OCS-A 0501

MASS USA

VINEYARD WIND

Draft Construction and Operations Plan

Volume III Appendices

Vineyard Wind Project

September 29, 2020

Submitted by
Vineyard Wind LLC
700 Pleasant Street, Suite 510
New Bedford, Massachusetts 02740

Submitted to
Bureau of Ocean Energy Management
45600 Woodland Road
Sterling, Virginia 20166

Prepared by
Epsilon Associates, Inc.
3 Mill & Main Place, Suite 250
Maynard, Massachusetts 01754

Epsilon ASSOCIATES INC.

Draft Construction and Operations Plan

Volume III

Appendices

Vineyard Wind Project

Submitted to:

BUREAU OF OCEAN ENERGY MANAGEMENT
45600 Woodland Rd
Sterling, VA 20166

Submitted by:

VINEYARD WIND LLC
700 Pleasant Street, Suite 510
New Bedford, MA 02740

Prepared by:

EPSILON ASSOCIATES, INC.
3 Mill & Main Place, Suite 250
Maynard, MA 01754

In Association with:

Baird & Associates
Biodiversity Research Institute
C2Wind
Capitol Air Space Group
Clarendon Hill Consulting
Ecology and Environment
Foley Hoag
Geo SubSea LLC
Gray & Pape
JASCO Applied Sciences
Morgan, Lewis & Bockius LLP
Public Archaeology Laboratory, Inc.
RPS
Saratoga Associates
Swanson Environmental Associates
Wood Thilsted Partners Ltd
WSP

September 29, 2020

Appendix III-D

Benthic Habitat Monitoring Plan

Vineyard Wind Project
Benthic Habitat Monitoring Plan

Prepared for:

Vineyard Wind LLC

700 Pleasant Street, Suite 510

New Bedford, MA 02740

Prepared by:

Geo SubSea LLC

RPS

Epsilon Associates, Inc.

September 2020

TABLE OF CONTENTS

List of Figures

List of Figures (Continued)

List of Tables

BENTHIC HABITAT MONITORING PLAN

1.0 Introduction & Monitoring Background

Vineyard Wind LLC (Vineyard Wind) will implement a benthic monitoring plan to document the disturbance to and recovery of marine benthic habitat and communities as a result of construction and installation of different project components. These components include the Wind Turbine Generator (WTG) scour protection and inter-array cables within the Wind Development Area (WDA) and the export cable in the Offshore Export Cable Corridor (OECC) that stretches from the WDA to shore. A monitoring program focusing on seafloor habitat and benthic community will be undertaken to measure potential impacts and the recovery of these resources compared to reference areas outside of the areas potentially impacted by construction activities. This monitoring program was developed based on best practices available in the literature along with an analysis of preliminary benthic survey information to determine the sample size needed for sufficient statistical power.

Benthic habitat and community monitoring is an active area of research with a wide variety of methods and indices used to detect changes in the environment. Several comprehensive reviews of the topic were used to inform the design of this monitoring plan, including:

- A Bureau of Ocean and Energy Management (BOEM)-funded review of existing monitoring protocols for effects of offshore renewable energy (McCann, 2012);
- A BOEM-funded review of site assessment and characterization methods for offshore wind in both the US and Europe (Rein et al., 2013);
- A marine benthic habitat monitoring guidance report developed by the Joint Nature Conservation Committee of the UK (Noble-James et al., 2017); and
- A draft guidance document for survey and monitoring of renewable energy deployments on behalf of Scottish Natural Heritage and Marine Scotland (Saunders et al., 2011).

In addition to guidance documents, the design of studies and resulting detection of effects by existing monitoring programs were evaluated for best practices. Analyses of existing programs reviewed include those found in:

- Research papers describing the sampling design and effort needed to detect environmental change based on benthic monitoring case studies (Daan et al., 2009; Franco et al., 2015) and benthic quality indicators (Borja et al., 2000; Borja and Dauer, 2008; Van Hoey et al., 2007; Warwick et al., 2010);
- Summaries of environmental impacts of offshore wind farms in the Belgian part of the North Sea (Degraer et al., 2013; Degraer et al., 2017); and
- A BOEM-funded study of the benthic monitoring during construction and operation of the Block Island Wind Farm offshore of Rhode Island (HDR, 2017).

A lack of a "one-size-fits-all" approach is apparent in the literature, so appropriate monitoring protocols must be developed on a case-by-case basis (McCann, 2012). Despite the multitude of options for benthic habitat assessment and monitoring (Warwick et al., 2010), some generally-accepted guidelines exist. First, standardized protocols are important for comparison over time and between projects within an area, to obtain a fuller picture of cumulative impacts on the environment.

Many monitoring studies apply a Before-After-Control-Impact (BACI) design, or a Beyond BACI design that incorporates multiple control sites. In past benthic monitoring programs, there has not generally been much agreement on how many control sites should be used, or when or for how long data should be collected (McCann, 2012). It is generally agreed that control sites should be placed where similar environmental conditions (substrate type, hydrodynamics, other anthropogenic impacts) to those at the impact sites also occur (McMann, 2012). Sampling stations should encompass all unique habitats and other environmental gradients, such as depth and currents. A consensus in the literature is that at least three replicate samples should be taken at each sampling station to evaluate small-scale variability, increase the likelihood that sparsely-distributed taxa will be captured and accounted for, and obtain a more representative sample of the site (McMann, 2012; Noble-James et al., 2017).

There are dozens of different kinds of benthic community indices in use (Warwick et al., 2010), including the AMBI (AZTI's Marine Biotic Index), an index designed to represent the response of European soft-bottom benthic assemblages to changes in environmental quality (Borja et al., 2000), and the Benthic Ecosystem Quality Index (BEQI), which is used in Belgian wind farm impact monitoring and incorporates the AMBI and further classifies outcomes on a scale between 0 and 1 to allow for rapid assessments of changes in status (bad, poor, moderate, good, high) (Coates et al., 2013). In the BOEM benthic habitat monitoring guidelines (BOEM, 2013), they suggest benthic habitat data should be classified according to the Coastal and Marine Ecological Classification Standard (CMECS) to the lowest taxonomic unit possible. The CMECS standard is a hierarchical system of classifying ecological units in the marine environment (FGDC, 2012). Basic benthic community indices (species abundance, richness, diversity) are combined with knowledge of the abiotic environment within which they tend to occur (water column and substrate features) to identify biotopes that can be monitored. For this monitoring plan, the benthic habitats and communities surveyed will be classified under the CMECS standard, with unique biotopes defined where possible.

2.0 Statistical Analysis of Prior Data

Extensive sampling of the Vineyard Wind Project area began in 2016. Geological and biological characterization efforts employed a variety of sampling gears, including multibeam, side scan sonar, magnetometer, grab samples, vibracores, and underwater video imagery. The various sampling programs have been conducted across the entire proposed project area to establish fine-scale resolution of the geophysical properties, habitat composition, and benthic communities (additional details on sampling provided in Volume II of the Construction and Operations Plan [COP] and in the Supplemental Draft Environmental Impact Report submitted to the MEPA Office). With these data, the project area was categorized into six major habitat zones, which were defined by primary seabed characteristics including surficial sediment types/geology, seafloor features, and general benthic conditions (Figure 1a; also see Table 1 in Volume II-A). For this plan, the six zones were further delineated between those along the OECC (five zones) and those within the WDA (one zone).

The majority of the WDA is classified as Zone 1 habitat (flat sand). The largely homogeneous sand habitat supports high abundances but overall low diversity in benthic infaunal species. Bray-Curtis similarities of the transformed infaunal abundances indicated that the WDA could be classified into Type 1-A in the north and a smaller segment classified as Type 1-B in the south (Figure 1b below and Figure 14 in Report 4 within Appendix II-H of Volume II of the COP). However, the two types are similar enough to analyze together as one habitat within the WDA. The OECC passes through five identified habitat zones (see Table 1 and Figure 1). The first zone alone the OECC is the same habitat type as that found within the WDA. For more information on habitats and the classification thereof, refer to Section 5 and Appendix II-H of Volume II-A of the COP (CR Environmental, 2017; ESS Group, 2017; Normandeau, 2017). This monitoring plan includes a total of six habitat zones (one in the WDA and five along the OECC; Table 1).

Table 1 Summary of Habitat Zones within Each Project Region that will be Addressed by the Monitoring Plan

Project Region and Habitat Zone	Habitat Type
WDA – 1	Flat fine/silty sand habitat, deeper water offshore (30-50 m) within the WDA
OECC – 1	Flat sand-mud habitat, deeper water offshore (>20 m), along the OECC segment nearest the WDA
OECC – 2	Sand and gravel with patches of course materials with some small sand waves/ mega ripples, waters from 6-30 m, along the OECC between Martha's Vineyard and Nantucket
OECC – 3	Mainly featureless sandy bottom with some patches of dense shell hash and high ripples/sand waves, waters from 10-20 m along the OECC in Nantucket Sound
OECC – 4	Flat, featureless sand with some silty areas, shallow water depths from 1-10 m) along the OECC nearest shore
OECC – 5	High relief bottom topography with abundance of coarser material and hard bottom areas, high currents, water depths between 6-15 m, along the OECC in the middle of Muskeget Channel

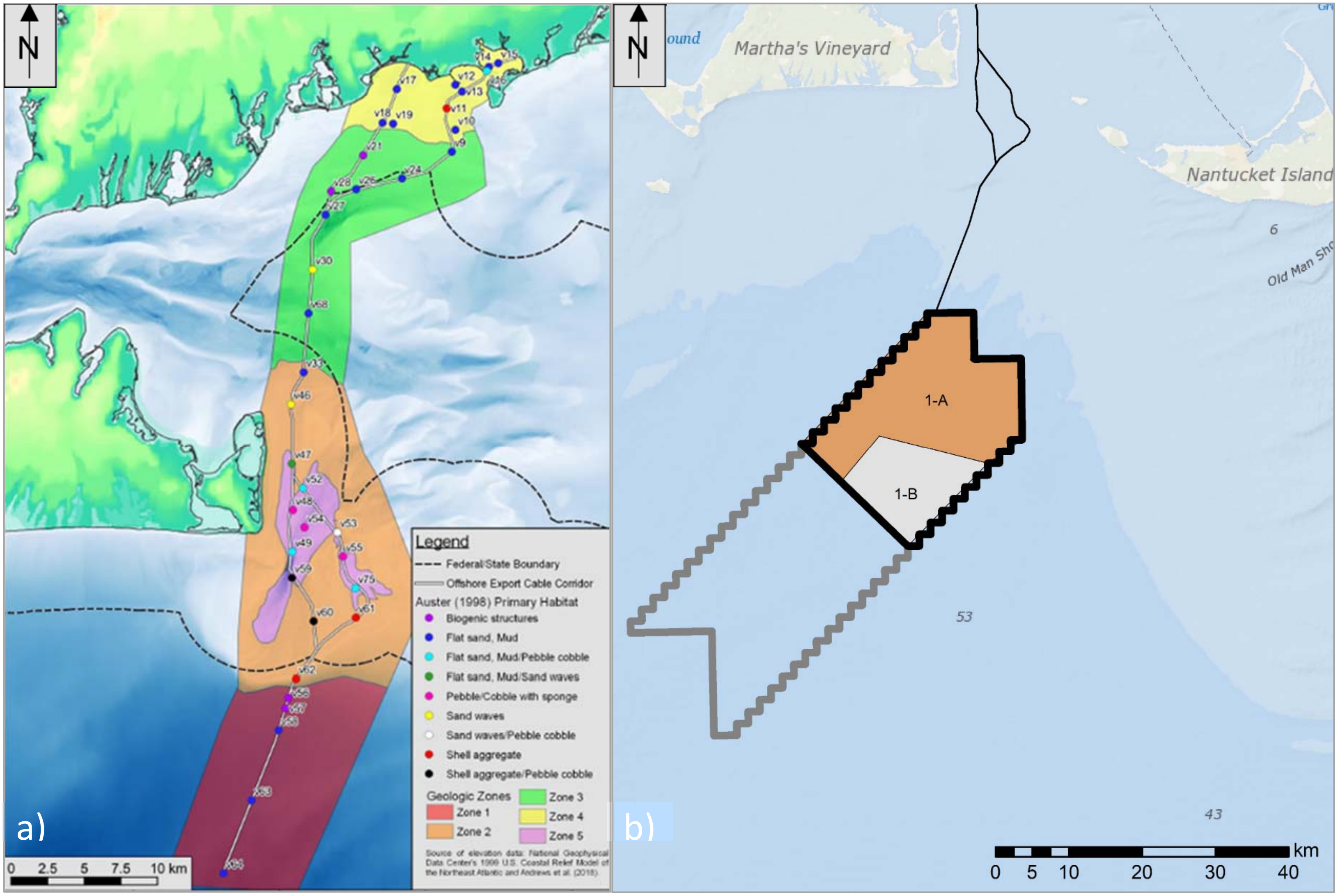

Figure 1. a) Primary habitats along the OECC based on Auster (1998) (adapted from Volume II-A of the COP). b) Rough areas of habitat subtypes within the WDA (Type 1-A and 1-B) based on Bray-Curtis similarities of the transformed infaunal abundances. For the monitoring plan, the entire WDA is being considered one habitat zone, as the majority of the WTGs will be placed within the 1-A area.

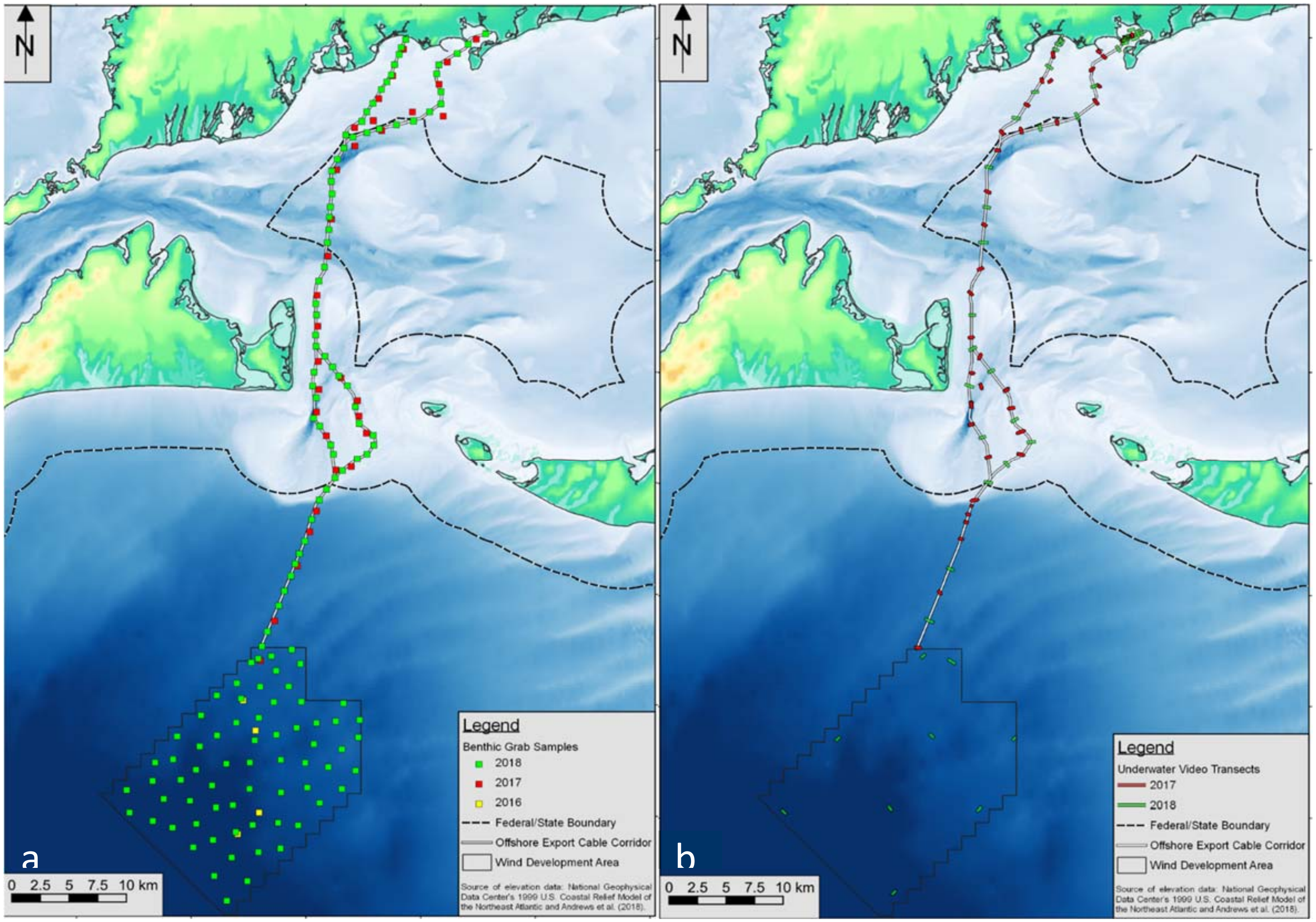

Figure 2. a) 2016 benthic grab samples collected in the WDA (yellow squares), 2017 benthic grab samples acquired in the OECC (red squares), and 2018 benthic grab samples acquired in the OECC and WDA. b) 2017 underwater video transects crossing the OECC (red rectangles) and 2018 underwater video transects collected in the OECC and WDA (green rectangles).

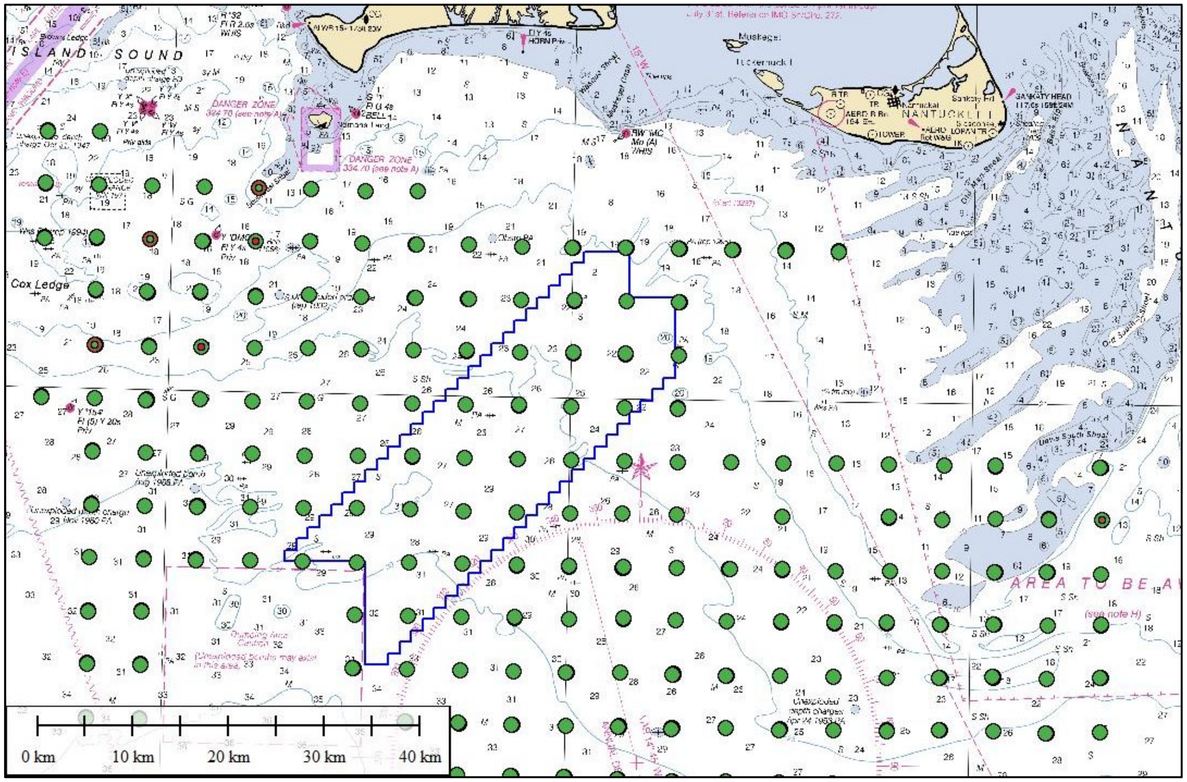

Figure 3. Underwater imagery locations surveyed by SMAST in 2013 and 2014 for research studies in the Massachusetts Wind Energy Area (green dots).

The proposed study design was based on habitat zonation informed by geological zones and the benthic grab sample and underwater video collected in the WDA and along the OECC in 2017 and 2018 (Figure 2). Underwater imagery was also captured by SMAST in the WDA in 2013 and 2014 (Figure 3). The assessment of the benthic grab data included the calculation and summarization of various infaunal indices such as species density, diversity, and richness, and cluster testing using the Bray-Curtis dissimilarity index. These were used to assess general trends in the communities across the Project area (see Report 4 within Appendix II-H of Volume II of the COP). Analysis of the infaunal data collected along the OECC from 2017 and 2018 indicated a similarity in the community composition at stations within some of the habitat zones defined above (Figure 5.1-5 in Volume II-A of the COP). To increase the accuracy of measurements and capture the variation in benthic communities across the different habitat zones, monitoring stations were stratified by habitat zone. Stratified sampling can increase precision by ensuring adequate sampling in each habitat zone and allows for inter-area comparisons (Underwood and Chapman, 2013; Noble-James et al., 2017).

To inform sample size, an a *priori* power analysis was conducted with GPower software using benthic grab sample data collected in the Project area in 2017 and 2018. When conducting a statistical test, its power is the probability of correctly rejecting the null hypothesis. A power analysis estimates the necessary sample size to detect changes in environmental indices at a particular power level. It is based on the effect size, tests to be run, and the specified level of power and significance (Antcliffe, 1992). The level of power is commonly defined as 0.80, which represents an 80% chance of detecting an effect where one exists, or a 20% chance of failing to reject the null hypothesis when it is false (Type II error). The significance is usually set to 0.05, which represents a 5% chance of detecting an effect where one does not exist, or incorrectly rejecting the null hypothesis when it is true (Type I error) (Cohen, 1988; Antcliffe, 1992; Noble-James et al., 2017).

The power analysis for the current study was based on a three-factor analysis of variance (ANOVA) to test three null hypotheses:

- $H_0 1$: There will be no difference in benthic community metrics (e.g., abundance, diversity, or other indicator) before and after construction;
- $H_0 2$: There will be no difference in benthic community metrics between impact and control monitoring areas; and
- $H_0 3$: There will be no difference in benthic community metrics along a gradient of distance from potential impact source.

Effect size, which is the expected or meaningful change to be detected, was estimated based on the variability in infaunal community diversity from the 2017 and 2018 benthic grab samples. Diversity (Shannon-Wiener) was used as the effect size indicator because it is a relatively sensitive index based on both abundance and evenness of an infaunal community. A 25% change in the benthic community diversity index was simulated in the data to calculate effect size and input into G*Power 3.1 (Faul et al., 2009) to determine required sample sizes. A 25% change in community indices has been used before in benthic monitoring studies and has been found to be detected with power close to 80% for most benthic taxa (Lambert et al., 2017).

Results from G*Power (total number of sample stations required for the analysis) were applied within the survey design (Section 3.0) to illustrate the number of replicate grab samples, sample stations, and transects needed to detect a 25% percent change in community diversity indices at significance levels of 0.05 and power of 0.80 (Table 2).

Table 2 Sample Sizes Required to Detect 25% Percent Changes in Benthic Community Diversity, Based on *A Priori* Power Analysis Results

Needed to detect:	25% change in diversity
Total sample size (G*Power output)	73
# sample stations per transect	7 (4 impact, 3 control)
# transects per habitat zone (73 stations / 7 stations per transect / 6 habitat zones rounded to nearest integer)	2
# stations per habitat zone (7 stations x 2 transects)	14
total # grab samples for each survey, across all 6 habitat zones (6 habitat zones x 14 stations x 3 replicate samples)	252

3.0 Survey Design

Different aspects of this monitoring plan are defined as follows:

- WDA = Wind Development Area, a rectangular region (dimensions approximately 50 km by 16 km) oriented northeast-southwest, approximately 23 km south of Martha's Vineyard and Nantucket;
- OECC = Offshore Export Cable Corridor, a corridor typically 810-m wide centered on the planned cable route from the Lease Area to the potential Landfall Sites, for a length of approximately 70-80 km;
- Impact monitoring area = discrete survey transects oriented in a cross-wise pattern with respect to the export cable or WTG scour protection base, within which sample stations will be placed for monitoring potential impacts (see Figure 6);
- Control monitoring area = discrete control areas paired with each impact monitoring area, located a specified distance from nearest impact sample station, within which sample stations will be placed to help distinguish general environmental changes from impacts;

- Sample stations = discrete locations at which grab samples will be obtained, impact monitoring sample stations will be placed at specific distances from expected impact source;
- Replicate = repeated benthic grab samples at each sample station to capture within-site variability and obtain a more representative sample of species present; and
- Transect = survey line perpendicular to the potential impact source (export cable or scour protection) along which grab samples and underwater video footage will be collected.

As recommended in McCann (2012), the following parameters will be monitored:

- Changes in the infaunal density, diversity, and community structure;
- Changes to the seafloor morphology and structure;
- Changes in median grain size; and
- Changes in abundance, diversity, and cover of epibenthic species, with focus on important species and those colonizing hard structures (i.e., reef effects).

3.1 Infauna and Epifauna Surveys

Based on the results of the power analysis (Section 2.0), a total of 14 sample stations in each habitat zone are required to detect a 25% difference in benthic community diversity pre- and post-construction (i.e., before and after impact), between impact and control monitoring areas, and between stations at different distances from the impact source, with sufficient statistical power. Locations for two impact monitoring transects and three control sites were randomly chosen with each habitat zone from equidistant points mapped along the OECC and within the WDA.

We will apply a combination BACI-gradient sampling design which places sample stations at regular distances from the impact source (either WTG scour protection or export cable) along impact monitoring transects, and sample stations placed outside impact monitoring areas to serve as controls. A gradient sampling design allows for comparison of species indices over both space and time and determines the spatial extent of a particular impact, which is useful for future planning of similar projects. Gradient survey designs have been shown to be more powerful in detecting changes due to disturbances than BACI and simple random block designs (Elliott 1997; Bailey et al. 2014); however, BACI designs analyzed with Analysis of Variance (ANOVA) tests are widespread in environmental monitoring literature (Underwood and Chapman, 2013). The proposed combination BACI-gradient design incorporates elements of each sampling design[1] and will allow for a rigorous assessment of impacts and recovery.

Each habitat zone in the Project area will contain 2 randomly placed transects (Figures 4, 5, 6). Schematics of the proposed sampling layout for grab sampling are presented in Figure 7; this

[1] A gradient-only design is not recommended because it was not possible to conduct an *a priori* power analysis on available data for a gradient regression.

layout will occur at each of the monitoring areas depicted in Figure 4a. The proposed layout for benthic grab sampling is along a transect extending outward approximately 150 m from the WTG scour protection or export cable. This length is expected to capture potential near-field impacts from both scour protection and export cable installation, based on sediment transport modeling that predicted deposition from export cable installation would primarily occur within 80-100 m of the route centerline (see Appendix III-A of the COP). Video sampling will occur both perpendicular and parallel to the cable and WTG foundations for each of the monitoring areas, as shown in Figure 8.

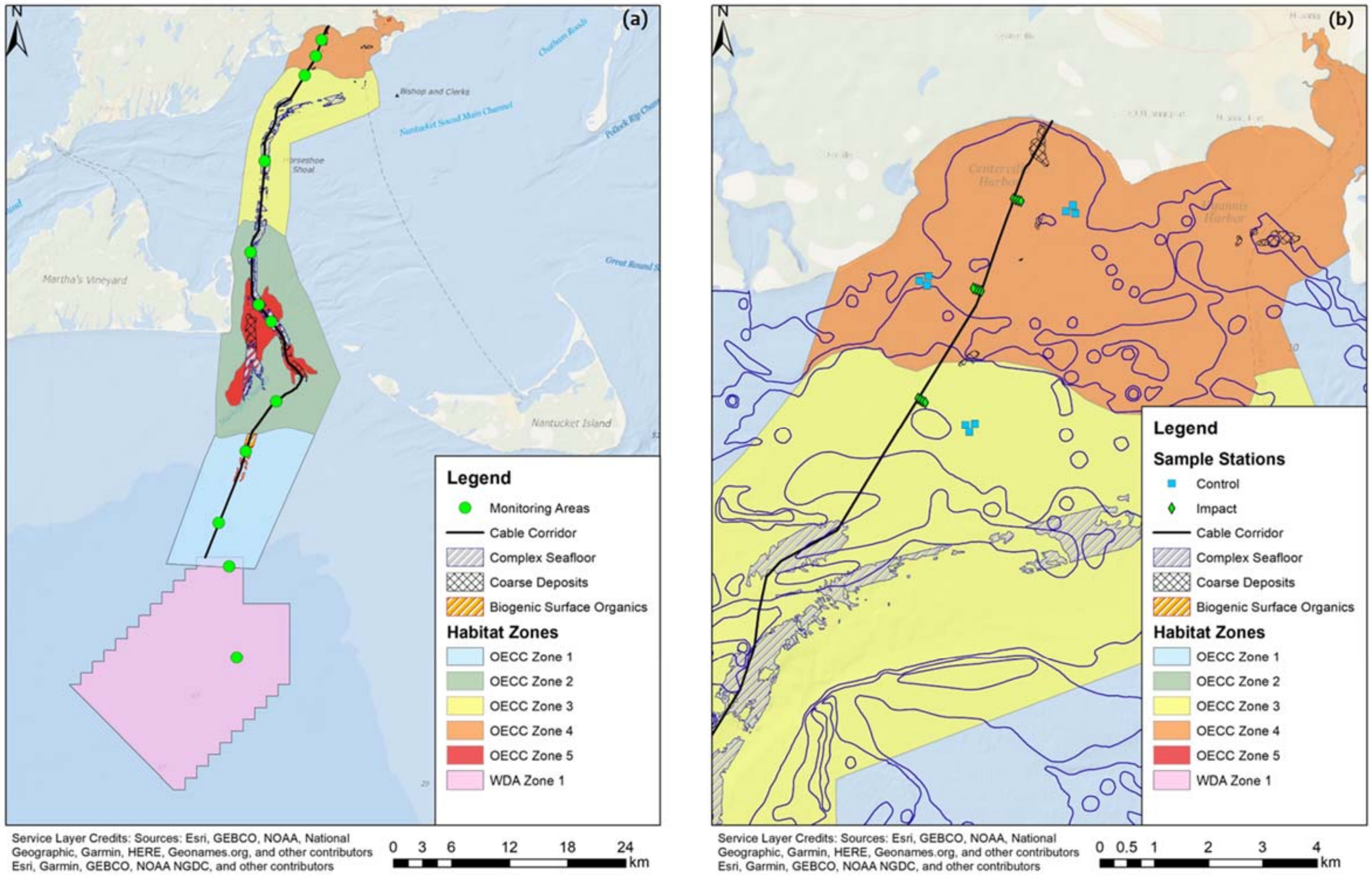

Figure 4. Representative layout of monitoring areas (a) within the overall study area, and (b) within the habitat zones nearest shore, zone 3 and 4.

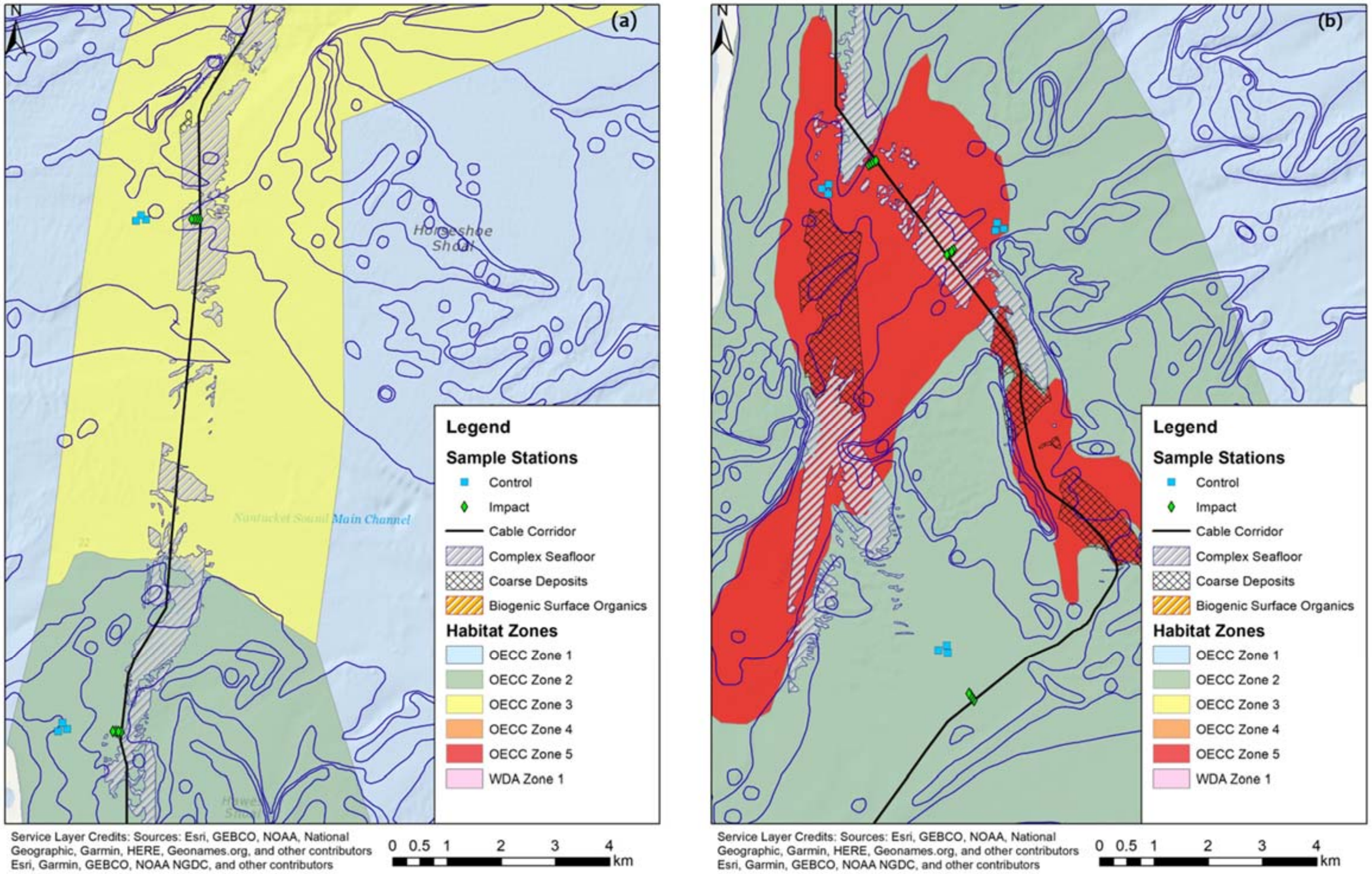

Figure 5. Representative layout of monitoring areas (a) within habitat zones 3 and 2, and (b) within habitat zone 5, which is contained within zone 2.

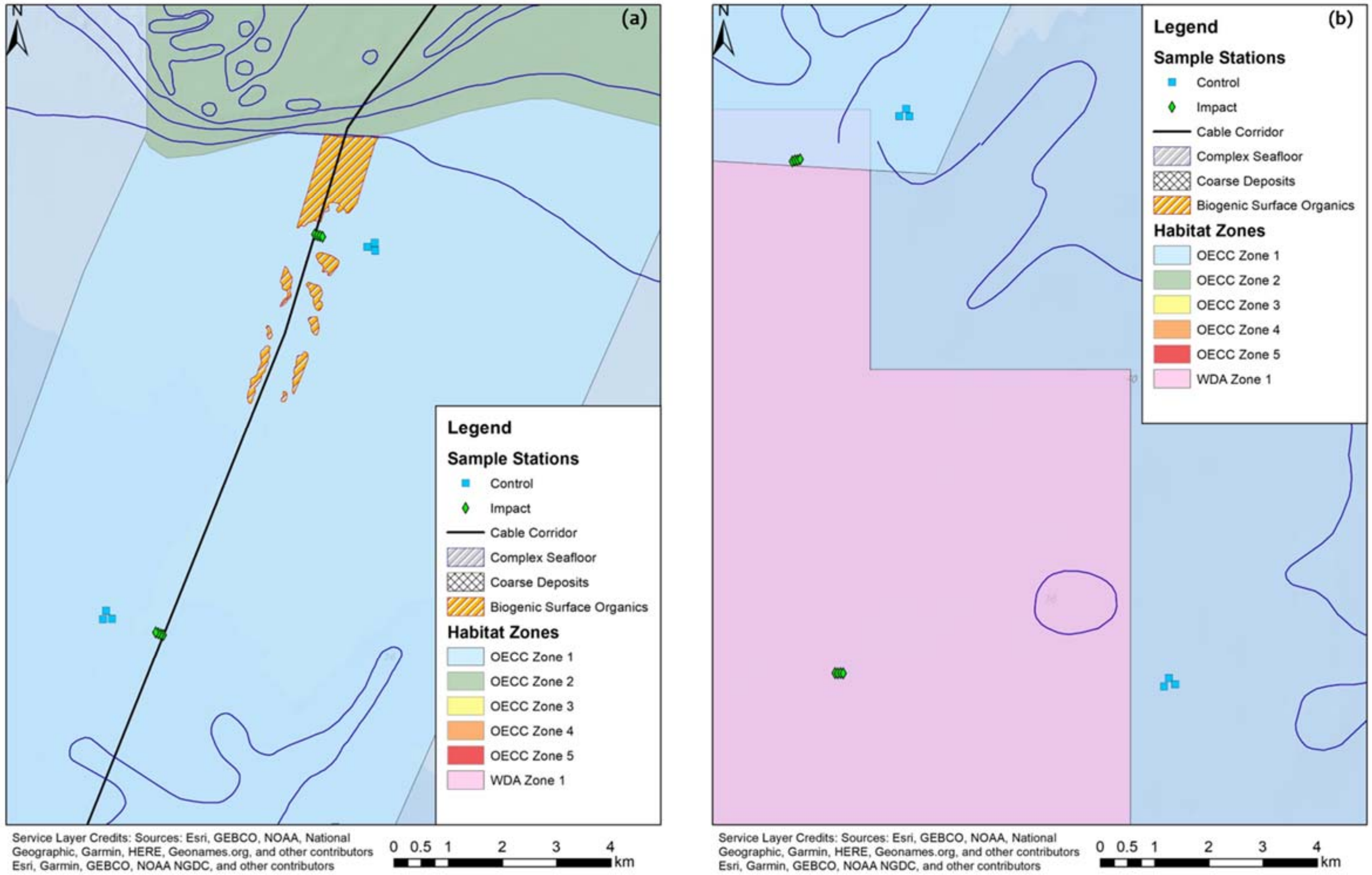

Figure 6. Representative layout of monitoring areas (a) within OECC habitat zone 1 and (b) within WDA habitat zone 1.

Stations for benthic grab samples will be placed along the transects at 0-m, 50-m, 100-m, and 150-m distances from the potential impact source, with 3 replicate benthic grab samples collected at each sample station (Figure 7). Including three replicated grab samples at each station increases understanding of small-scale variability, improves the precision of the mean indices analyzed for each sample station in the ANOVA, and increases capture of organisms that are rare or patchily distributed while also reducing the effects of random variation at the station (Gotelli and Ellison, 2004; Noble-James et al. 2017). Replicated grab samples will be processed separately to analyze variation within the station and then averaged for each sample station.

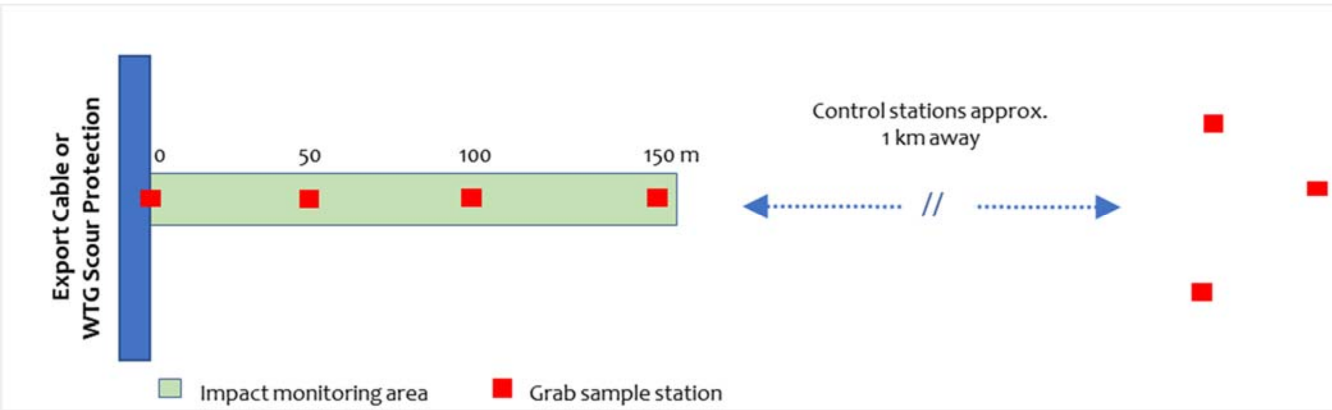

Figure 7. Schematic of infauna benthic grab sampling layout. The expected potential impact area covers approximately 150 m out from the base of the wind turbine generator WTG scour protection or export cable. Each red square represents a sample station at which three replicate benthic grab samples will be obtained. Control stations will be placed 1 km away for all OECC transects, with WDA control stations placed outside the WDA boundary.

Video surveys will be captured along 300-m of each impact monitoring transect, both perpendicular and parallel to the cable or WTG foundation (Figure 8). Three control monitoring areas, each comprising 100 m of video footage and one benthic grab sample station, will be placed some distance away from the nearest impact monitoring stations. For OECC transects, a minimum of 1 km will be maintained between control and impact stations where geography allows within the bounds of a habitat zone, based on the distance at which differences in community indices observed in a gradient sampling design around an oil platform leveled off (Ellis and Schneider, 1997). For the WDA, control stations will be placed outside of the WDA boundary in the control survey area designated in the Fisheries Monitoring Plan. Only grab samples will be collected in the control monitoring area for the WDA, as the drop camera surveys in the Fisheries Monitoring Plan can be used to quantify epifauna and habitat cover. Control areas will be selected to have similar physical and environmental characteristics to detect natural environmental shifts that may occur unrelated to Project activities. Multibeam depth sounding coverage will be collected along the entire OECC area.

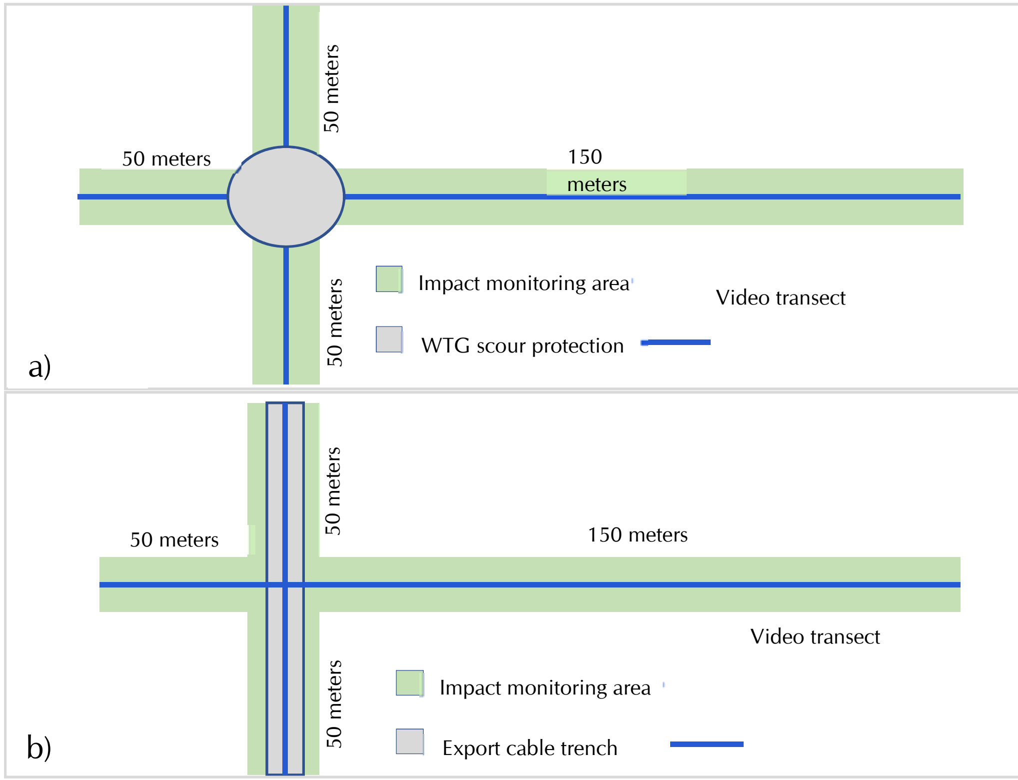

Figure 8. Schematic of epifauna/benthic habitat video survey layout. One transect extends 150 m out from the base of the wind turbine generator WTG scour protection (a) or export cable trench (b) over the same locations where grab sampling occurs. Shorter transects (50 m) will radiate from the WTG and along/ across the export cable to capture a more complete picture of the area of disturbance.

This sampling design of 4 sample stations along each of 12 impact monitoring transects (2 transects in each of the 6 habitat types), with 3 replicate grab samples per station, yields 144 grab samples in monitoring areas. In the control areas, there will be an additional 108 grab samples (3 control stations a distance away from each transect, with 3 replicate grab samples per station, for 12 impact monitoring areas), for a total of 252 grab samples for each annual survey (144 grabs in impact monitoring areas and 108 grabs in control areas). This configuration is designed to document the benthic variability in and around the zone of potential disturbance from cables or scour protection installation and allow for comparison between samples at different distances from the impact source. Additionally, 3,600 m of video survey will be collected along the impact monitoring transects (300 m of video per each of the 12 impact monitoring transects) and 3,000 m of video survey will be collected along the control area transects (300 m of video per the 10 impact monitoring transects along the OECC; drop camera survey data from the Fisheries Monitoring Plan will be used for the WDA control transects), for a total of 6,600 m of video collected per survey. The impact and control monitoring areas will be surveyed in accordance with Section 4.0 timelines.

3.2 Sand Lance Surveys

In addition to benthic invertebrate community monitoring, Vineyard Wind will assess the presence of Sand Lance (*Ammodytes dubius* and *A. americanus*) in ten additional monitoring sites within the project area. Sand Lance are a forage fish species that link lower and upper trophic levels in the food web and serve as a food source for commercially important fish species such as Atlantic Cod (Gadus morhua), marine mammals such as the Humpback Whales (Megaptera novaeangliae), and sea birds such as the endangered Roseate Tern (Sterna dougallii) (Nelson and Ross 1991; MA DFW, 2015). Generally, Sand Lance are schooling, diurnal, semi-demersal foragers that burrow into sandy sediments at night for rest and predator evasion (Auster and Stewart, 1986). Previous research on other Sand Lance species indicates that they associate with habitats containing sandy substrates with less than ten percent fine material and high bottom current velocities, which keeps interstitial substrate aerated (Reay 1970; Wright et al., 2000). Although trawls are not efficient at capturing Sand Lance, long-term trawl sampling data from the Massachusetts Division of Marine Fisheries (DMF) show a highly variable annual distribution throughout the region with semi-consistent occurrence through Muskeget Channel and south of Martha's Vineyard and Nantucket (M. Staudinger, USGS Northeast Climate Adaptation Science Center, personal communication).

Comprehensive sampling of Sand Lance is difficult and requires acoustic surveys with specialized sonar equipment and underwater video and benthic grab sampling (L. Kaufman, Boston University Marine Program, personal communication). Because the benthic habitat monitoring plan is not designed with a single species focus and resources need to be allocated effectively, sampling is limited to benthic grab samples to detect potential presence in the project area. A total of ten monitoring sites will be sampled with night time benthic grabs in order to capture fish during their nocturnal burial. Based on their preferred habitat and historic distribution, the monitoring sites will be distributed throughout Zones 1, 2 and 5 along the OECC. Within each site, three replicate grabs within a 100-m radius of the station position will be taken (Ware et al., 2010; McCann, 2012). Exact sampling stations for Sand Lance monitoring plan will be chosen using long-term trawl data from DMF, sediment samples and assessments from Vineyard Wind's 2017 and 2018 Marine Surveys seabed sampling, and consultation from regional experts.

4.0 Program Schedule

Pre-construction baseline surveys will be conducted in all monitoring and control areas prior to construction activities to identify and document the natural background conditions at each site, with increased attention on any hard bottom habitats that are in the direct path of the planned cable. February through April has been noted as an ideal time to survey the benthos as it is before the main recruitment period for pelagic larvae (Judd, 2011); however, this timing is extremely difficult for offshore work, and several studies have noted a continuity in benthic community indices between seasons in nearby Block Island Sound (see studies cited within HDR, 2017). Thus, monitoring surveys may occur at the most logical time based on staggered project construction schedules, as long as they occur at roughly the same time from year to year.

Post-construction monitoring surveys are planned to occur within the first year after impact to capture short-term recolonization, and to repeat for multiple years after impact to establish whether benthic community metrics and habitats have recovered to states similar to what they were before impact. These surveys will assess recovery progression of the various habitats that overlap the Project, species composition and benthic habitat quality at monitoring sites, and presence of Sand Lance (*Ammodytes dubius* and *A. americanus*). In prior studies (Coates et al, 2013; 2015) benthic recovery has been observed within a year, so early surveys are useful for observing the start of recovery. Monitoring will occur in years 1, 3, and, if necessary, year 5 post-construction, unless benthic community metrics indicate recovery has occurred and it is agreed that monitoring may cease. If recovery is not observed within 5 years for the portion of the Offshore Export Cable Corridor located in state waters, Vineyard Wind and the Massachusetts Department of Environmental Protection (MassDEP) will confer regarding potential additional monitoring.

Program updates will be shared with the appropriate federal and state agencies, throughout the monitoring study, in the form of processed reports and data made available for regional use. Monitoring reports will include:

- methods employed to conduct the monitoring study;
- summary of monitoring results;
- analysis and summary of habitat recovery; and
- a list of planned monitoring activities to be conducted at the next survey interval.

5.0 Monitoring Equipment and Methods

Pre- and post-construction monitoring surveys will be conducted using the same gear, methods, and monitoring areas to maximize comparability and determine differences in survey results before and after construction. Table 3 summarizes the methods that have been integrated into the monitoring plan. Further details on these techniques are discussed in the following sections. It is important to note that the exact monitoring locations and number of samples collected may vary slightly depending on the substrate and oceanographic conditions in each of the monitoring and control areas.

Table 3 Summary of Methods Proposed for the Benthic Habitat Monitoring Plan

Monitoring System	Focus Area	Purpose
Grab sampler	Surface and Subsurface; epifaunal, infaunal organisms, Sand Lance, and structures	Identify surface and subsurface organisms and features. Provides specific organism-level evidence concerning habitat recovery.
Multibeam depth sounder	Surface; seafloor morphology	Pre- and post- changes in bottom morphology and micro-relief, changes in the seabed scar over time. Data can show the detailed topographic differences in the seafloor between successive mappings.
Underwater video	Surface; benthic habitats, epifaunal organisms	Identify gross habitat changes pre- and post- as well as during the recovery process. Documents epifaunal activity for comparison between mappings.

5.1 Benthic Grab Sampling and Analysis

An industry standard benthic/sediment grab sampler (e.g., Van Veen, Day, Ponar) will be employed to retrieve sediments from the seabed for analysis. These sampling devices recover material from the seabed by using lever arms to force two halves of a metal bucket closed after the unit has been lowered to the bottom. Material from the upper 10 to 20 centimeters (cm) of the seabed is then raised to the deck of the vessel for photographs and subsampling.

Two or more subsamples of the same specified volume (to the extent possible) will be removed from the grab for sieving and lab analysis. Subsample volumes will be documented in a field logsheet along with other sediment and benthic descriptors. This information supports estimates of species abundance values and ensures all data and results are comparable. For Sand Lance-specific sampling grabs, the entire sample volume will be processed.

After the grab samples are collected, they will be processed onboard, passed through a 0.5-millimeter (mm) sieve and fixed in 10% neutral buffered formalin. Rose bengal can be added in the field or in the lab. Once delivered to the lab and prior to being sorted, the sample material will be emptied in its entirety into a 0.5-mm mesh sieve for a second time. Tap water will then be gently run over the sieve to rinse away the formalin fixative and any additional fine sediment that is not removed during the initial sieving process. Rinsed samples will be preserved in 70% ethanol. Each sample will then be sorted to remove benthic organisms from residual debris.

Samples will be sorted under a high-power dissecting microscope (up to 90X magnification). All sorted organisms will then be identified by a qualified taxonomist to the lowest practicable taxonomic level using a dissecting microscope with magnification up to 90X and readily available taxonomic keys. Identification of slide-mounted organisms will be conducted under a compound microscope with magnification up to 1,000X. Enumerations of macroinvertebrates will be made and species abundances from each sample will be standardized to number of individuals per square meter, considering the sampling equipment dimensions and sub-sampling effort.

To describe existing conditions and compare pre- and post- construction conditions, measures of benthic macrofaunal diversity, abundance, and community composition will be made for each sampling site and characterized under the CMECS standard (FGDC, 2012). Changes in community structure will be determined using a three-factor ANOVA and multidimensional scaling plots of Bray-Curtis dissimilarity to compare species compositions. Results can be presented as tabular data and plots annually in order to track recovery status and progress.

5.2 High Resolution Multibeam Depth Sounding and Video Survey

Vineyard Wind will conduct high-resolution multibeam depth sounding and video surveillance within the designated monitoring and control areas. Seabed surface maps to centimeter-level resolution will be created using a multibeam depth sounding system to allow detailed comparisons of bottom morphology and detection of minute changes between successive mappings. An underwater remotely operated vehicle (ROV) will record continuous video imagery along pre-planned transects (Figure 4).

Pre- and post-construction video and digital terrain maps will be analyzed and compared to assess in seabed morphology within the monitoring sites. Underwater video viewed at normal speed will be used to count larger epibenthic organisms, while high quality still frames will be randomly selected for analysis of smaller organisms (Sheehan et al., 2010). The following observations will be made:

- Locations, presence, and general characterization of the substrate (three-dimensional surface features and regularity) in accordance with the CMECS standards (FGDC, 2012);
- Quantification and general characterization of epibenthic invertebrates (e.g., lobster and crabs);
- Quantification and general characteristics of shellfish (e.g., clams, scallops);
- Changes in invasive species coverage;
- Evidence of burrowing activity; and
- Presence and general characterization of benthic and nektonic habitats observed.

Results will be documented in the form of high-resolution digital terrain model (DTM) surfaces of the seabed created from the multi-beam and difference maps between mappings. Still images of the video footage will be captured of discrete objects or obvious changes in the substrate. Findings will be summarized in a technical report with a supporting series of charts/figures for each monitoring program documenting results from all survey methodologies performed and will include comparisons with previous monitoring surveys, other related survey data, and relevant desktop studies.

6.0 References

Antcliffe, B. 1992. Impact assessment and environmental monitoring: the role of statistical power analysis. Pages 16 in. Canadian Environmental Assessment Research Council, Vancouver.

Auster, P. J., and L. L. Stewart. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)- Sand Lance. U.S. Fish Wildlife Service Biological Report 82 (11.66). U.S. Army Corps of Engineers, TR EL-82-4. 11 pp.

Borja, A., J. Franco, and V. Pérez. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Borja, A., and D.M. Dauer. 2008. Assessing the environmental quality status in estuarine and coastal systems: Comparing methodologies and indicies. Ecological Indicators 8: 331 - 337.

Coates, D., G. Van Hoey, J. Reubens, S. Vanden Eede, V. De Maersschalck, M. Vincx, and J. Vanaverbeke. 2013. Chapter 9: The microbenthic community around an offshore wind farm. Pages 86-98 *in* S. Degraer, R. Brabant, and B. Rumes (*eds*). Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Learning from the past to potimise future monitoring programmes. . Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management Section. 239 pp.

Coates, D.A., G. van Hoey, L. Colson, M. Vinex, and J. Vanaverbeke. 2015. Rapid microbenthic recovery after dredging activities in an offshore wind farm in the Belgian part of the North Sea. Hydrobiologia 756: 3-18.

Cohen, J. (1988) *Statistical power analysis for the behavioral sciences*, 2nd edn. LEA, Hillsdale, New 458 Jersey.

CR Environmental, Inc. 2017. Memorandum: Underwater Video Review, Vineyard Wind Project, Nantucket Sound and Atlantic Ocean. Dated 15 November 2017, 21 pp.

Daan, R., M. Mulder, M.J.N. Bergman. 2009. Impact of windfarm OWEZ on the local macrobenthos community. Report OWEZ_R_261_T1_20091216. 77 pp.

Degraer, S., R. Brabant, and B. Rumes (eds). 2013. Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Learning from the past to potimise future monitoring programmes. . Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management Section. 239 pp.

Degraer, S., R. Brabant, B. Rumes, and L. Vigin (eds). 2017. Environmental impacts of offshore wind farms in the Belgian part of the North Sea: A continued move towards integration and quantification. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section.

Dernie, K. M., M. J. Kaiser, and R. M. Warwick. 2003. Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology, 72 (6),1043-1056.

Elliott, J. B., K. Smith, D. R. Gallien, and A. Khan. 2017. Observing Cable Laying and Particle Settlement During the Construction of the Block Island Wind Farm. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2017-027. 225 pp.

Ellis, J.I., and D.C. Schneider. 2007. Evaluation of a gradient sampling design for environmental impact assessment. Environmental Monitoring and Assessment 48: 157-172.

English, P. A., T. I. Mason, J. T. Backstrom, B. J. Tibbles, A. A. Mackay, M. J. Smith, and T. Mitchell. 2017. Improving Efficiencies of National Environmental Policy Act Documentation for Offshore Wind Facilities Case Studies Report. US Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Sterling. OCS Study BOEM 2017-026. 217pp.

Epsilon Associates, Inc. and CR Environmental, Inc. 2015. Martha's Vineyard Hybrid Submarine Cable Post-Construction Marine Survey Report. Prepared for Comcast and NSTAR Electric Company.

ESS Group, Inc. 2017. Benthic Macroinvertebrate Sample Analysis Report. Vineyard Wind Project Offshore Lease Area OCS-A 0501 Massachusetts. Prepared for Vineyard Wind, LLC. Project No. O207-000.

Faul, F., Erdfelder, E., Buchner, A., and A.-G. Lang. 2009. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behavior Research Methods, 41, 1149-116. Available online: http://www.gpower.hhu.de/

Federal Geographic Data Committee (FGDC). 2012. Coastal and marine ecological classification standard. Marine and Coastal Spatial Data Subcommittie. FGDC-STD-018-2012. Available online: https://www.fgdc.gov/standards/projects/cmecs-folder/CMECS_Version_06-2012_FINAL.pdf (Accessed May 2019). 353pp.

Franco, A., V. Quintino, and M. Elliott. 2015. Benthic monitoring and sampling design and effort to detect spatial changes: A case study using data from offshore wind sites. Ecological Indicators 57: 298-304.

Gotelli, N.J., and A.M. Ellison. 2004. A Primer of Ecological Statistics. Sinauer Associates, Inc. Sunderland, MA, USA.

HDR. 2017. Benthic Monitoring during Wind Turbine Installation and Operation at the Block IslandWind Farm, Rhode Island. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2018-047. 155 pp.

Judd, A. 2011. Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Final Cefas contract report: ME5403-Module 15. 97 pp.

Lambert, G.I., L.G. Murray, J.G. Hiddink, H. Hinz, H. Lincoln, N. Hold, G. Cambie, and M.J. Kaiser. 2017. Defining thresholds of sustainable impact on benthic communities in relation to fishing disturbance. Scientific Reports 7: 5440, DOI:10.1038/s41598-017-04715-4.

Massachusetts Division of Fisheries and Wildlife (MA DFW) Natural Heritage & Endangered Species Program. 2015. Roseate Tern. Accessed July, 2018. Retrieved from: https://www.mass.gov/files/documents/2016/08/wh/roseate-tern.pdf.

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

Muniz, P., N. Venturini, A.M.S. Pires-Vanin, L.R. Tommasi, and A. Borja. 2005. Testing the applicability of a Marine Biotic Index (AMBI) to assessing the ecological quality of soft-bottom benthic communities in the South America Atlantic region. Marine Pollution Bulletin 50: 624-637.

Nelson, G.A. and M.R. Ross. 1991. Biology and population changes of northern sand lance (Ammodytes dubius) from the Gulf of Maine to the middle Atlantic Bight. J. Northwest Atl. Fish. Sci. 11: 11–27.

Noble-James, T., A. Jesus, and F. McBreen. 2017. Monitoring guidance for marine benthic habitats. JNCC Report No. 598. JNCC, Peterborough. 118 pp.

Normandeau Associates, Inc. 2017. Benthic Sample Processing Results, Vineyard Wind Cable Route Survey, September 2017, 29 pp.

Rees, H.L. (ed), 2009. Guidelines for the study of the epibenthos of subtidal environments. ICES Techniques in Marine Environmental Sciences No. 42, 88 pp

Rein, C.G., A.S. Lundin, S.J.K. Wilson, and E. Kimbrell. 2013.Offshore Wind Energy Development Site Assessment and Characterization: Evaluation of the Current Status and European Experience. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA. OCS Study BOEM 2013-0010. 273 pp.

Rhoads, D.C. and J. D. Germano. 1982. Characterization of Organism-Sediment Relations Using Sediment Profile Imaging: An Efficient Method of Remote Ecological Monitoring of the Seafloor (Remots™ System). Marine Ecology, Volume 8, p. 115-128.

RPS ASA 2012. Sediment Transport Analysis of Cable Installation for Block Island Wind Farm and Block Island Transmission System. ASA project number 2011-243.

Salas, F., J.M. Neto, A. Borja, and J.C. Marques. 2004. Evaluation of the applicability of a marine biotic index to characterize the status of estuarine ecosystems: the case of Mondego estuary (Portugal). Ecological Indicators 4: 215-225.

Saunders, G., G.S. Bedford, J.R. Trendall, and I. Sotheran. 2011. Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 5. Benthic Habitats. Unpublished draft report to Scottish Natural Heritage and Marine Scotland. 121 pp.

Sheehan, E. V., Stevens, T. F. and Attrill, M. J. 2010. A Quantitative, Non-Destructive Methodology for Habitat Characterisation and Benthic Monitoring at Offshore Renewable Energy Developments. PLoS ONE 5(12): e14461.doi:10.1371/journal.pone.0014461.

Stokesbury, K. D. E. 2013. MA Windfarm Survey, Final Report. SMAST video survey of Western portion of the offshore Windfarm area, School for Marine Science and Technology (SMAST), University of Massachusetts Dartmouth, 13 pp.

Stokesbury, K. D. E. 2014. MA Windfarm Survey, Final Report. SMAST video survey of Western portion of the offshore Windfarm area, School for Marine Science and Technology (SMAST), University of Massachusetts Dartmouth, 18 pp.

Underwood, A.J., and M.G. Chapman. 2013. Chapter 1: Design and analysis in benthic surveys in environmental sampling. Pages 1-40 *in* A. Eleftheriou (ed) Methods for the Study of the Marine Benthos, Fourth Edition.

Van Dalfsen, J. A. and K. Essink. 2001. Benthic community response to sand dredging and shoreface nourishment in Dutch coastal waters. *Senckenbergiana marit*, 31(2),329-32.

Van Hoey, G., J. Drent, T. Ysebaert, and P. Herman. 2007. The Benthic Ecosystem Quality index (BEQI), intercalibration and assessment of Dutch Coastal and Transitional Waters for the Water Framework Directive. NIOO rapport 2007-02. 245 pp.

Ware, S., S. G. Bolam, and H.L. Rees. 2010. Impact and recovery associated with the deposition of capital dredgings at UK disposal sites: lessons for future licensing and monitoring. Marine Pollution Bulletin, 60: 79-90.

Warwick, R.M., K.R. Clarke, and P.S. Somerfield. 2010. Exploring the marine biotic index (AMBI): variations on a theme by Ángel Borja. Marine Pollution Bulletin 60: 554-559.