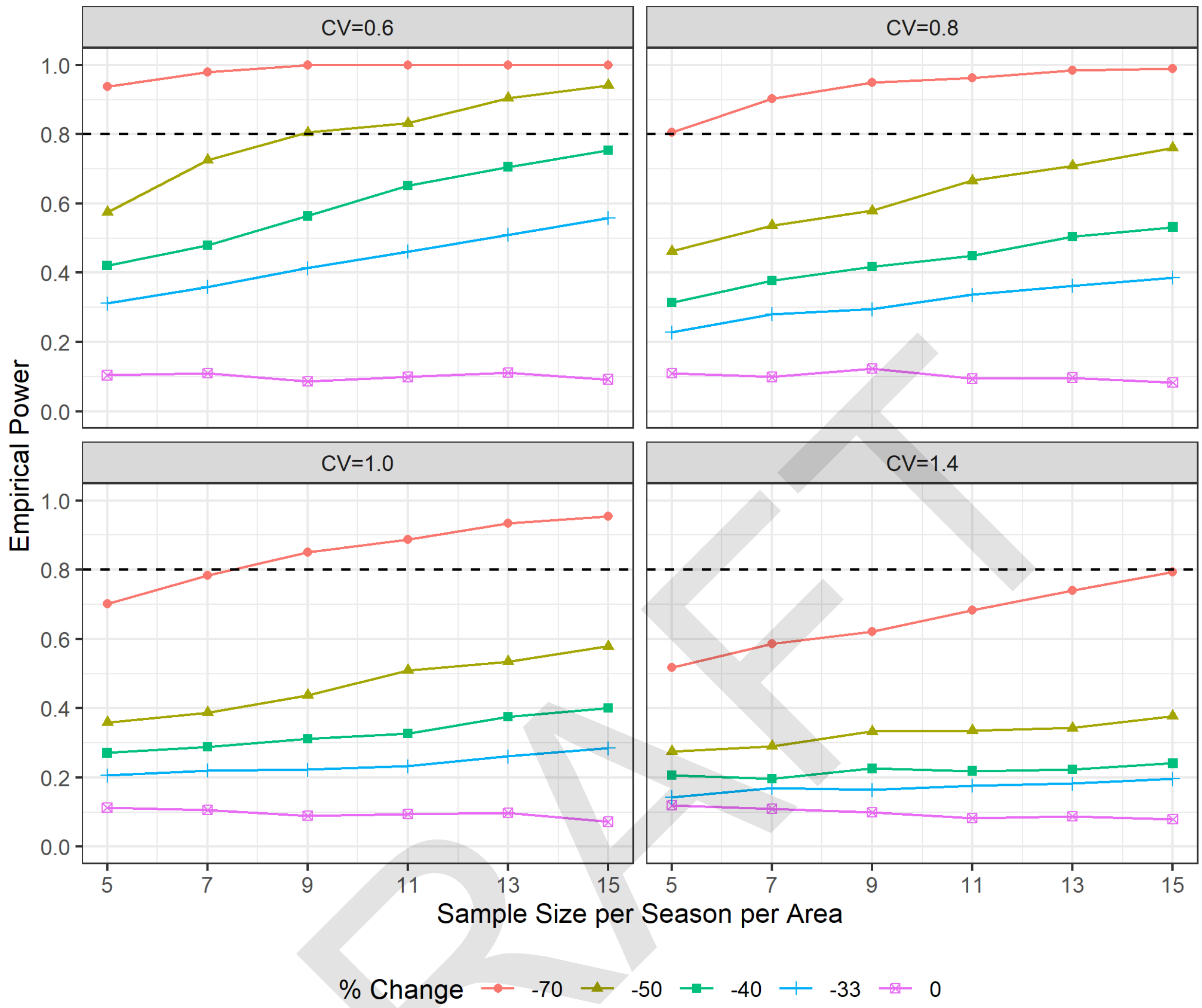

Figure A5. Power curves for the BACI interaction contrast within a saturated GLM (see text) for a range of variance (CV), effect sizes (% Change) and seasonal sample sizes in each area (n), using a nominal α that achieves a type I error rate of 0.10 where the results for 0% change illustrate the type I error.

5.0 Summary and Conclusions

- Data from regional trawl surveys indicate that longfin squid in the region have generally exhibited moderate to high levels of natural variability.
- Given the underlying variability (inter-annual and intra-annual) in catch rates that will likely be exhibited in the EW trawl survey, it does not appear to be practical to attempt to document effect sizes less than 50% for longfin squid.
- For moderate CV estimates for longfin squid (e.g., 0.6 – 0.8), a seasonal sampling intensity of more than 15 tows/area would yield > 80% power to detect an effect size of approximately 50% or greater.
- This power analysis will be re-visited after the first year of the EW 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.

6.0 References

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Addendum – R Script for the Statistical Power Simulation.

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

################# SIMULATE BACI DESIGN AND TEST OF COMPLEX INTERACTION (planned contrast)
# Areas:
#          Two areas: 1 impact and 1 ref
# Population means and applying percent change:
#     pop1 = baseline distribution is lognormal(mean, CV); one season
#          - 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 = distribution altered by the percent change (PC)
#          - mean.pop2 = (1-PC)*mean.pop1
#          - applies to impact area in each of the AFTER years
# Seasonality
#          - only 1 season is sampled
# Balanced design, i.e., n samples from each season, year, and area
# MODEL fit as glm(response ~ grp.pd.seas.yr, family=Gamma(link=log))
#          This is a fully saturated model; most conservative because it uses up most degrees of freedom
# 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.
#          - 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.
########################

## set up scenarios:
 PC.vec <- c(.7, .5, .4, .33, 0)        #these are % decreases
 cv.vec <- c(0.6, 0.8, 1, 1.2, 1.4)
n.vec <- seq(5,15,2)
n.sims <- 1000
foo.num <- as.numeric(rep(NA,n.sims*length(PC.vec)*length(cv.vec)*length(n.vec)*1))
baciContr.pwrsim <- data.frame(expand.grid(PC=PC.vec,
samp.size=n.vec, cv=cv.vec, mean=20, sim=1:n.sims),
baci1ref.p1=foo.num, baci1ref.p2=foo.num, baci2ref.p1=foo.num,
baci2ref.p2=foo.num, pit1ref.p1=foo.num, pit1ref.p2=foo.num, pit2ref.p1=foo.num,
pit2ref.p2=foo.num) %>% as_tibble()
#note p1 results are for glm(Gamma(log link)), p2 for lm(log(catch))
 baciContr.pwrsim <- arrange(baciContr.pwrsim, PC, samp.size, cv, mean, sim)
```

```
#set total number of seasons sampled before, each area (seasons/year * #years)
 b <- 1*2
#set total number of seasons sampled after, each area
 a <- 1*2
#set number of controls:            #calculate results for both 1 and 2 controls.
 n.c <- 2
my.mean <- 20             #does not affect outcome.
## loop it:
for (m in 1:length(cv.vec)) {                    #alternative cv values
 this.cv <- cv.vec[m]
 for (k in 1:length(PC.vec)) {                   #effect sizes
  this.PC <- PC.vec[k]
  for (j in 1:length(n.vec)) {                   #sample sizes
   this.n <- n.vec[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("fall"),
rep=1:this.n), value=as.numeric(rep(NA,this.n*(b+a)*(n.c+1))))
   foo.data.df <- arrange(foo.data.df, location, period, year, season, rep)
   foo.data.df$grp.pd.seas.yr <- factor(with(foo.data.df,
           paste(substring(location,1,5),period,season,year)))
 ### SIMULATE DATA
  for (i in 1:n.sims){
    foo.data.df$value[foo.data.df$period=="Before"]  <-
rlnormAlt((n.c+1)*(b)*this.n, mean=my.mean, cv=this.cv)
    foo.data.df$value[foo.data.df$period=="After" & (foo.data.df$location=="CtrlA" |
           foo.data.df$location =="CtrlB")] <-
rlnormAlt(n.c*(a)*this.n, mean=my.mean, cv=this.cv)
    foo.data.df$value[foo.data.df$period=="After" & foo.data.df$location=="Impact" ] <-
rlnormAlt((a)*this.n, mean=my.mean*(1-this.PC), cv=this.cv)

### fit saturated glm
  #comparisons with 1 ref:
   foo1.glm <- glm(value ~ 0 + grp.pd.seas.yr, data=subset(foo.data.df, location!="CtrlB"),
family=Gamma(link="log"))
   foo1.t2 <- emmeans(foo1.glm, ~ grp.pd.seas.yr)
   #double check that contrast coefficients give the desired contrast!
   foo1.contr2 <- contrast(foo1.t2, list(baci.contrast=0.5*c(rep(c(rep(1,a), rep(-1,b)), 1), rep(-1,a),
           rep(1,b))))
  #comparisons with 2 ref:
   foo2.glm <- glm(value ~ 0 + grp.pd.seas.yr, data=foo.data.df, family=Gamma(link="log"))
   foo2.t2 <- emmeans(foo2.glm, ~ grp.pd.seas.yr)
   foo2.contr2 <- contrast(foo2.t2, list(baci.contrast=0.5*c(rep(c(rep(1/n.c,a), rep(-1/n.c,b)), n.c), rep(-
           1,a), rep(1,b))))
###grab p-value for interaction contrast and add to baciContr.pwrsim:
  baciContr.pwrsim$baci1ref.p2[baciContr.pwrsim$mean == my.mean & baciContr.pwrsim$cv == this.cv
           & baciContr.pwrsim$PC == this.PC & baciContr.pwrsim$samp.size == this.n &
           baciContr.pwrsim$sim==i] <- as.data.frame(foo1.contr2)$p.value
```

```
  baciContr.pwrsim$baci2ref.p2[baciContr.pwrsim$mean == my.mean & baciContr.pwrsim$cv == this.cv
        & baciContr.pwrsim$PC == this.PC & baciContr.pwrsim$samp.size == this.n &
        baciContr.pwrsim$sim==i] <- as.data.frame(foo2.contr2)$p.value
}}}}

finalBaci.pwrsim <- baciContr.pwrsim

#summarize simulated power (here alpha = 0.10)
baciContr.pwrsim.10.summ <- finalBaci.pwrsim %>% group_by(mean, cv, PC, samp.size) %>%
  summarize(count=n(), Power.1ref.glm = sum(baci1ref.p2 <= 0.1)/count,
   Power.2ref.glm = sum(baci2ref.p2 <= 0.1)/count)
 #separate factor variable for the facet labels (mean.cv):
 baciContr.pwrsim.10.summ$cv.factor <- factor(baciContr.pwrsim.10.summ$cv,
levels=c(0.6, 0.8, 1.0, 1.2, 1.4),
labels=c("CV=0.6", "CV=0.8", "CV=1.0", "CV=1.2", "CV=1.4"))

##### ADJUST NOMINAL ALPHA TO ACHIEVE EMPIRICAL ALPHA OF 10%
# observed alpha different from nominal alpha for the glms.
# recalibrate results to get observed closer to 0.1
 foo.nomalpha <- finalBaci.pwrsim %>% filter(PC==0) %>% group_by(mean, cv) %>%
summarize(nominal.alpha1ref.glm = quantile(baci1ref.p2, 0.1),
 nominal.alpha2ref.glm = quantile(baci2ref.p2, 0.1))
 foo.nomalpha
 #   mean    cv nominal.alpha1ref.glm nominal.alpha2ref.glm
 #1    20   0.6              0.0796              0.0816
 #2    20   0.8              0.0691              0.0672
 #3    20   1.0              0.0641              0.0597
 #4    20   1.2              0.0547              0.0581
 #5    20   1.4              0.0419              0.0447
 #note this summarizes across all samp.size values.
 # there is an inverse relationship between relative variance and empirical alpha.
 finalBaci.pwrsim <- left_join(finalBaci.pwrsim, foo.nomalpha)
# Apply adjusted nominal alpha to all glm results:
 baciContr.pwrsim.AlphaMOD.summ <- finalBaci.pwrsim %>%
  group_by(mean, cv, PC, samp.size) %>%
  summarize(count=n(), Power.1ref.glm = sum(baci1ref.p2 <= round(nominal.alpha1ref.glm,2))/count,
   Power.2ref.glm = sum(baci2ref.p2 <= round(nominal.alpha2ref.glm,2))/count)
 #separate factor variable for the facet labels:
 baciContr.pwrsim.AlphaMOD.summ$cv.factor <- factor(baciContr.pwrsim.AlphaMOD.summ$cv,
levels=c(0.6, 0.8, 1.0, 1.2, 1.4),
labels=c("CV=0.6", "CV=0.8", "CV=1.0", "CV=1.2", "CV=1.4"))

##plot power curves with modified nominal alpha
# skip 25% ES and CV=1.2
ggplot(subset(baciContr.pwrsim.AlphaMOD.summ,PC != 0.25 & cv.factor != "CV=1.2"),
   aes(x=samp.size, y=Power.1ref.glm, 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") +
  scale_y_continuous(limits=c(0,1), breaks=seq(0,1,.2))+
  scale_x_continuous(limits=c(5,15), breaks=seq(5,15,2))+
  labs(colour="% Change", shape="% Change", x="Sample Size per Season per Area", y="Empirical
        Power")
ggsave("GLM power curves, MODified alpha , saturated baci.png", width=7, height=6, units="in")
#####################################################

##output for appendix table
foo <- baciContr.pwrsim.AlphaMOD.summ %>% filter(PC != 0.25) %>%
 pivot_wider(id_cols=(PC:samp.size), names_from="cv", values_from="Power.1ref.glm")
write.csv(foo, "foo.csv")
```

Attachment B - Sediment Profile and Plan View Imagery to Assess Shifts in Benthic Ecological Functions

Sediment Profile and Plan View Imagery to Assess Shifts in Benthic Ecological Functions

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 (1) the provision of biogenic structures as habitat, (2) the facilitation of organic matter processing (carbon and nutrient cycling), and (3) the provision of food to upper trophic levels (secondary production). These ecosystem functions are detectable using data obtained from SPI/PV imagery as described in more detail below.

Biogenic Habitats

SPI/PV is an effective means to assess the presence and relative distribution of biogenic structure-forming fauna in soft sediment environments. Common emergent fauna in this environment includes cerianthids (burrowing anemone). Other biogenic structure-forming organisms in this environmental context include mussels, tube-building amphipods and polychaetes including sabellid worms, that can serve to bind sediments and create reefs. Biogenic structure-forming organisms are often difficult to capture using traditional sediment grab sampling as they are able to effectively evade collection. Also, sediment grab collection is destructive sampling, which should be avoided in areas with sensitive benthic organisms. High-resolution SPI and PV imaging can non-invasively identify and quantify these emergent and structure-forming fauna. The presence and densities of these emergent and structure-forming fauna can be obtained using the SPI/PV approach, and any changes in spatial distributions in response to offshore wind development can be detected through this proposed monitoring survey design.

Benthic Organic Matter Processing

SPI/PV is an effective means to assess the degree of, and changes to, organic matter processing and cycling in soft sediments. Benthic communities in soft sediments serve an important role in facilitating organic matter processing and cycling. The ability of soft sediment communities to process organic matter delivered from the water column is highly dependent on the benthic community activity, specifically bioturbation, bioirrigation, and sediment mixing by shallow and deep-burrowing organisms. These infaunal activities deliver oxygenated water to the sediment column, facilitating aerobic respiration of organic matter. The degree of organic matter processing can be assessed by measuring the depth of oxygen penetration into the sediment column, which can be done through SPI analysis (apparent redox discontinuity [aRPD] depth). Other indicators of benthic organic matter processing include infaunal succession stage, feeding voids, methane, and presence of *Beggiatoa*. 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. Because the epifaunal growth on the novel wind turbine structures is likely to increase the delivery of organic matter to the sediments below, organic matter processing and sediment respiration is likely to increase in these adjacent soft sediments, causing a decrease in the depth of oxygen penetration into the sediment column (aRPD depth). SPI is an effective approach in assessing this change in organic matter processing with distance from the turbine as SPI analysis can accurately assess and detect changes in aRPD depths and bioturbation depths.

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).

There has been considerable research conducted on the effects of bioturbation on sediment geotechnical and geochemical properties as well as on sediment diagenesis (Ekman et al. 1981; Nowell et al. 1981; Rhoads and Boyer 1982; Grant et al. 1982; Boudreau 1986, 1994, 1998; Sturdivant and Shimizu 2017). Additional research has focused on the rates of contaminant flux in sediments (Reible and Thibodeaux 1999; François et al. 2002; Gilbert et al. 2003) and the two parameters that primarily affect the rate of benthic fluxes: erosion and bioturbation (Reible and Thibodeaux 1999). The depth to which sediments are bioturbated, or the biological mixing depth, can be an important parameter for understanding and predicting nutrient or contaminant flux from the sediments to the water column (and vice versa). The biological mixing depth is also a useful indicator for the degree of organic enrichment in sediments. Burrow depth has been shown to be reduced under hypoxic conditions and burrowing fauna respond quickly (within an hour) to sediment accretion and erosion (Sturdivant et al. 2012; Sturdivant and Shimizu 2017). While the aRPD depth is one potential measure of biological mixing depth, it is quite common in sediment profile images to see evidence of biological activity (burrows, voids, or actual animals) well below the mean aRPD. Biogenic particle mixing depths can be estimated by measuring the maximum and minimum depths of imaged fauna, burrows, or feeding voids in the sediment column. In this study, the minimum and maximum linear distances from the sediment surface to feeding voids and the maximum linear distance to the deepest feature of biological activity will be measured. The latter parameter represents the maximum observed particle mixing depth of head-down feeders, mainly polychaetes.

Benthic Secondary Production and Food Provisioning

Soft sediment benthic communities can be important prey to upper trophic levels. Although SPI/PV imagery does not provide estimates of biomass or detailed taxonomic identification, these measurements do not necessarily relate to the value of any given benthic community as prey resource. Regional and interannual variability in biomass and species composition does not reflect changes in prey availability or value in the ecosystem. This natural variability is not likely to be ecologically meaningful. SPI/PV imagery can provide information on the level of succession of benthic community present after a physical (or chemical) disturbance. 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). 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). The successional stage has a strong predictive power for benthic functional response to physical disturbance (Germano et al. 2011) and will be the key metrics used during this set of soft bottom monitoring surveys.

Infaunal successional stage describes the biological status of a benthic community and is useful in quantifying the biological recovery after a disturbance (physical or organic enrichment-related). 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 by 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 frequency of physical disturbance is high, which is generally the case in naturally dynamic benthic habitats such as the sandy environment of the outer continental shelf, the benthic community successional stage will remain low at Stage 1 or 2 (Germano et al. 2011).

Physical Benthic Characteristics and Dynamics

Evidence of physical sediment characteristics and dynamics, important factors associated with benthic functioning, can be readily gleaned from paired SPI and PV imagery. Specifically, parameters such as sediment grain size, CMECS Substrate Group and Subgroup, gravel sizes and distributions, presence and characteristics of small-scale bedforms (e.g., ripples) are measurements that can be obtained from SPI/PV. This imagery provides concurrent information about the physical conditions of the benthic habitat that directly relate to the species inhabiting the area and the community ecological function.

Coupling SPI and PV paired imagery allows for the assessment of benthic functioning over a spatial scale of several square meters at each station. PV images provide a 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.

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