# Appendix II-K

## Fisheries Monitoring Plan

# ATLANTIC SHORES FISHERIES MONITORING PLAN

December 14, 2021

rpsgroup.com

| Version | Authored by | Reviewed by | Approved by | Review date |
|---|---|---|---|---|
| Draft 1 | JZ | SD,JR | JR | June 2, 2021 |
| Draft 2 | JZ | SD,JR | JR | June 30, 2021 |
| Draft 3 | JZ | SD,JR | JR | July 9, 2021 |
| Draft 4 | JZ | JR | JR | July 27, 2021 |
| Draft 5 | JZ | SD | JZ | November 21, 2021 |
| Draft 6 | JZ | SD | JZ | December 14, 2021 |

The purpose of RPS' services will be to inform ASOW and EDR of future potential actions to abide by BOEM guidelines. Information provided by RPS may only be relied upon in the context of RPS' scope of works. ASOW and EDR will necessarily inform itself and make independent decisions, based on its own business needs and on key aspects in relation to the project.

| Prepared by**:** | Prepared for**:** |
|---|---|
| **RPS** | **Atlantic Shores and EDR** |

Joseph Zottoli, Stephanie Berkman, Stephen Davies,
Jill Rowe

55 Village Square Drive
South Kingstown RI
02879

**T** +1 401 789 6224
**E** joseph.zottoli@rpsgroup.com

# Contents

# Figures

# Tables

# 1 INTRODUCTION

Atlantic Shores Offshore Wind, LLC (Atlantic Shores) is a 50/50 joint venture between EDF-RE Offshore Development, LLC (a wholly owned subsidiary of EDF Renewables, Inc. [EDF Renewables]) and Shell New Energies US LLC (Shell). On behalf of Atlantic Shores, RPS prepared this Fisheries Monitoring Plan in support of the submission of the Construction and Operations Plan (COP) to the Bureau of Ocean Energy Management (BOEM) for the development of two offshore wind energy generation projects within the southern portion of Lease Area OCS-A 0499 (the Lease Area).

Atlantic Shores' Lease Area is located on the OCS within the New Jersey Wind Energy Area, which was identified by BOEM as suitable for offshore renewable energy development through a multi-year, public environmental review process. The Projects will be located in an approximately 102,124-acre (413.3-square kilometer [$km^2$]) Wind Turbine Area (WTA) located in the southern portion of the Lease Area. Project 1 is located in the western 54,175 acres (219.2 $km^2$) of the WTA, and Project 2 is located in the eastern 31,847 acres (128.9 $km^2$) of the WTA, with a 16,102-acre (65.2-$km^2$) Overlap Area that could be used by either Project 1 or Project 2.

In addition to the WTA, the Projects will include two offshore Export Cable Corridors (ECCs) within federal and New Jersey state waters as well as two onshore interconnection cable routes, two onshore substation and/or converter station sites, and a proposed operations and maintenance (O&M) facility in New Jersey. The Offshore Project Area includes the WTA and the ECCs.

The purpose of Atlantic Shores' Fisheries Monitoring Plan (Monitoring Plan) is to provide a comprehensive means to document baseline environmental conditions relevant to fisheries in the WTA (Figure 1-1) and to prescribe how to monitor those conditions throughout construction and operation of the proposed offshore wind facilities. This will allow Atlantic Shores to understand potential changes in the fisheries in the WTA throughout various phases of a project life-cycle. The Monitoring Plan has been prepared in consideration of a variety of fisheries related federal, state, and stakeholder guidance and the requirements set forth in 30 CFR Part 585 Subpart F (30 CFR § 585.626 and § 585.633). This draft plan will be implemented in support of both Projects. Individual plans for Project 1 and Project 2 will be developed for BOEM review and acceptance prior to construction with each Project's Facility Design Report and/or Fabrication and Installation Report.

To support the development of this Monitoring Plan, a comprehensive review of available pre-existing data was conducted to identify historical baseline conditions. The baseline data, combined with regulator and stakeholder input, informed the selection of appropriate monitoring surveys (e.g., focus species, survey types, survey objectives, survey design, sample size, etc.). Specifically, catch diversity, catch density, catch size distributions, and some other survey-specific variables including stomach contents will be sampled with surveys designed to detect significant changes after construction. This document describes the relevant pre-existing data and proposed Monitoring Plan purpose and design.

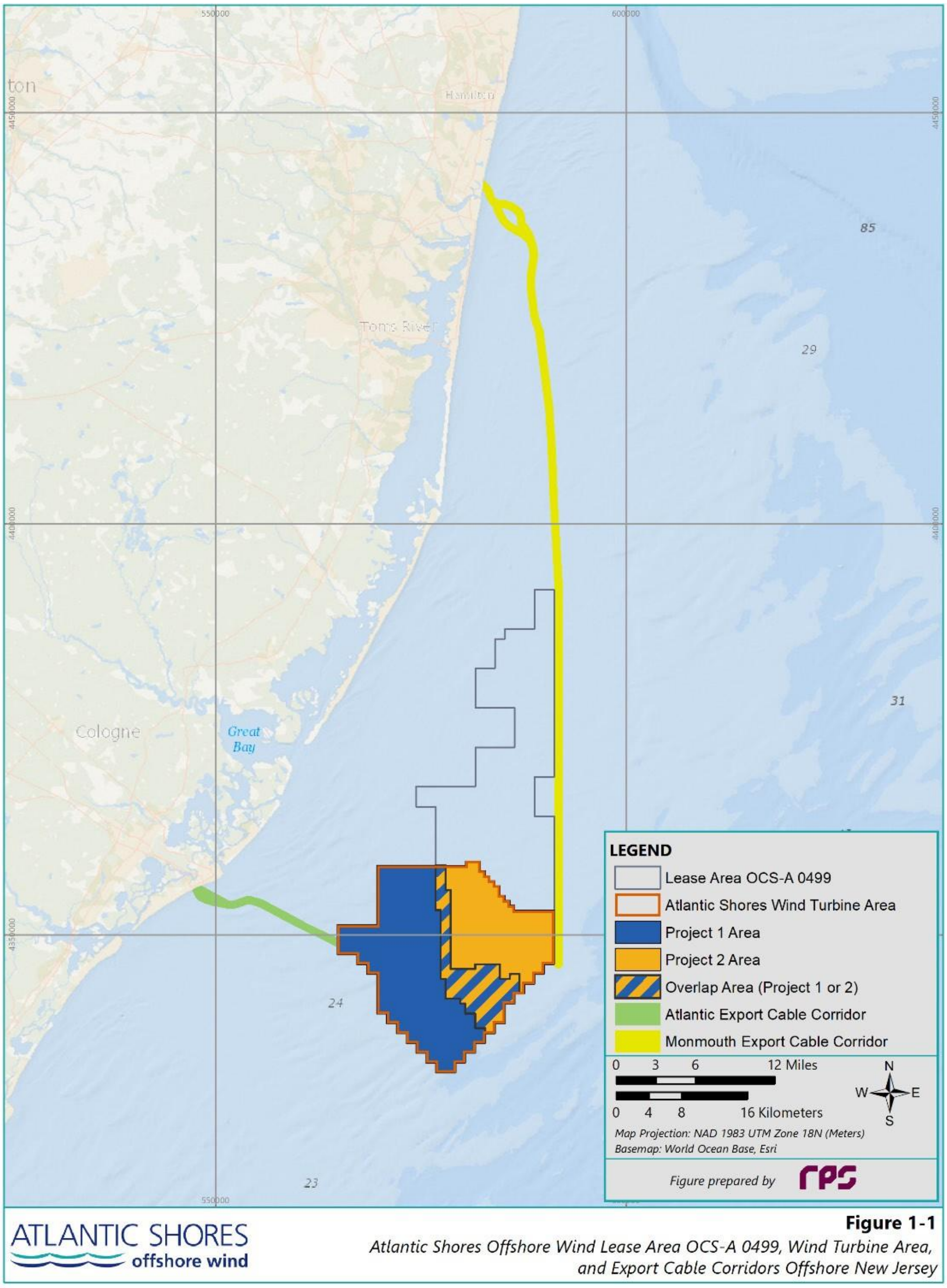

Figure 1-1. Atlantic Shores Offshore Wind Lease Area OCS-A 0499, Wind Turbine Area, and Export Cable Corridors Offshore New Jersey.

# 2 BACKGROUND

## 2.1 Federal Guidance (BOEM)

Under 30 CFR Part 585 Subpart F (30 CFR § 585.627), the COP must detail resources, conditions, and activities that could be affected by proposed activities, or that could affect the activities proposed. Potentially affected resources and activities relevant to this Monitoring Plan include the benthic community, fish, shellfish, and fisheries that affect these resources.

According to guidance released by BOEM (2019):

> "The fisheries survey plan should aim to:
>
> - Identify and confirm the dominant benthic, demersal, and pelagic species 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."

This Monitoring Plan aims to fulfill the goals as defined by BOEM (2019) using the most appropriate survey gears and designs. Consideration of newer recommendations and guidance of other federal and state agencies (NOAA National Marine Fisheries Service [NMFS] and New Jersey Department of Environmental Protection [NJDEP]) as well as other stakeholder groups (ROSA, Rutgers University, NYSERDA, etc.) and scientific best practices were also used to enhance the Monitoring Plan design as summarized further in Sections 2.2 and 2.3.

## 2.2 Stakeholder Guidance

The Responsible Offshore Science Alliance (ROSA) produced a set of guidelines for fisheries monitoring surveys based on input from multiple stakeholder groups. These guidelines (ROSA 2021) were developed to help create an integrated regional monitoring approach. The primary steps of the ROSA recommended approach include:

1. Evaluate available data describing fishery resources and stressors within the project area.
2. Define concise and appropriate monitoring objectives and hypotheses.
3. Identify focus species (or groups) to monitor.
4. Set indicators and define thresholds that are appropriate and measurable.
5. Design a plan to collect the appropriate data to address monitoring objectives.
6. Analyze data collected to achieve monitoring objectives and test hypotheses.
7. Adjust sampling design/methods as needed to continue to address monitoring objectives.

The development of this Monitoring Plan strongly considered ROSA's recommendations as well as the input of BOEM, state agencies and other federal agencies, the Atlantic Shores Fisheries Liaison Officer (Captain Kevin Wark), other stakeholders, and scientific best practices. Atlantic Shores met with NMFS and NJDEP on September 9, 2020; with NMFS, NJDEP, NYSERDA, and Rutgers University on January 22, 2021; and with NMFS, NJDEP, and BOEM on October 12, 2021. During these meetings, Atlantic Shores outlined the survey and gear types being considered and received feedback and guidance from the stakeholders.

## 2.3 Scientific Best Practices

Potential offshore wind effects on fishes include reef effects; changes to abundance distribution; installation noise effects; operational noise effects; and electromagnetic field effects (McCann 2012). Impacts from these effects range from localized to broad; thus, it is important to sample with appropriate methods to detect changes at an appropriate scale.

An early BOEM-funded desktop study to help develop environmental protocols identified trawl surveys as an established method for monitoring effects to fishes at large scales, especially for demersal species, whereas acoustic surveys could better assess pelagic species and ventless trap surveys could be used to monitor valuable invertebrates, such as lobster (McCann 2012). Additional fishery sampling method suggestions documented by BOEM include the use of gilllnets/trammel nets, beam trawls, grab samples, and benthic visual imagery (BOEM 2019). Mid-water trawls, hook gear, dredges, bongo nets, sediment profile imaging, acoustic telemetry, AUVs with acoustic cameras, moored buoy and vessel mounted acoustic surveys, tagging, and molecular sampling composed the other possible gear types presented by ROSA (2021). Both ROSA (2021) and BOEM (2019) documents stressed the importance of choosing appropriate sampling gear based on effects area characteristics obtained from existing information and monitoring plan objectives.

Regardless of gear type, it is important to standardize surveys and implement designs that are repeatable and can be compared between lease areas, ideally implementing a rigorous pre-existing design utilized by federal, state, or other research groups (ROSA 2021). Relevant pre-existing surveys used to support the development of this Monitoring Plan are described in Section 2.4.

To date, most fisheries monitoring studies associated with offshore wind have used variations of a Before-After Impact-Control (BACI) survey design (Methratta 2020), which employs sampling at control and impact sites both before and after an impact occurs (Green 1979). The BACI design allows for statistical analysis of hypotheses with Analysis of Variance (ANOVA) testing and is widespread in environmental monitoring literature (Underwood and Chapman 2013). Some published drawbacks of the BACI design are 1) difficulty in locating a control site that fulfills the assumption that is both statistically similar to- and independent of the impact site (Stewart-Oaten et al. 1986); 2) the assumption that the areas within control and impact sites are homogenous from a habitat perspective; and 3) the assumption that the spatial scale of the impact is correctly estimated and sampled (Methratta 2020). However, proper survey design and appropriate application can mitigate these drawbacks (Methratta 2020).

Another environmental impact assessment survey design is the Before-After Gradient (BAG) design which like the BACI design also measures environmental variables before and after an impact occurs, but rather than select impact and control sites, BAG sampling occurs along a spatial gradient from the impact source (Ellis and Schneider 1997). Depending on assumptions about the relationship between distance and the response variable, various regression techniques can be applied to assess potential distance-associated changes while considering other independent variables.

Irrespective of the survey design and sampling gear, a complete, coherent survey plan should contain a clear purpose, objectives, assumptions, hypotheses, methods, and indicators (ROSA 2020). Selection of appropriate surveys should examine existing information and incorporate fishery and other stakeholder group feedback (BOEM 2019) because stakeholder engagement is a key process for the formation of mutual goals (Pomeroy and Douvere 2008).

## 2.4 Available Pre-Existing Data

### 2.4.1 Fisheries-Independent Data

There are multiple fishery-independent surveys utilizing a range of gear types that occur regularly within or near the WTA and potential ECCs. These surveys include three demersal otter trawl surveys and three bivalve dredge surveys, and two ventless fish trap surveys. These data were evaluated for their ability to describe fishery resources within the WTA and some were applied as part of power analyses to inform planned monitoring surveys (Table 2-1). For more information on pre-existing survey designs and locations relative to the Project, refer to Attachment A.

Table 2-1. Pre-existing Survey Data sources and their characteristics.

| Survey Type | Survey | Overlaps WTA? | Used for Power Analysis |
|---|---|---|---|
| Demersal trawl survey | NJDEP Ocean Stock Assessment Trawl Survey | Yes | Yes |
| Demersal trawl survey | NEAMAP Trawl Survey | No | No |
| Demersal trawl survey | NEFSC Bottom Trawl Surveys | Yes | No |
| Dredge survey | NJDEP Surf Clam Survey | No | No |
| Dredge survey | NEFSC Scallop Survey | No | No |
| Dredge survey | NEFSC Clam Survey | Yes | Yes |
| Dredge survey | VIMS Scallop Survey | Yes | No |
| Ventless trap survey | NJDEP Artificial Reef Survey | No | Yes |
| Ventless trap survey | Borden et al. 2013 | No | No |

### 2.4.2 Fisheries-Dependent Data

In November of 2020, the NMFS released estimates of fishing landings and revenue from within the Lease Area over the previous 12 years (NMFS 2020). The estimates were based on commercial fisheries landings data, vessel trip reports, and surf clam/ocean quahog logbooks. Note that these values are for the entire Lease Area, not just the WTA. Based on these estimates, surf clams and ocean quahogs composed 72.8% of total revenue for the area followed by sea scallops (20.2%). The remaining two Fishery Management Plan (FMP) groups and roughly 110 species without a federal FMP composed the remaining 7.0% of revenue (Table 2-2).

When aggregated by fishery gear type, clam and scallop dredges composed 93.0% of total revenue followed by bottom trawls, pots (non-lobster), gillnets, purse seines, and a variety of other gear with relatively little total revenue (Table 2-3).

Table 2-2. Total fisheries landings and revenue over the previous Twelve years (2008-2019) aggregated by Fisheries Management Plan (FMP). Modified from NMFS (2020).

| FMP | Twelve Year Total Revenue | Twelve Year Total Landings (Pounds) |
|---|---:|---:|
| Surf Clam, Ocean Quahog | $12,830,000 | 20,087,000 |
| Sea Scallop | $3,563,000 | 433,000 |
| No Federal FMP | $690,000 | 3,970,000 |
| Summer Flounder, Scup, Black Sea Bass | $320,000 | 150,000 |
| Mackerel, Squid, and Butterfish | $221,000 | 382,000 |
| **Total** | **$17,623,000** | **26,023,000** |

Table 2-3. Total fisheries landings and revenue over the previous twelve years (2008-2019) aggregated by gear type.

| Gear Type | Twelve Year Total Revenue | Twelve Year Total Landings (Pounds) |
|---|---:|---:|
| Dredge-Clam | $12,857,000 | 21,091,000 |
| Dredge-Scallop | $3,522,000 | 435,000 |
| Trawl-Bottom | $527,000 | 591,000 |
| Pot-Other | $366,000 | 105,000 |
| Gillnet-Sink | $233,000 | 536,000 |
| Seine-Purse | $235,000 | 2,593,000 |
| All Others | $117,000 | 1,062,000 |
| Gillnet-Other | $36,000 | 70,000 |
| Pot-Lobster | $16,000 | 5,000 |
| Trawl-Midwater | $9,000 | 91,000 |
| Handline | $6,000 | 2,000 |
| **Total** | **$17,924,000** | **26,581,000** |

## 2.5 Survey Selection

### 2.5.1 Monitoring Plan Surveys

Three survey methods are being proposed after significant review of the best available scientific and commercial information (as summarized in Section 2.4 and detailed in Attachment A) and after consultation and coordination with state, federal, and fishing stakeholders. The three surveys types proposed are—clam dredge survey, demersal fish trawl survey, and fish pot survey.

Multiple considerations and approaches (i.e., economic, ecologic, spatial, and stakeholder information) were used to determine which survey gear types will be most appropriate for identifying and confirming the dominant benthic, demersal, and pelagic species using the WTA and establishing a pre-construction baseline which may be used to assess whether detectable changes occur in adherence with BOEM (2019) guidance.

Consideration of fisheries revenue is a quantitative approach that was used to identify the most valuable species from an economic perspective. Given their economic value, ocean quahogs and Atlantic surf clams, and sea scallops warrant survey efforts that can detect changes in their population, i.e., **clam dredge surveys**. It appears that finfish and other invertebrates do not have equal (<7%) commercial output in the area so a survey for these species groups are not justified when solely considering the fisheries dependent data.

Rather than assume that commercial revenue data can accurately represent relative abundance of finfishes and other invertebrates, fisheries independent surveys can provide a better estimate of which species are present in the WTA. Bottom trawl research surveys have widespread current and historical use in the U.S. and Europe as a tool to monitor and assess fish stocks (McCann 2012) and bottom trawls were also the commercial gear type estimated to land the third highest total revenue in the Lease Area over the last 11 years (NMFS 2020). According to 32 tows from the NJDEP ocean stock assessment trawl survey between 2009 to 2019 within the WTA, the five species in the catch with the most biomass were spiny dogfish, Atlantic herring, clearnose skate, northern sea robin, and round herring which composed 65% of total biomass in all trawls despite the presence of 74 other species. The broad catch diversity with biomass concentrated over a few species is typical of trawl surveys and illustrates how a trawl can be effective at detecting the presence (but not absence) of many species in addition to capturing some species regularly enough to detect significant change. In general, a **demersal trawl survey** may be able to detect changes in soft-bottom species abundance especially if effects cause changes throughout the WTA and possibly beyond as noted by Degraer et al. (2013).

Stakeholder input in the form of direct comments from NMFS, NJDEP, and the Atlantic Shores Fisheries Liaison Officer and consideration of the ROSA fisheries monitoring draft guidelines were also incorporated into this draft of the Monitoring Plan. As a direct result of NMFS concerns over the ability of demersal trawl surveys to sample fine spatial scales, a statistical analysis of regional fish pot data was conducted to confirm the viability of a **fish pot survey** due to its fine scale sampling resolution and easy application in a BAG survey design. A need for fine scale sampling resolution is clear, as effects on reef-associated fishes are likely to occur within 20 m of the turbine Wilhelmsson et al. (2006) and a meta-analysis of fisheries monitoring studies found that sampling inside of 20 m is important for detecting increases in both soft-bottom and complex-bottom oriented species (Methratta and Dardick 2019).

Other comments from fisheries managers emphasized the need for monitoring data to supplement information potentially lost due to project interference with existing fisheries-independent surveys. Specifically, it was suggested that the surveys should be focused on collecting biomass information with gear that can be calibrated with the existing fisheries-independent surveys. With this in consideration, the surveys were designed to use existing gear and methodology (i.e., NEAMAP trawl survey, NJDEP funded ventless trap survey, and hybrid of NJDEP and NEFSC clam survey) to facilitate broader application of data.

In summary, after consideration of economic, ecologic, spatial, and stakeholder information, it was determined that a demersal fish trawl survey, fish pot survey, and clam dredge survey were most appropriate for addressing federal guidelines, requirements, and recommendations while remaining reasonably cost-effective.

### 2.5.2 Additional Research

In addition to the surveys outlined in this monitoring plan, Atlantic Shores is funding and coordinating other fisheries research. The current efforts are outlined in this section because they provide complementary information to the fishery monitoring plan surveys. However, due to the nature of the partnerships and study designs, the methods of these additional research projects are not contingent upon the approval of this fisheries monitoring plan and will therefore have greater flexibility for improvement in the future.

#### Surfclams

Atlantic Shores is partnering with Rutgers, The State University of New Jersey, to conduct a multi-phase modeling study in collaboration with the surfclam industry. The goal of the study is to better understand how Mid-Atlantic wind farm developments that are anticipated over the next 30 years, along with climate change, may influence the distribution and abundance of surfclams. The study will also examine the economics of the surfclam fishery within the Atlantic Shores' Lease Area and the greater Mid-Atlantic Bight.

This study builds off Rutgers' existing Spatially explicit, Ecological, agent-based Fisheries and Economic Simulator (SEFES). Developed in partnership with the surfclam industry and fisheries managers, including the Bureau of Ocean Energy Management (BOEM) and the National Marine Fisheries Service (NMFS), SEFES simulates the surfclam fishery in the Mid-Atlantic Bight. The simulator models the surfclam stock biology along with fishery captain and fleet behavior, federal management decisions, fishery economics, port structure, and now, wind farm development.

The model is currently used to address these interactions using present day conditions. However, over the course of the lifetime of planned wind energy installations (~3 decades), projected changes in ocean conditions may lead to changes in surfclam stock distribution that could alter these interactions.

The partnership with Atlantic Shores will increase SEFES' capabilities to assess fisheries and wind development activities from present day to 30 years in the future. The model will not only be able to look at changing conditions across the Mid-Atlantic Bight, but it will also be used to run scenarios that factor in the presence of Atlantic Shores' proposed portfolio of projects within its Lease Area. Atlantic Shores' goal is to better understand the changes in surfclam habitat and abundance within its Lease Area and more accurately understand and mitigate any potential effects on the surfclam industry from the construction and operation of Atlantic Shores' future proposed projects.

#### Artificial Reefs

Atlantic Shores is partnering with Stockton University to research artificial reefs off the coast of New Jersey. One of the main functions for the artificial reef program in New Jersey and throughout the country is to increase habitat for structure-oriented finfish and invertebrate communities. The goal of this project is to utilize acoustic and video observation techniques to document the ecological succession of newly submerged structures while providing a vocational platform for workforce development in the field of hydrography. Central to this effort will be precise 3-D mapping of structures to provide base layers on which to overlay the biological assessments. Surveys will be undertaken using side scan sonar (SSS) and multibeam echosounder (MBES) and direct observations will be conducted by remotely operated vehicle (ROV). While the initial focus is on observing the ecology of artificial reefs, it is anticipated that the project structure and lessons learned will help inform methodologies for monitoring and research needs for future offshore wind developments.

#### Acoustic Antennae

In the fall of 2021, Atlantic Shores installed Innovasea antennae on the 2 existing met ocean buoys in the Lease Area. The antennae will track tagged fishes including pelagic and highly migratory fish species. Atlantic Shores is currently working with the New England Aquarium to ensure the data collected inform not only its Fisheries Monitoring Plan, but also larger research efforts and the public.

# 3 METHODOLOGY

This section details the methodologies for each of the three proposed surveys: The demersal otter trawl survey (Section 3.1) trap survey (Section 3.2), and hydraulic clam dredge survey (Section 3.3). For each survey method the objectives, questions, hypotheses, assumptions, survey design, gear specifications, measurements, sampling operations, and data analyses are detailed. For all methods, references to "season" correspond to the following months (Table 3-1). Proper permitting will be required to perform each type of sampling.

Table 3-1. Seasonal breakdown by month.

| Season | Months |
|---|---|
| Winter | December 1 – February 28 |
| Spring | March 1 – May 31 |
| Summer | June 1 – August 31 |
| Fall | September 1 – November 30 |

## 3.1 Demersal Otter Trawl Survey

*The primary purpose of the trawl survey is to look for significant changes in fish and megainvertebrate communities from project impacts in the form of ecological metrics and presence data.* The secondary purpose of the demersal trawl survey is to detect significant changes in length/weight and diet of dominant benthic species from project impacts. The survey will employ methodology derived from the NEAMAP bottom trawl survey with a modified “beyond BACI” (Underwood 1994) sampling design[1] stratified by distance from impacts (i.e., nearest installed foundation) and sampled so that the results can be analyzed with both traditional BACI statistical tests and BAG design statistical tests.

### 3.1.1 Objectives, Questions, Hypotheses, and Assumptions

The demersal otter trawl survey has been designed to achieve the following **Objectives**:

- Identify and confirm the dominant benthic and demersal species using the Offshore Project Area.
- Establish a pre-construction baseline of benthic and demersal species density in terms of biomass and abundance catch per unit effort (CPUE) and length.
- Measure post-construction benthic and demersal species density and length.
- Collect additional information aimed at reducing uncertainty associated with baseline estimates and/or to inform the interpretation of research results (e.g., stomach contents, temperature, depth, dissolved oxygen, salinity).
- Assess whether detectable changes associated with project operations occurred.
- Collect data that can be used by other research groups (e.g., fishery managers).

The demersal otter trawl survey has been designed to answer the following **Questions:**

Q1: Does the diversity of the fish community change because of project effects? If so, by how much?

Q2: Does the density (i.e., combined CPUE) of fishes change because of project effects? If so, by how much?

Q3: Do the length/weight distributions of fishes change because of project effects? If so, by how much?

Q4: Does the diet of selected fishes change because of project effects? If so, how?

The same independent variables will be used to estimate each dependent variable separately with generalized linear models (GLMs) and generalized additive models (GAMs) to statistically test the following main **Hypotheses:**

---

[1] A “beyond BACI” sampling design is defined as a BACI design with multiple control sites.

$H_0$1: The diversity of the demersal fish community before and after effects does not depend on the strata (i.e., distance from impacts).

$H_0$2: The combined CPUE of dominant demersal fish species before and after effects does not depend on the strata (i.e., distance from effects).

$H_0$3: The lengths/weights of dominant demersal fish species before and after effects does not depend on the strata (i.e., distance from effects).

Additional components in the GLMs/GAMs (see Section 3.1.5) allow for testing of the secondary hypothesis that the dependent variables before and after effects are not dependent on oceanographic conditions.

The survey design, statistical analyses, and power analyses make the following **Assumptions:**

- The time-weighted position of each tow (i.e., weighted average distance from nearest Wind Turbine Generator (WTG) is representative of the distance from effects
- Tow biomass values will be lognormally-distributed
- Tow diversity will be normally distributed
- Predictor-response relationships for continuous variables are linear
- The strata spacing will be sufficient for detecting the full extent of change
- The species assemblages/habitat types within and between strata are statistically similar (i.e., functionally homogenous) based on benthic habitat characterization surveys

### 3.1.2 Survey Design

The trawl survey will follow a “beyond BACI” design (Underwood 1994) modified so that the results can be analyzed with both traditional BACI statistical tests and BAG design statistical tests with two control sites (more appropriately called strata in this case) used to examine interaction of strata and effects status. The effects group (i.e., effects strata) will consist of all tows conducted within 0.9 kilometers (km) (0.5 nautical miles [nm]) of the footprint of the outermost WTGs and OSSs in the WTA. One control group (i.e., “close control strata”) will contain tows outside the WTG footprint with a time-weighted average distance between 0.9 - 2.8 km (0.5 - 1.5 nm) from the nearest turbine and the second control group (i.e., “far control strata”) will contain tows outside the WTG footprint with a time- weighted average distance between 2.8 - 5.6 km (1.5 - 3 nm) from the nearest turbine (Figure 3-1). Each strata (effects and both controls) will be sampled with 9 tows in the winter, spring, summer, and fall based on the power analysis (see Attachment B) for a total of 108 tows per year. Sampling will occur for at least one year prior to construction, during construction wherever feasible, and in the three years post-construction. The dual-analysis hybrid design was selected in response to stakeholder comments about the likely non-independence of strata suggested in the BOEM (2019) guidelines.

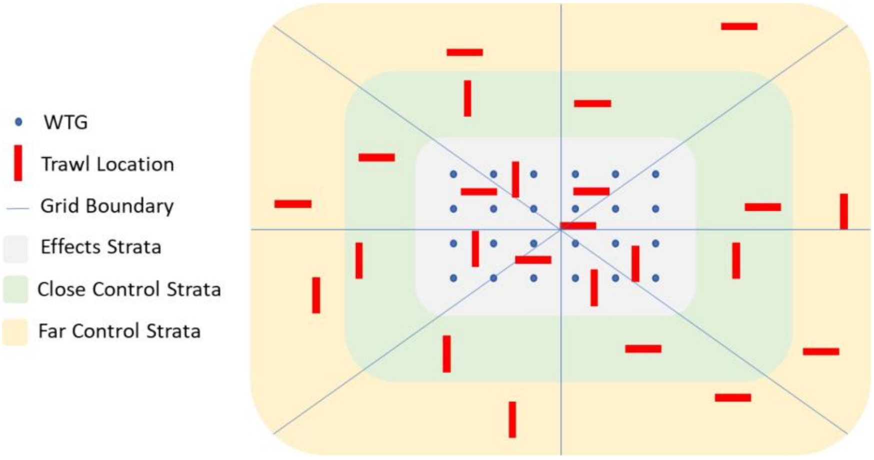

Figure 3-1. Hypothetical diagram of tow locations. Tows (red lines) are randomly located within the bounds of each grid (thin blue line) for each strata (gray, green, and yellow blocks). Note that this image is not to scale and the grid that will be used to select sample locations will be subject to the most likely project design at the time of the survey.

Tow locations for each strata will be chosen using a radially-gridded random approach (i.e., selected from radially delineated substrata with the location within each substrata also randomly chosen) (Figure 3-1). The direction of the tow will be randomly selected from one of four headings. The four headings will match those created by the lanes of the WTA array (i.e., parallel to the two lanes run in either direction). For sampling within the WTA array, tow paths will be conducted down the center of lanes created by the grid-shaped WTA array for both pre- and post-construction surveys. Tow locations selected for the first survey will be repeated for subsequent surveys. In-field adjustments to tow directions within the WTA will be permissible for the sake of safe operation. The time-weighted average distance from effects for each control tow will be calculated.

Sampling will not specifically target the ECCs because sampling in the WTA will cover potential effects of subsea cables. In addition, as described in the Benthic Monitoring Plan (Appendix II-H of the COP), monitoring of benthic communities and habitats will occur along the ECC.

### 3.1.3 Gear Specifications and Mensuration

Trawls will be conducted with the same gear as the NEAMAP trawl survey. The trawl net that will be used is a four-seam, three bridle, 400 cm x 12 cm (157.5 in x 4.7 in) net with a cookie sweep and 1 in knotless liner in the cod end. The fishing circle is 400 meshes of 12 cm (4.7 in), 4 mm braided polyethylene twine (4800 cm fishing circle). At the opening of the net, the head rope length is 20.7 m (68 ft). The total headrope length, including extension chains, hammerlocks, shackles, and combination cable is 24.6 m (80.7 ft) long, with extension cables fully slacked out while fishing. Sixty 20.3 cm (8 in) orange center-hole floats run the length of the headrope. The upper and lower wing ends are made of stainless-steel combination cable and measure 552 cm (217.3 in) and 459 cm (180.7 in) respectively. The footrope length is 24.1 m (79 ft). The total footrope length including hammerlocks, shackles, and extension wires is 27 m (88.6 ft) long. The cod end is made of 12 cm (4.7 in), double 4 mm braided polyethylene with a 2.54 cm (1 in) knotless nylon liner. The flat sweep is made of three sections: The center piece measures 890 cm (29.2 ft), constructed of 1.9 cm (0.75 in) stainless steel wire and is covered with 7.6 cm (3 in) rubber cookies. Each of the two sweep wing sections measure 820 cm (26.9 ft) constructed of 1.9 cm (0.75 in) stainless steel wire covered with 7.6 cm (3 in) rubber cookies. 39 drop chains run the length of the sweep. The top and center bridles each measure 18.3 m (60 ft) long, and the bottom bridle measures 36.6 m (120 ft) long.

The doors will be Thyboron type IV, 167.64 cm (66 in) otter trawl doors with 2.25 $m^2$ (24.2 $ft^2$) area weighing 360 kg (794 lbs). The warp is made of 1.9 cm (0.75 in) diameter steel wire. A Netmind digital trawl net monitoring system will be incorporated with sensors measuring wing spread, vertical net opening, bottom contact, and a catch sensor in the cod end to trip at ~5,000 lbs. Prior to sampling, salinity, temperature, and dissolved oxygen will be measured during a cast to the seafloor with an appropriate oceanographic probe.

The vessel used for the survey will likely be commercially or academically owned. Proper permitting will be completed in accordance with the Magnuson-Stevens Act depending on vessel owner and operator which are unknown at this time.

### 3.1.4 Sampling Operations

Sampling will only occur between 30 minutes after sunrise and 30 minutes before sunset. First, oceanographic conditions will be recorded at each station. Once the tow cable is deployed to a length of at least 3 times the water column depth (3:1 scope) [or more in depths of about 10 m (32.8 ft) or less)], tow duration will be 20 minutes at a speed of 3 knots (kt) (i.e., 2.9-3.3 kt) before hauling back. The tow path will be regularly logged. Once onboard, the catch will be dumped and sorted by species into buckets and baskets unless the tow is deemed a failure.

Tows will be failed and repeated if mensuration equipment detects a substantial deviation limited by thresholds adapted from the NEAMAP survey. These thresholds will include consistent deviation for at least 5 minutes of more than 15% from the midpoint of the optimal range of the vertical net opening and wing spread.

Species identification will be consistent with the Integrated Taxonomy Information System (ITIS) using dichotomous keys as necessary. The total weight of individuals of each species will be measured and the length and weight of all individuals of each species caught, or a representative subsample for large catches, will be measured to the nearest cm before release. Fork or total length, depending on tail shape, will be measured for all fishes except stingrays, which have disk width measured instead. For invertebrates, carapace width will be measured for crabs, carapace length for lobster, mantle length for squid, and shell length for whelks. Catches containing abundant small organisms will be mixed and subsampled by weight. The mixed subsample will be sorted and measured, and species components later extrapolated, based upon the composition of the subsample.

A subset of fishes will be selected for biotic sampling. A maximum of five stomachs per targeted species will be collected within each stratum each season and processed using NEAMAP methods. A maximum of 10 stomachs will be collected per tow. The targeted species will be the “A” priority species from the NEAMAP survey: black sea bass, bluefish, pollock, scup, silver hake, striped bass, summer flounder, weakfish, and winter flounder (Bonzek et al. 2008). Selected individuals will also be checked for sex and reproductive status using NEAMAP protocols and body parts that are used to determine age (ear bones or scales) will be archived without processing and made available upon request for collaborative research.

Bycatch reduction gear and methods will be used wherever possible and protected species encounters will be reported through the proper channels with the following considerations from the National Marine Fisheries Service Protected Species Best Management Practices and Risk Reduction Measures for Offshore Wind Fisheries Surveys:

- Protected species interaction will be reported according to guidance provided by the NMFS Greater Atlantic Region Fisheries Office’s (GARFO) Protected Resources Division (PRD).
- Missing fishing gear will be reported to nmfs.gar.incidental-take@noaa.gov.
- The survey will comply with ESA and MMPA regulations (e.g., Marine Mammal Authorization Program requirements, Atlantic Large Whale Take Reduction Program, Harbor Porpoise Take Reduction Program, or Bottlenose Dolphin Take Reduction Program regulations).
- The survey will comply with the Atlantic Trawl Take Reduction Strategy measures to reduce the risk of interactions between small cetaceans and trawl (bottom or mid-water) gear.
- To minimize the introduction of additional trawl effort, partnering with a local bottom trawl commercial fisher will be strongly considered.

### 3.1.5 Data Analysis

An *a priori* power analysis was conducted to determine the number of samples required to detect a change in the diversity of fishes. A second power analysis was conducted to determine the number of samples required to detect a change in the all-species biomass density measured by the indicator, CPUE. For this survey CPUE refers specifically to the catch per standardized tow. When conducting a statistical test, power is the probability of correctly rejecting the null hypothesis. The power analyses were completed by generating datasets containing observations from multiple distances from the effects both before and after simulated effects and fitting a GLM with categorical and continuous variables as described in Attachment B. These power analyses used a conservative approach by assessing power using one year of baseline data compared to one year of post-effects data.

Once real data are collected for multiple years using standard formats, two separate analytical approaches will be applied: one with a BACI approach and one with a BAG approach. For the BACI approach, a GLM that has tow diversity as the dependent variable will be used to determine if significant changes occurred from project effects. Specifically, the *p value* for the “treatment:location” interaction term will be evaluated at an alpha level of 0.05 for significance to assess the null hypothesis ($H_{o1}$) by determining if the diversity-location relationship was different after construction occurred. GLMs using CPUE and organism lengths as dependent variables will also be used in the same manner to assess the other null hypotheses (i.e., $H_{o2}$ and $H_{o3}$ respectively). For the BAG approach, a GAM that has tow diversity as the dependent variable will be used to determine if significant changes occurred from project effects. Specifically, the *p value* for the “treatment(after): distance” interaction term will be evaluated at an alpha level of 0.05 for significance to assess the null hypothesis ($H_{o1}$) by determining if the diversity-location relationship was different after construction occurred. GAMs using organism lengths as the dependent variable will also be used in the same manner to assess the other null hypothesis (i.e., $H_{o2}$ and $H_{o3}$). See Attachment B for more information about model structure and inputs as well as other covariates that will be tested.

In addition to statistical modelling, data visualization will be provided through multidimensional scaling plots of Bray-Curtis dissimilarity to compare species composition between sites. Analysis of similarities (ANOSIM) and analysis of similarity percentages (SIMPER) will provide supplementary quantitative assessment of multidimensional similarity of catches between groupings (e.g., treatments and location). PERMANOVA will also be applied to stomach content data.

## 3.2 Trap Survey

*The purpose of the trap (i.e., fish pot) survey is to be able to detect significant changes in the presence and size of dominant structure-associated species from cumulative project effects and assess the spatial extent of cumulative effects.* The survey will employ a BAG survey design using methodology and gear adapted from a Rutgers and NJDEP trap survey of artificial reefs offshore New Jersey (Jensen et al. 2018) and visual imagery using camera methods modified from Bacheler et al. (2014).

### 3.2.1 Objectives, Questions, Hypotheses, and Assumptions

The trap survey has been designed to achieve the following **Objectives**:

- Identify and confirm dominant structure-associated fish and invertebrate species within the WTA.
- Establish a pre-construction baseline of structure-associated species densities (CPUE) and lengths.
- Measure post-construction structure-associated species densities and lengths.
- Collect additional information aimed at reducing uncertainty associated with baseline estimates and/or to inform the interpretation of research results including visual observations.
- Assess whether detectable changes associated with project operations occurred.
- Collect data that can be used by other research groups (e.g., fishery managers).

The trap survey has been designed to answer the following **Questions:**

Q1: Does the density (i.e., CPUE) of structure-associated species change because of project effects? If so, by how much?

Q2: Do the length/weight distributions of local structure associated species change because of project effects? If so, by how much?

Q3: Does the diversity of structure-associated species change because of project effects? If so, by how much?

The same independent variables will be used to estimate each dependent variable separately with generalized additive models (GAMs) or Generalized Additive Mixed Models (GAMMs) to statistically test the following main **Hypotheses:**

$H_{o1}$: The CPUE of structure-associated “fishes” before and after effects does not depend on the distance from effects (i.e., WTGs).

$H_{o2}$: The lengths/weights of structure-associated “fishes” before and after effects does not depend on the distance from effects.

$H_{o3}$: The diversity of structure-associated “fishes” before and after effects does not depend on the distance from effects.

The survey design, statistical analyses, and power analyses make the following **Assumptions:**

- Catch abundances can be represented by a negative binomial distribution.
- A change in local abundance will be reflected in CPUE (in at least a roughly proportional manner).
- The trap spacing will be sufficient for detecting the full extent of the gradient of change.
- The habitat types within and between transects are statistically similar (i.e., functionally homogenous) based on benthic habitat characterization surveys.
- Due to the absence of local winter catch data, the same sample size for the other seasons (i.e., spring, summer, and fall) as determined by the power analysis will be sufficient for winter sampling efforts.

### 3.2.2 Survey Design

The trap survey will follow a “BAG” design with sample sites located at regular distances from WTG or OSS locations (Figure 3-2). A literature review revealed no precedent for an environmental monitoring fish trap survey using a BAG design, so this survey was designed with consideration of other survey types based on the design of Ellis and Schneider (1997). The first trap in a trawl will be set as close to the WTG (or planned WTG location for baseline survey) as safely as possible (roughly 20 m) with remaining traps set at nearly logarithmic intervals of about 15 m (50 ft), 50 m (164 ft), 150 m (492 ft), 400 m (1,312 ft), and 1,100 m (3,608 ft) from the first trap (further referred to as a “transect”). The location of the furthest trap is limited by the shortest midpoint between two turbines. The logarithmic spacing was chosen to concentrate sampling near the WTGs where fish aggregation has been observed in offshore structures (typically less than 100 m) (Aabel 1997, Stanley and Wilson 2020, Griffin et al. 2016, Soldal et al., 2002, Lokkeborg et al., 2002, Valdemarsen, 1979). Transect locations in the WTA will be selected by randomly choosing a WTG or OSS within a block (number of blocks pending construction design), then randomly choosing an orientation to the WTG or OSS (0-359 degrees). Transect locations selected for the first survey will be repeated for subsequent surveys. The actual locations are expected to vary slightly. Transect locations along the ECC will be excluded because this trap survey is intended to target structure-oriented species. Twelve transects of six traps will be left to soak for two, one-week (5-7 day) periods in each of four seasons (winter, spring, summer, and fall) for a total of 72 traps sampled eight times per year which translates to an expected 576 trap fishing weeks per year given no gear loss based on the power analysis (see Attachment B). Sampling will occur for at least one year prior to construction, during construction wherever feasible, and in the three years post-construction.

Cameras will be added to each trap in one transect each sampling period. The selected transect will be the same throughout the survey. If camera failure is common, this portion of the survey will be modified or eliminated.

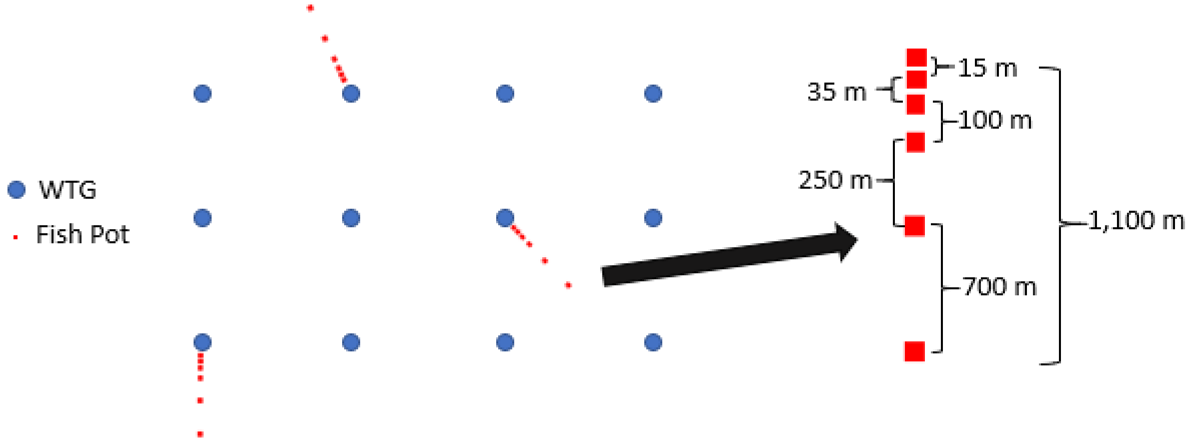

Figure 3-2. Hypothetical diagram of trap locations. The trap locations (red squares) and orientations are randomly selected within the wind turbine area. Note that this image is not to scale and the WTG locations that will be used to select sample locations will be subject to the most likely project design at the time of the baseline survey.

### 3.2.3 Gear Specifications and Mensuration

Unbaited ventless traps with dimensions of 110.5 cm x 56 cm x 38 cm (43.5 in x 22 in x 15 in) with 3.8 cm (1.5 in) mesh will be the applied sampling gear for this survey. Each trap will be deployed in a trawl attached to a groundline to prevent gear loss and protected species entanglement. Temperature loggers will be affixed to a trap in each trawl. The camera applied for this survey will have a viewing width of approximately 60° with appropriate underwater housing and settings comparable to Bacheler et al. 2014. The camera will be affixed to the trap facing outward above the entrance. Exact positioning of the camera will remain consistent throughout the survey and be recorded in the metadata.

The vessel used for the survey will likely be commercially or academically owned. Proper permitting will be completed in accordance with the Magnuson-Stevens Act depending on vessel owner and operator which are unknown at this time.

### 3.2.4 Sampling Operations

The GPS position of each sampling site will be recorded as each trap is set and recovered to allow for calculation of distance from nearest effects. Once all unbaited traps are set, they will be allowed to soak for two periods of 5-7 days (weather dependent). Data will be standardized to these 1 week (5-7 day) sets and 1 trap fishing for one 5-7 day period will be equivalent to one “trap fishing week”.

Each time the traps are hauled in, the total weight of individuals of each species will be measured and the length and weight of all individuals of each species caught, or a representative subsample for large catches, will be measured to the nearest cm before release. Species identification will be consistent with the Integrated Taxonomy Information System (ITIS) using dichotomous keys as necessary. Fork or total length, depending on tail shape, will be measured for all fishes. For invertebrates, carapace width will be measured for crabs and carapace length for lobster and the sex and shell disease severity will be recorded.

Internal-anchor floy tags will be properly inserted into a subset of fishes in collaboration with an existing tagging program to acquire information about spatial movements, growth rates, and potential application of mark-recapture analyses. Tag data is not currently planned to be analyzed by Atlantic Shores but will be made publicly available through the tagging partner or as described in Section 4. Biotic sampling (stomach contents, invasive sex determination, aging, etc.) is not currently planned because it does not assess the survey objectives and leads to mortality but could be included as part of collaborative research. In addition, individuals that have remained in traps for multiple days could have biased stomach contents. Individuals measured for length/weight will be gently rubbed/squeezed to look for ripe/running status and corresponding sex.

Cameras will be left on the trap to record video until the camera memory or battery runs out and data will be recovered after the full trap soak time. Only imagery from minute 10 to minute 30 after trap settlement on the sea floor will be included in data analyses with a one second clip analyzed every 30 seconds for a total of 41 clips per trap (i.e., 246 clips per transect) per sampling event. The average number of individuals of each species in the 41 snapshots (i.e., MeanCount) will be the CPUE value for this part of the survey. Substrate, relief, biota, and current direction will be recorded as described in Bacheler et al. (2014).

Bycatch reduction gear and methods will be used wherever possible and protected species encounters will be reported through the proper channels with the following considerations from the National Marine Fisheries Service Protected Species Best Management Practices and Risk Reduction Measures for Offshore Wind Fisheries Surveys:

- Protected species interaction will be reported according to guidance provided by the NMFS GARFO PRD.
- Missing fishing gear will be reported to nmfs.gar.incidental-take@noaa.gov.
- The survey will comply with ESA and MMPA regulations (e.g., Marine Mammal Authorization Program requirements, Atlantic Large Whale Take Reduction Program, Harbor Porpoise Take Reduction Program, or Bottlenose Dolphin Take Reduction Program regulations).
- There will be no wet storage[2] of gear. All gear needs will be removed from the water between surveys.
- The number of vertical lines used will be reduced by the use of ropeless gear.
- Biodegradable components will be used wherever possible to reduce fishing time for ghost gear.

---

[2] Per ALWTRP regulations, in the Northeast Region, all gear must be hauled out of the water at least once every 30 days.

### 3.2.5 Data Analysis

An *a priori* power analysis was conducted to determine the number of samples required to detect a change in the CPUE of commercially and recreationally important structure associated species (i.e., black sea bass, tautog, American lobster, Jonah crab, and rock crab). For this survey, CPUE refers specifically to the rounded up whole number of individuals caught after the standard 5-7 days of soak time. The power analyses were completed by generating datasets containing observations from multiple distances from the WTGs both before and after construction and fitting a GAM with categorical and continuous variables and a smoothing parameter for distance as described in Attachment B. These power analyses used a conservative approach by assessing power using one year of baseline data compared to one year of post-effects data.

Once real data are collected for multiple years using standard formats, a GAM or GAMM that has CPUE (from trap catches and imagery separately) as the dependent variable will be used to determine if significant changes occurred from project effects. Specifically, the *p value* for the “treatment(after): distance” interaction term will be evaluated at an alpha level of 0.05 for significance to assess the null hypothesis ($H_{o1}$) by determining if the CPUE-location relationship was different after construction occurred. GAMs or GAMMs using organism lengths as the dependent variable will also be used in the same manner to assess the other null hypotheses (i.e., $H_{o2}$ and $H_{o3}$). Whether a GAM or GAMM is applied will depend on assumptions about the independence of traps within each sample transect. See Attachment B for more information about model structure and inputs as well as other covariates that will be tested.

In addition to statistical modelling, data visualization will be provided through multidimensional scaling plots of Bray-Curtis dissimilarity to compare structure associated species composition between sites. Analysis of similarities (ANOSIM) and analysis of similarity percentages (SIMPER) will provide supplementary quantitative assessment of multidimensional similarity of catches between groupings (e.g., treatments and distance) and across the sampling area.

## 3.3 Hydraulic Clam Dredge Survey

*The purpose of the clam dredge survey is to be able to detect significant changes in the presence and size of ocean quahogs and Atlantic surf clams from cumulative project effects.* The survey will employ a dredge matching the NJDEP surf clam survey gear and using NEFSC clam dredge survey methodology at sample locations chosen to follow a modified "beyond BACI" design (Underwood 1994).

### 3.3.1 Objectives, Questions, Hypotheses, and Assumptions

The clam dredge survey has been designed to achieve the following **Objectives**:

- Confirm Atlantic surf clams and ocean quahogs are using the WTA.
- Establish a pre-construction baseline of Atlantic surf clam and ocean quahog distribution, abundance, size, and age.
- Measure post-construction Atlantic surf clam and ocean quahog distribution, abundance, size, and age.
- Collect additional information aimed at reducing uncertainty associated with baseline estimates and/or to inform the interpretation of research results.
- Assess whether detectable changes associated with project operations occurred.
- Collect data that can be used by other research groups (e.g., fishery managers).

The clam dredge survey has been designed to answer the following **Questions:**

Q1: Do the densities (i.e., CPUE) of Atlantic surf clams and ocean quahogs change because of project effects? If so, by how much?

Q2: Do the sizes and sizes-at-age of Atlantic surf clams and ocean quahogs change because of project effects? If so, by how much?

Q3: Does the distribution of Atlantic surf clams and ocean quahogs change because of project effects? If so, how?

The same independent variables will be used to estimate each dependent variable separately with GLMs and GAMs to statistically test the following main **Hypotheses:**

$H_0$1A: The CPUE of Atlantic surf clams before and after effects does not depend on the distance from effects.

$H_0$1B: The CPUE of ocean quahogs before and after effects does not depend on the distance from effects.

$H_0$2A: The lengths/weigts/size-at-age of Atlantic surf clams before and after effects does not depend on the distance from effects.

$H_0$2B: The lengths/weights/size-at-age of ocean quahogs before and after effects does not depend on the distance from effects.

The survey design, statistical analyses, and power analyses make the following **Assumptions:**

- The time-weighted position of each tow (i.e., weighted average distance from nearest WTG) is representative of the distance from effects.
- Abundance per tow can be approximated by a negative binomial distribution.
- Predictor-response relationships for continuous variables are linear.
- The strata delineation spacing will be sufficient for detecting the full extent of change.
- The habitat types within and between strata are statistically similar (i.e., functionally homogenous) based on benthic habitat characterization surveys.

### 3.3.2 Survey Design

The dredge survey will follow a “beyond BACI” design (Underwood 1994) modified so that the results can be analyzed with both traditional BACI statistical tests and BAG design statistical tests with two control sites (more appropriately called strata in this case) used to examine interaction of strata and effects status. The effects group (i.e., effects strata) will consist of all tows conducted within 0.9 kilometers (km) (0.5 nm) of the footprint of the outermost wind turbine generators (WTGs) and offshore substations (OSSs) in the WTA. One control group (i.e., “close control strata”) will contain tows outside the WTG footprint with a time-weighted average distance between 0.9 - 2.8 km (0.5 - 1.5 nm) from the nearest turbine and the second control group (i.e., “far control strata”) will contain tows outside the WTG footprint with a time-weighted average distance between 2.8 - 5.6 km (1.5 - 3 nm) from the nearest turbine (Figure 3-3). Each strata (effects and both controls) will be sampled with 16 tows (48 total) once a year in the summer based on the power analysis (see Attachment B) Sampling will occur for at least one year prior to construction, during construction wherever feasible, and in the three years post-construction. The dual-analysis hybrid design was selected in response to stakeholder comments about the likely non-independence of strata suggested in the BOEM (2019) guidelines.

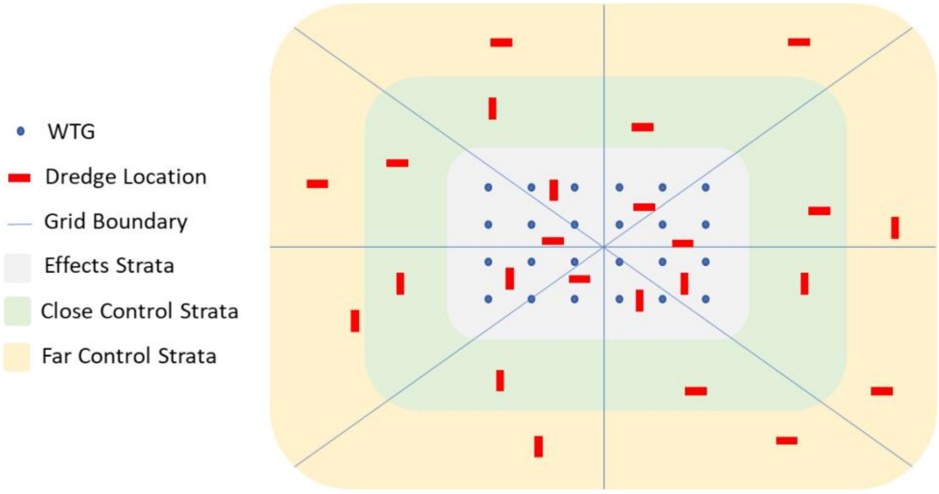

Figure 3-3. Hypothetical diagram of dredge locations. Tows (red lines) are randomly located within the bounds of each grid (thin blue line) for each strata (gray, green, and yellow blocks). Note that this image is not to scale and the grid that will be used to select sample locations will be subject to the most likely project design at the time of the survey.

Tow locations for each strata will be chosen using a radially gridded random approach (i.e., selected from radially delineated substrata with the location within each substrata also randomly chosen) (Figure 3-3). The direction of the tow will be randomly selected from one of four headings. The four headings will match those created by the lanes of the WTA array (i.e., parallel to the two lanes run in either direction). For sampling within the WTA array, tow paths will be conducted down the center of lanes created by the grid-shaped WTA array for both pre- and post-construction surveys and tows that would cross over buried cables will be removed. Tow locations selected for the first survey will be repeated for subsequent surveys. In-field adjustments to tow directions within the WTA will be permissible for the sake of safe operation. The time-weighted average distance from effects for each control tow will be calculated.

Sampling will not specifically target the ECC because sampling in the WTA will cover potential effects of subsea cables. In addition, as described in the Benthic Monitoring Plan (Appendix II-H of the COP), monitoring of benthic communities and habitats will occur along the ECC.

### 3.3.3 Gear Specifications and Mensuration

Sampling will be conducted with the same dredge gear as the NJDEP inventory of New Jersey's surf clam resources survey (NJDFW 2010) because it uses a dredge that is smaller (183 cm [72 in]) and more maneuverable than the NMFS clam survey dredge (396 cm [156 in]). Maneuverability is important for safety while operating in and around the WTA. The dredge will have the knife depth set at 5 inches. The floor, door and storage end will be lined with 51 mm (2 in) by 51 mm mesh. Pump water pressure will be 90 $\text{lbs/in}^2$.

The vessel used for the survey will likely be commercially or academically owned. Proper permitting will be completed in accordance with the Magnuson-Stevens Act depending on vessel owner and operator which are unknown at this time.

The dredge will be outfitted with an inclinometer and two pressure sensors (depth and pump pressure) and will record temperature. Onboard sensors will record GPS position, heading, and speed.

### 3.3.4 Sampling Operations

Once the tow cable is deployed to an appropriate length based on the water column depth (fixed scope ratio), tow duration will be 5 minutes at a speed of 3 knots kt before hauling back. The tow path will be regularly logged and tow duration will be recorded. Once onboard, the catch will be processed unless the tow is deemed a failure.

Tows will be failed and repeated if mensuration equipment detects a substantial deviation. Effective fishing time will be later calculated based on inclinometer data.

The total weight of individuals of each species will be measured and the length of all individuals of each species caught, or a representative subsample by weight for large catches, will be measured to the nearest mm. In addition to lengths, meat weights will be appropriately measured in subsets of catch. Length-based subsets of clams will be processed each year to determine sizes-at age.

Non-protected species bycatch will also be processed with NMFS clam dredge survey methods (i.e., identified, counted, weighed).

Bycatch reduction gear and methods will be used wherever possible and protected species encounters will be reported through the proper channels with the following considerations from the National Marine Fisheries Service Protected Species Best Management Practices and Risk Reduction Measures for Offshore Wind Fisheries Surveys:

- Protected species interaction will be reported according to guidance provided by the NMFS GARFO PRD.
- Missing fishing gear will be reported to nmfs.gar.incidental-take@noaa.gov.
- The survey will comply with ESA and MMPA regulations (e.g., Marine Mammal Authorization Program requirements, Atlantic Large Whale Take Reduction Program, Harbor Porpoise Take Reduction Program, or Bottlenose Dolphin Take Reduction Program regulations).
- The survey will comply with the Atlantic Trawl Take Reduction Strategy measures to reduce the risk of interactions between small cetaceans and tow (bottom or mid-water) gear.

### 3.3.5 Data Analysis

Based on power analyses of the existing data in the region (see Attachment B), a hydraulic dredge survey will only be able to detect very large changes (i.e., effect size) in CPUE (of abundance for this section) without employing an unreasonable number of tows. It is possible that increased sampling resolution from the first year of sampling will provide better data that suggests smaller effect sizes will be detectable so an adaptive approach will be used to reevaluate the power analysis and sample size after the first round of sampling.

Once real data are collected for multiple years using standard formats, two separate analytical approaches will be applied: one with a BACI approach and one with a BAG approach. For the BACI approach, a GLM that has CPUE as the dependent variable will be used to determine if significant changes occurred from project effects. Specifically, the *p value* for the "treatment:location" interaction term will be evaluated at an alpha level of 0.05

for significance to assess the null hypothesis ($H_{o1}$) by determining if the CPUE-location relationship was different after construction occurred. GLMs using the dependent variable “size” will also be used in the same manner to assess the other null hypothesis (i.e., $H_{o2}$). For the BAG approach, a GAM that has CPUE as the dependent variable will be used to determine if significant changes occurred from project effects. Specifically, the *p value* for the “treatment(after): distance” interaction term will be evaluated at an alpha level of 0.05 for significance to assess the null hypothesis ($H_{o1}$) by determining if the CPUE-location relationship was different after construction occurred. GAMs using the dependent variable “size” will also be used in the same manner to assess the other null hypothesis (i.e., $H_{o2}$). See Attachment B for more information about model structure and inputs as well as other covariates that will be tested.

# 4 DATA STORAGE AND ACCESS

Annual survey reports describing fishery monitoring plan sampling and results will be made available online. In addition, it is Atlantic Shore’s intention to make raw data publicly available in a way that maintains data integrity and interpretability. An exact data sharing platform or procedure will be selected in accordance with anticipated future guidance and opportunities for regional data sharing and formatting led by organizations such as ROSA. If no sharing platform is developed by the time data is ready for dissemination, data will be provided through written requests or automated queries. Survey reports and shared raw data and metadata will require adequate lead time for review, QAQC, and possibly collaborator publication in some cases.

# 5 SUMMARY

Three monitoring surveys will be conducted to answer research questions and test hypotheses focused on potential effects from project activities in the WTA. These surveys include a demersal otter trawl survey, fish trap survey, and hydraulic clam dredge survey that were designed after consideration of diverse inputs (Table 5-1). The survey designs are based on scientific best practices and sample sizes are backed by power analyses. Findings will be summarized in post-survey technical reports with a series of supporting tables and figures for each monitoring program documenting results and drawing comparisons with previous monitoring surveys, other related survey data, and relevant desktop studies. The focus of the technical reports will be testing the defined hypotheses. Hypothesis testing will be completed using proper statistical analysis, with emphasis on statistical modelling with GLMs and GAMs. This draft plan will be implemented in support of both Projects. Individual plans for Project 1 and Project 2 will be developed for BOEM review and acceptance prior to construction with each Project’s Facility Design Report and/or Fabrication and Installation Report.

Table 5-1. Proposed fisheries monitoring surveys for the WTA.

| Survey | Parent Survey Protocol/Gear | Samples per Year | Samples per Stratum Per Event | Seasons Sampled | Years Sampled | Design | Key Metrics | Primary Statistical Analysis |
|---|---|---|---|---|---|---|---|---|
| Demersal Otter Trawl Survey | NEAMAP Trawl Survey | 108 Tows | 9 Tows | Winter, Spring, Summer, Fall | Pre-construction, Mid-construction, Year 1 post-construction, Year 2 post-construction, Year 3 post-construction | BAG/ “Beyond BACI” hybrid | Diversity, CPUE, Size, stomach contents | GLM/GAM |
| Ventless Trap Survey | NJDEP Artificial Reef Survey | 576 Trap Fishing Weeks | 144 Trap Fishing Weeks | Winter, Spring, Summer, Fall | | BAG | CPUE, Size | GAM/GAMM |
| Hydraulic Clam Dredge Survey | NEFSC Clam Survey/NJDEP Surf Clam Survey | 48 Tows | 16 Tows | Summer | | BAG/ “Beyond BACI” hybrid | CPUE, Size, Age | GLM/GAM |

# 6 REFERENCES

Aabel, J.P., Cripps, S., Jensen, A., and Picken G. 1997. Creating artificial reefs from decommissioned platforms in the north sea: review of knowledge and proposed programme of research.

Bacheler N.M., Berrane D.J., Mitchell W.A., Schobernd C.M, Schobernd Z.H., Teer B.Z., Ballenger J.C. 2014. Environmental conditions and habitat characteristics influence trap and video detection probabilities for reef fish species. Mar Ecol Prog Ser 517:1-14.

Bonzek, C. F., Gartland, J., Johnson, R. A., & Lange Jr, J. D. 2008. NEAMAP Near Shore Trawl Survey: Peer Review Documentation. A report to the Atlantic States Marine Fisheries Commission by the Virginia Institute of Marine Science, Gloucester Point, Virginia.

Borden, C., Skrobe, L., & Cadrin, S.X. 2013. Industry Based Survey on Black Sea Bass Utilizing Ventless Traps. Final Report to the NOAA Northeast Fisheries Science Center, NOAA Grant No. NA12NMF4540018.

Bureau of Ocean Energy Management (BOEM). 2019. Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585. June 2019. BOEM Office of Renewable Energy Programs, US Department of the Interior. 14 pp.

Degraer, S., Brabant, R., & Rumes, B. (Eds). 2013. Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Learning from the Past to Optimise Future Monitoring Programmes. Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management Section. 239 pp.

Ellis, J. I., & Schneider, D. C. 1997. Evaluation of a Gradient Sampling Design for Environmental Impact Assessment. Environmental Monitoring and Assessment, 48: 157–172.

Green, R. H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley and Sons: New York, NY

Griffin, R.A., Robinson, G.J., West, A., Gloyne-Phillips, I.T. and Unsworth, R.K., 2016. Assessing fish and motile fauna around offshore windfarms using stereo baited video. PLoS One, 11(3), p.e0149701.

Hastie, T. J., & Tibshirani, R. J. 1990. Generalized Additive Models. Chapman & Hall/CRC. ISBN 978-0-412-34390-2.

Jensen, O.P., Zemeckis, D., & Clarke, P. 2018. Year 3 Report: A Pilot Trap Survey of Artificial Reefs in New Jersey for Monitoring of Black Sea Bass, Tautog, and Lobster. Submitted to the New Jersey Department of Environmental Protection, Division of Fish and Wildlife*. 32 pp.*

Lambert, G.I.,. Murray, L.G., . Hiddink, J.G., Hinz, H. Lincoln, H., Hold, N., Cambie, G., & Kaiser M.J. 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.

Løkkeborg, S., Humborstad, O.B., Jørgensen, T. and Soldal, A.V., 2002. Spatio-temporal variations in gillnet catch rates in the vicinity of North Sea oil platforms. ICES Journal of Marine Science, 59(suppl), pp.S294-S299.

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.

Methrata, E.T. 2020. Monitoring Fisheries Resources at Offshore Wind Farms: BACI vs. BAG designs. ICES Journal of Marine Science, 77: 890-900.

Methratta, E.T. &Dardick, W.R. 2019. Meta-Analysis of Finfish Abundance at Offshore Wind Farms. Reviews in fisheries science & aquaculture 27: 242–260.

National Marine Fisheries Service (NMFS). 2020. Socioeconomic Impacts of Atlantic Offshore Wind Development. Available online at https://www.fisheries.noaa.gov/resource/data/socioeconomic-impacts-atlantic-offshore-wind-development Accessed June 24, 2021.

New Jersey Division of Fish and Wildlife. 2010. Inventory of New Jersey's surf clam (Spisula solidissima) resource. 3-IJ-236. 275 pp.

Pomeroy, R., & Douvre, F. 2008. The Engagement of Stakeholders in the Marine Spatial Planning Process. Marine Policy, 32: 816-822.

Roa-Ureta, R.H., Santos, M.N., & Leitão, F. 2019 Modelling Long-Term Fisheries Data to Resolve the Attraction Versus Production Dilemma of Artificial Reefs. Ecological Modelling 407:1-12.

ROSA, 2021. Offshore Wind Project Monitoring Framework and Guidelines March 2021. 55 pp.

Shannon, C. E. 1948. A mathematical Theory of Communication. The Bell System Technical Journal, 27, 379–423 and 623–656.

Soldal, A.V., Svellingen, I., Jørgensen, T. and Løkkeborg, S., 2002. Rigs-to-reefs in the North Sea: hydroacoustic quantification of fish in the vicinity of a "semi-cold" platform. ICES Journal of marine Science, 59(suppl), pp. S281-S287.

Stanley, D.R. and Wilson, C.A. 2000. Seasonal and spatial variation in the biomass and size frequency distribution of fish associated with oil and gas platforms in the northern Gulf of Mexico. OCS Study MMS 2000-005. Prepared by the Coastal Fisheries Institute, Center for Coastal, Energy and Environmental Resources Louisiana State University . U.S. Dept . of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, LA 252pp.

Stewart-Oaten, A., Murdoch, W. W., & Parker, K. R. 1986. Environmental Impact Assessment: "Pseudoreplication" in Time? Ecology, 67: 929–940.

Underwood, A. J. 1994. On beyond BACI: Sampling Designs that Might Reliably Detect Environmental Disturbances. Ecological Applications, 4: 3–15.

Valdemarsen, J.W., 1979. Behaviour aspects of fish in relation to oil platforms in the North Sea. ICES.

Wilhelmsson, D., Malm, T., & Ohman, M. 2006. The Influence of Offshore Windpower on Demersal Fish. ICES Journal of Marine Science, 63: 775–784.

Wood, S.N. 2017. Generalized Additive Models: An Introduction with R (2nd ed.). CRC Press. https://doi.org/10.1201/9781315370279. 496 pp.

# 7 ATTACHMENTS

# Attachment A - Pre-existing Surveys

## A.1 Demersal Trawl Surveys

A demersal otter trawl is a roughly conical net that is dragged behind a vessel along the seafloor with two “doors” that are located further up the net tow lines to spread the mouth of the net as it is fished. These nets can be equipped with mensuration equipment/sensors to confirm and calibrate the efficiency of each tow for reliable standardized results. There are three known relevant timeseries of trawl data with appropriate data quality, relevant and repeatable survey design, and proximity to the Offshore Project Area (WTA and ECCs). None of the existing surveys could adequately detect fine scale changes in fish assemblages from project effects throughout the entire Offshore Project Area if they were to continue to operate under their current design, but they can provide informative baseline data and replicable sampling methodology. Although demersal trawls are documented to have variable catchability between species and are better suited for monitoring demersal species, they can effectively capture more species than most other fishing gear types and are therefore commonly employed in monitoring efforts.

### A.1.1 NJDEP Ocean Stock Assessment Trawl Survey

The NJDEP Trawl Survey conducts tows annually in state and federal waters as part of five survey periods during the winter, spring, summer, and fall. A total of 89 tows overlapped with the western and northern portions of Lease Area OCS-A 0499 (Lease Area) between 2009 and 2019 with 32 tows occurring within the WTA and additional tows conducted within or near potential ECCs (Figure A-1). Spiny dogfish, Atlantic herring, clearnose skate, northern sea robin, and round herring were the five species with the most biomass caught in the 32 tows within the WTA, which composed 65% of total biomass in all trawls despite the presence of 74 other species. This survey has the largest known overlap with the Offshore Project Area and can provide the most relevant data for designing an otter trawl monitoring survey, so it was used to conduct a power analysis examining trawl survey sample size.

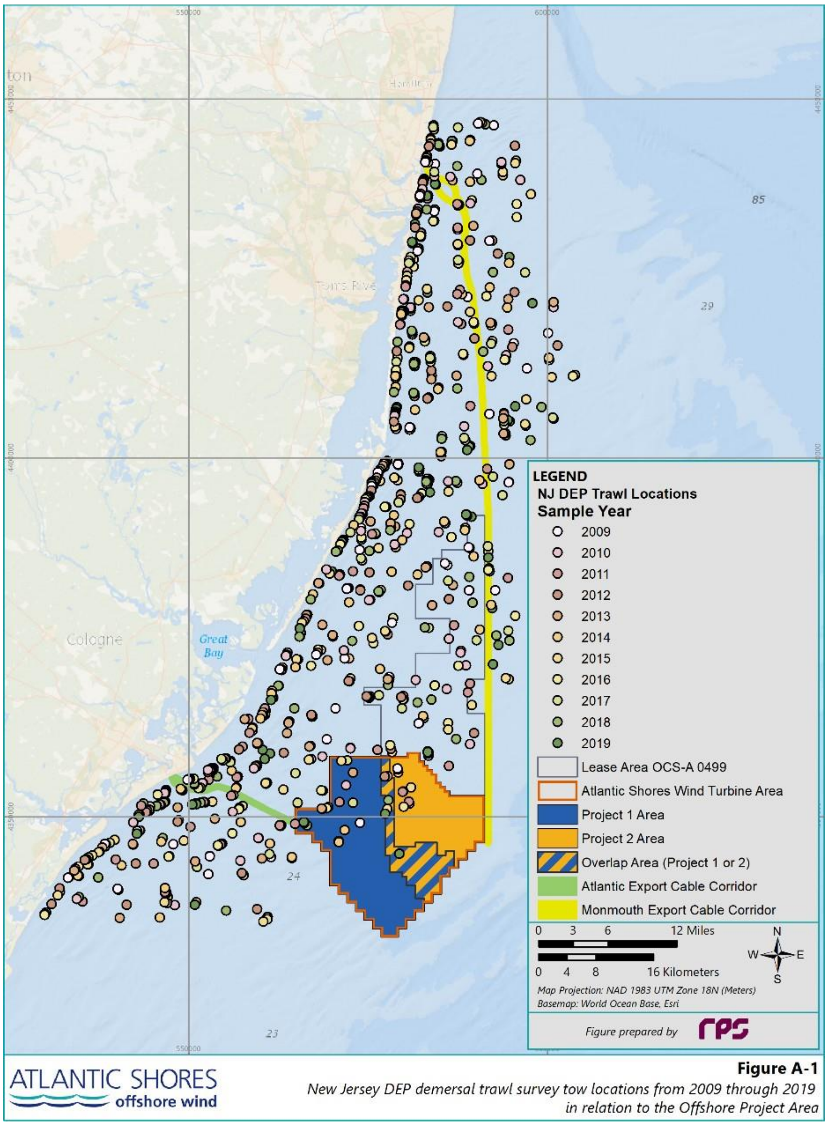

Figure A-1. New Jersey DEP demersal trawl survey tow locations from 2009 through 2019 in relation to the Offshore Project Area.

## A.1.2 NEAMAP Trawl Survey

The Northeast Monitoring and Assessment (NEAMAP) demersal trawl survey conducts tows annually in state and federal waters of the northeast U.S. during the spring and fall. No tows overlapped with the WTA between 2009 and 2019 with some tows conducted within or near potential ECCs (Figure A-2). This survey is conducted with a relatively high sampling density but is not sufficiently close to the WTA to fulfil monitoring requirements. In addition, this survey does not provide winter or summer sampling data to fully investigate seasonality. The methodology from this survey is being applied by at least one other offshore wind developer.

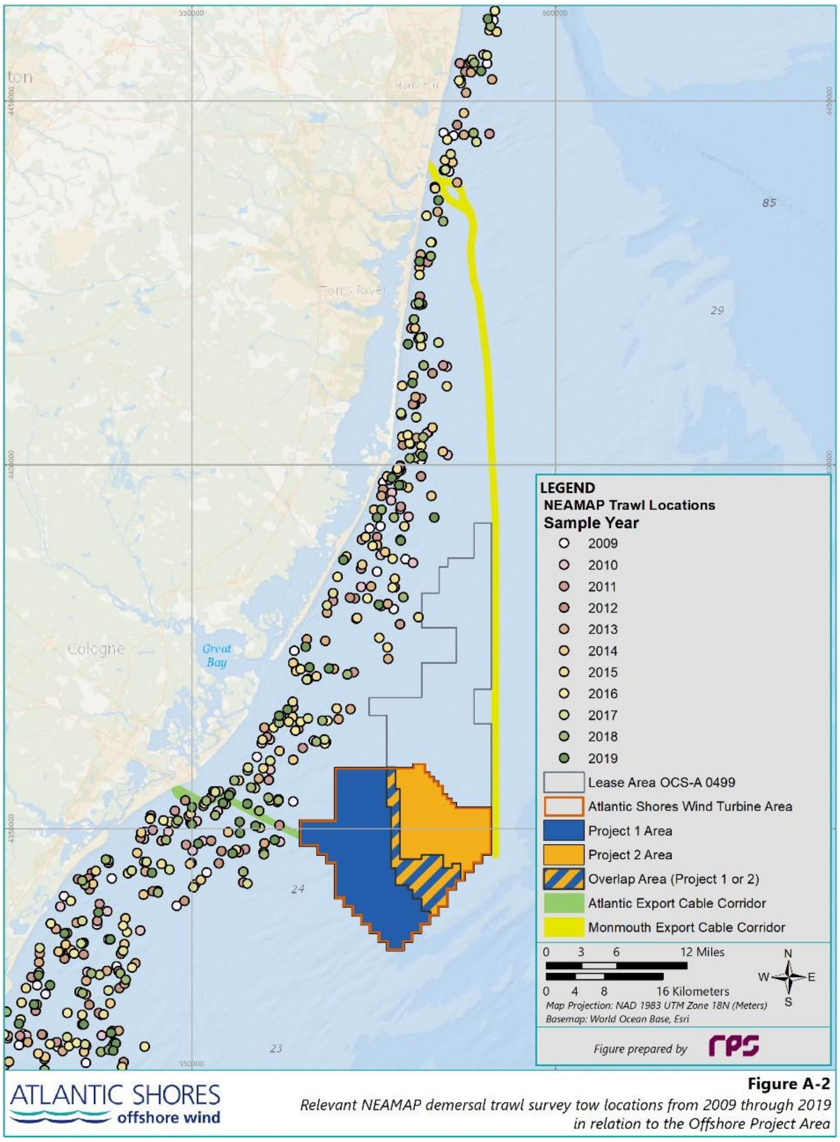

Figure A-2. Relevant NEAMAP demersal trawl survey tow locations from 2009 through 2019 in relation to the Offshore Project Area.

### A.1.3 NEFSC Bottom Trawl Surveys

The Northeast Fishery Science Center (NEFSC) Spring and Fall Bottom trawl surveys conduct tows annually in deeper waters of the northeast U.S. during the spring and fall. Between 2009 and 2019, 44 tows overlapped with the Lease Area with additional tows conducted within or near potential ECCs (Figure A-3). The data from these surveys can provide some baseline information and could be used for a power analysis to inform survey design if similar survey gear and methods were to be employed for monitoring. This survey does not provide relevant winter or summer sampling data to fully investigate seasonality.

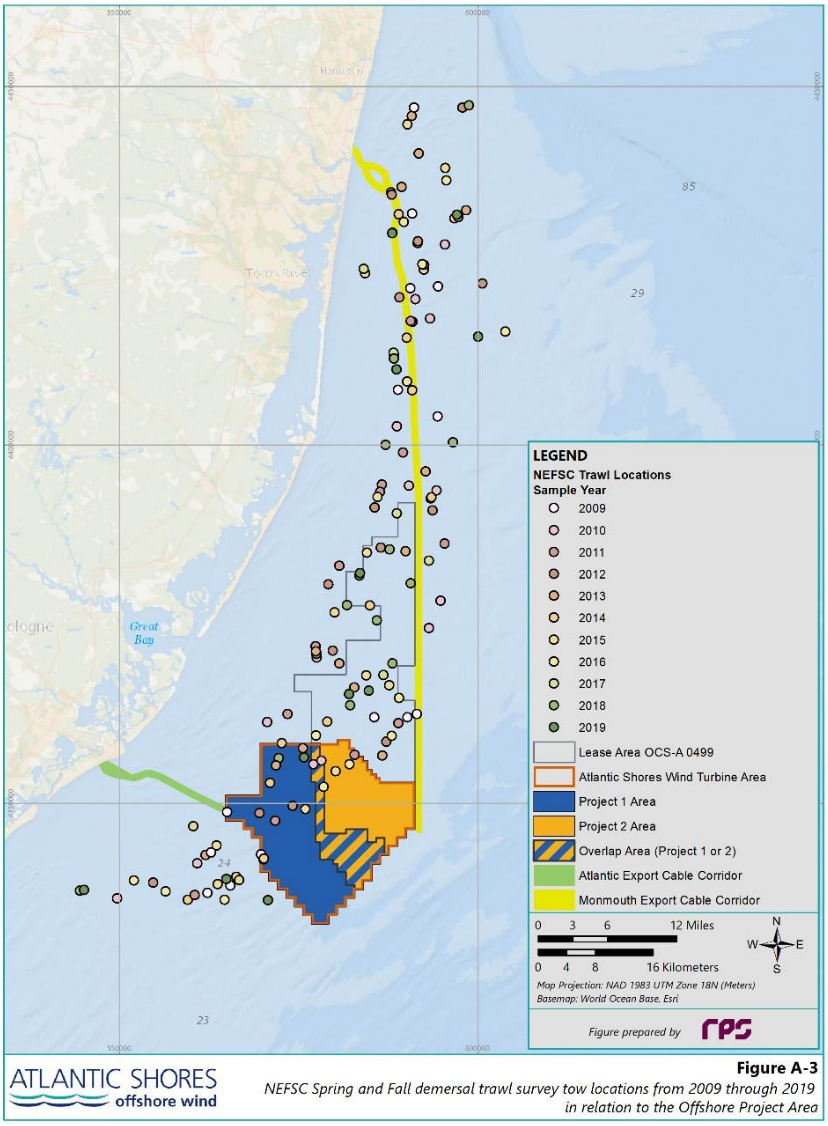

Figure A-3. Relevant NEFSC Spring and Fall demersal trawl survey tow locations from 2009 through 2019 in relation to the Offshore Project Area.

## A.2 Dredge Surveys

Dredges are generally designed to rake molluscan shellfish from the surface or top few inches of the seafloor. There are three relevant timeseries of dredge data with appropriate data quality, relevant and replicable survey design, and proximity to the Offshore Project Area. None of the existing surveys could adequately detect changes in bivalve abundances from project effects throughout the entire WTA if they were to continue to operate under their current design; however, these data were used for informative baseline information and their sampling methodology.

### A.2.1 NJDEP Surf Clam Survey

The NJDEP Inventory of New Jersey's surf clam resource occurs annually in state waters between June and August (with some exceptions). This survey specifically targets Atlantic surf clams. No sampling sites overlapped with the Lease Area between 2009 and 2019 but sampling events did occur near potential ECCs (Figure A-4). The dredge applied for this survey will serve as a model for the gear applied for the clam dredge monitoring survey.

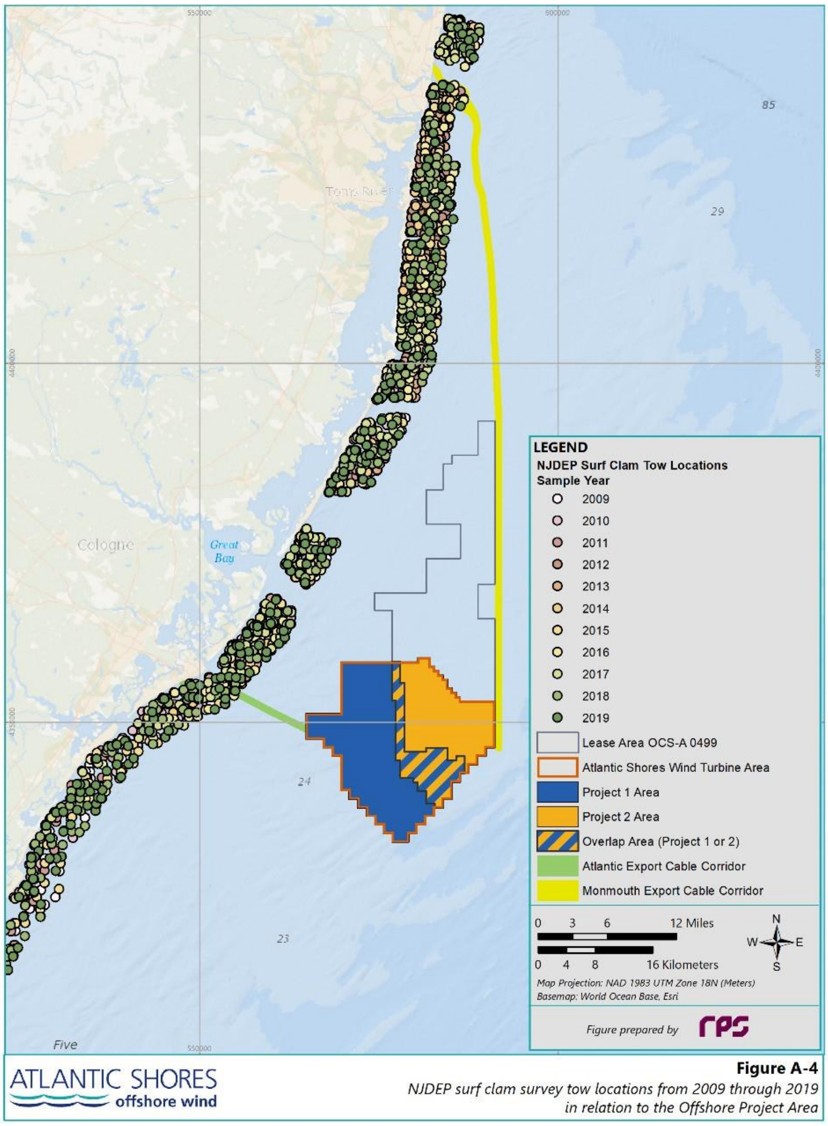

Figure A-4. NJDEP surf clam survey tow locations from 2009 through 2019 in relation to the Offshore Project Area.

## A.2.2 NEFSC Clam Survey

The NEFSC Clam Survey is an annual survey that takes three years to fully complete all sampling locations with some areas sampled every year. This survey specifically targets ocean quahogs and Atlantic surf clams. A total of 8 sites overlapped with the Lease Area (5 within the WTA), during the 2011, 2012, and 2015 surveys with other sampling events near potential ECCs (Figure A-5). These survey data were used to inform the design and sample size (i.e., through a power analysis) of a clam dredge monitoring survey.

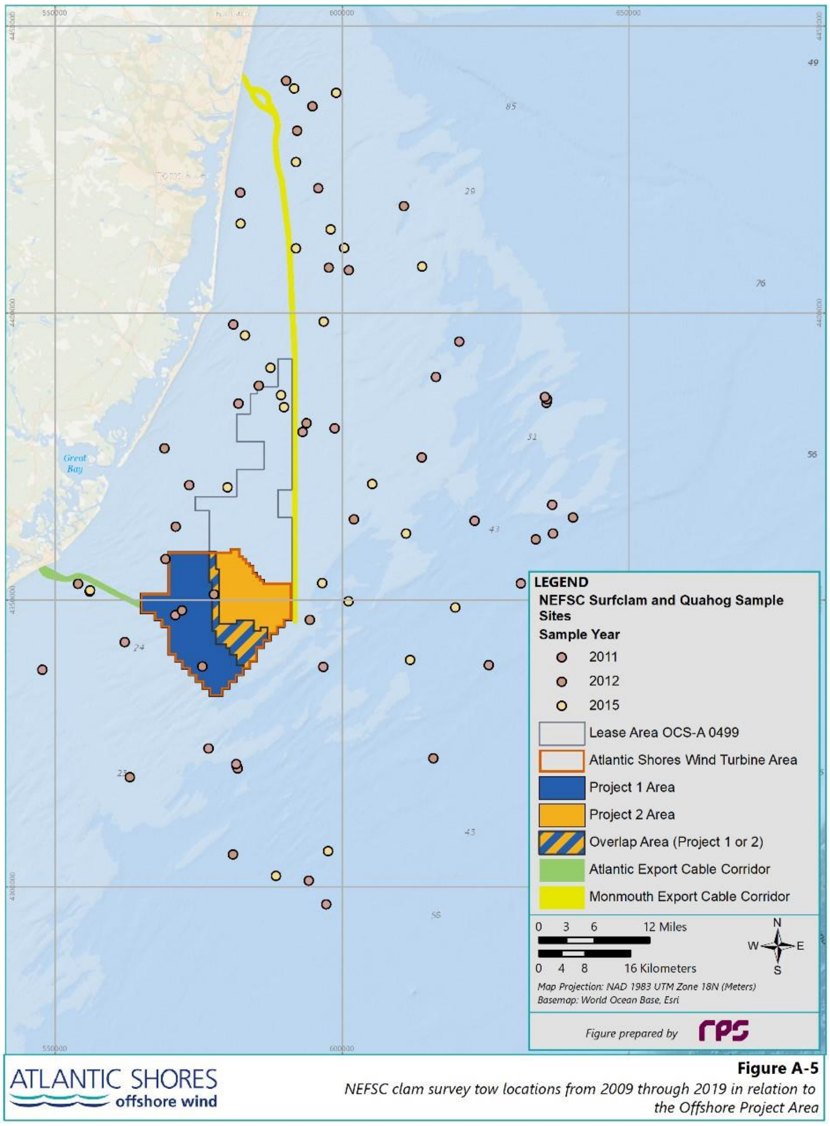

Figure A-5. Relevant NEFSC clam survey tow locations from 2011 through 2015 in relation to the Offshore Project Area.

## A.2.3 NEFSC Scallop Survey

The NEFSC Scallop Survey occurs along the northeast continental shelf targeting Atlantic sea scallops. None of the samples fell within the WTA during recent years (i.e., since 2009) and sites tend to be further offshore in this region (Figure A-6). These data have very limited potential to inform monitoring survey design within the Offshore Project Area.

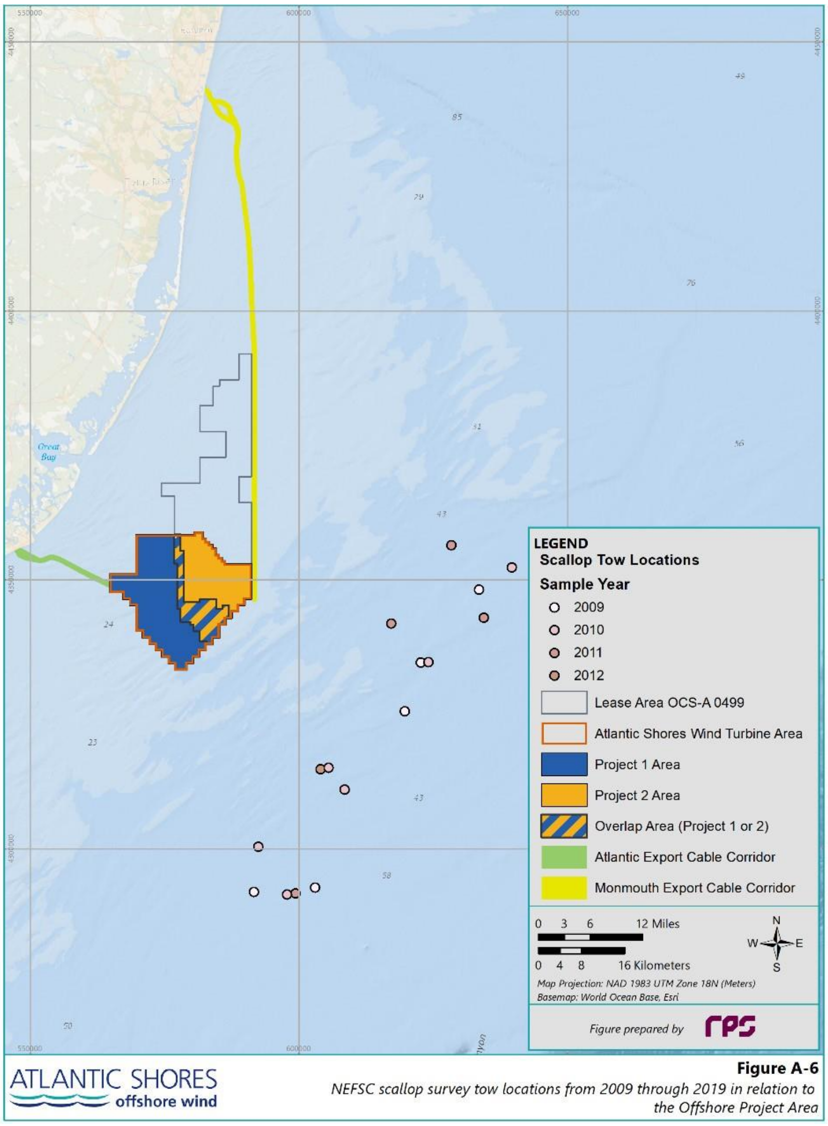

Figure A-6. Relevant NEFSC scallop survey tow locations from 2009 through 2012 in relation to the Offshore Project Area.

## A.2.4 VIMS Scallop Survey

The Virginia Institute of Marine Science (VIMS) Scallop Survey occurs along the continental shelf and targets Atlantic sea scallops. Only 3 of the samples fell within the WTA during a 2011 expansion into shallower waters (Figure A-7). These data have very limited potential to inform monitoring survey design within the Offshore Project Area.

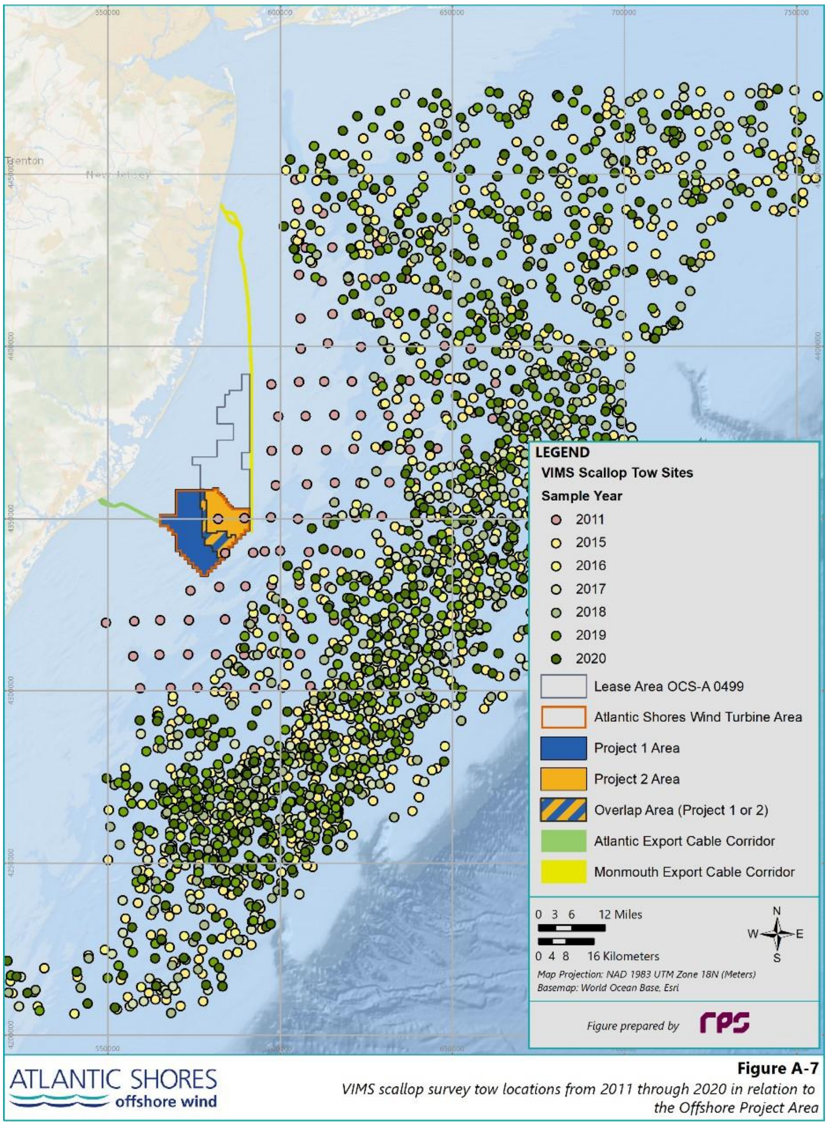

Figure A-7. Relevant VIMS scallop survey tow locations from 2011 through 2020 in relation to the Offshore Project Area.

## A.3 Ventless Trap Surveys

NJDEP has funded a trap survey of artificial reefs since 2016 to target structure-associated species that may not be sampled effectively by existing scientific trawl surveys (e.g., black sea bass, tautog, and American lobster). Sampling has taken place March through November on multiple reefs along most of New Jersey’s coastline. Some additional NMFS funded ventless trap sampling targeting black sea bass with 10-pot trawls occurred well south of the WTA during 2013 (Borden et al. 2013). The NJDEP ventless survey data were used to inform the design and sample size (i.e., through a power analysis) of a ventless trap monitoring survey.

## A.4 Visual and Other Surveys

The Woods Hole Habitat Mapping Camera System (HabCam) visually surveys large portions of the Northeast US continental shelf to collect biological information. Portions of the Mid-Atlantic Survey approach the WTA but tend to be deeper and further offshore than the WTA. UMass Dartmouth’s School for Marine Science and Technology (SMAST) has also visually sampled waters offshore New Jersey with some inshore samples occurring in at least 1 year. Data were not applicable to the Fisheries Monitoring Plan. More information about the results of these surveys can be found in the Benthic Section of the COP.

Additional biological sampling geared towards the benthos and habitat including benthic grab samples and visual imagery is planned as described in the Benthic Monitoring Plan (Appendix II-H of the COP).

# Attachment B - Power Analyses

## B.1 Demersal Otter Trawl Survey Power Analysis

An *a priori* power analysis was conducted to determine the number of samples required to detect a change in the diversity of fishes. A second power analysis was conducted to determine the number of samples required to detect a change in the all-species biomass density measured by the indicator, catch per unit effort (CPUE). For this survey CPUE refers specifically to the catch per standardized tow. When conducting a statistical test, power is the probability of correctly rejecting the null hypothesis. The power analyses were completed by generating datasets containing observations from multiple distances from the effects both before and after simulated effects and fitting a generalized linear model (GLM) with categorical and continuous variables as described in Attachment B. These power analyses used a conservative approach by assessing power using one year of baseline data compared to one year of post-effects data.

The NJDEP Ocean Stock Assessment Trawl Survey data were used to perform power analyses for this survey because the NEAMAP survey (that this monitoring plan draws its methods from) does not significantly overlap with the WTA whereas the NJDEP does. We assumed that the NJDEP data were substitutable with NEAMAP data for this purpose because the catch weight and catch diversity for spring (weight: $p = 0.002$, df = 335 and diversity: $p < 0.001$, df = 315) and fall (weight: $p < 0.001$, df = 419 and diversity: $p < 0.001$ , df = 394 ) trawls were not significantly different within the region (see Figure A-1 and A-2 for spatial extent of comparison) according to Welch two sample t-tests (Figure B-1 and FigureB-2). The NJDEP trawl methodology was not chosen for this survey because there is already precedent for use of NEAMAP methodology to monitor offshore wind impacts and applying the same methods should increase compatibility.

A dual-analysis hybrid design applying BAG analyses to the BACI-style BOEM recommendations was selected in response to stakeholder comments about the likely non-independence of strata suggested in the BOEM (2019) guidelines. The power analyses for this survey were based on the BACI-style analyses.

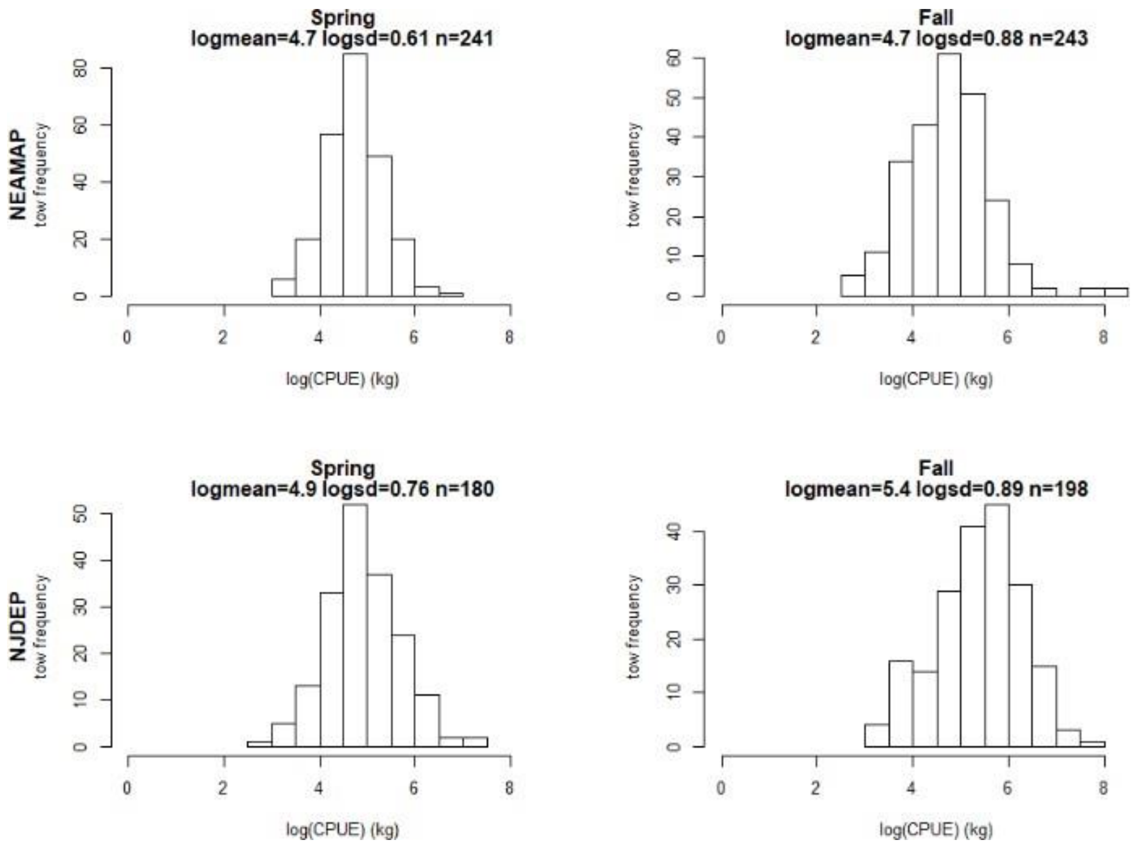

Figure B-1. Histograms of log transformed catch weights from the NJDEP Ocean Stock Assessment Trawl Survey and NEAMAP survey between 2009-2019.

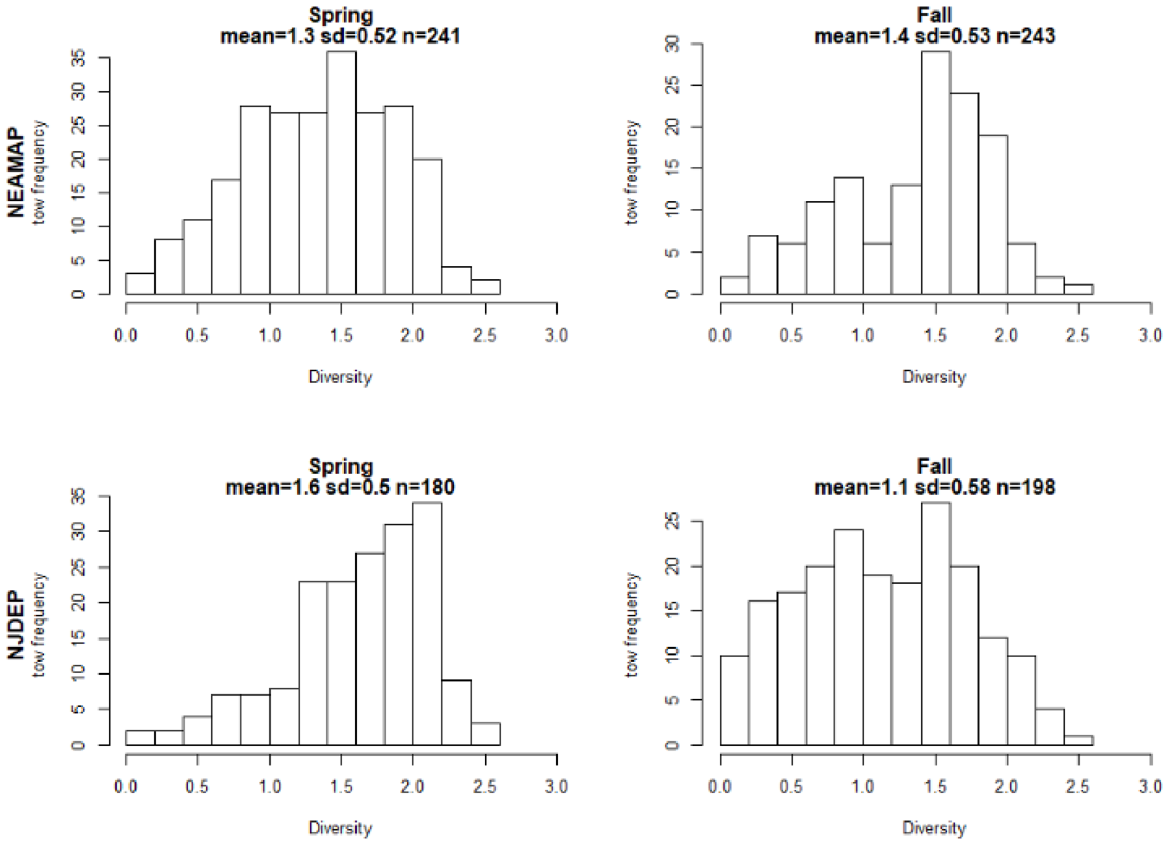

Figure B-2. Histograms of catch diversity from the NJDEP Ocean Stock Assessment Trawl Survey and NEAMAP survey between 2009-2019.

### B.1.1 Diversity Power Analysis

Samples of diversity were generated based on the center and spread of distributions fitted to real data from 89 tows conducted between 2009 and 2019 by the NJDEP within the Lease Area. The NJDEP dataset was used to calculate the Shannon-Wiener Diversity index H’ (Equation 1) for each of the 89 tows (Shannon 1948). Diversity values from tows in all years were pooled to create an adequate sample size because there were no significant changes in diversity over time at an annual level. The distribution of diversity observations followed normal distributions in the winter (Shapiro-Wilks, $n$ = 13, $p$ = 0.96), spring (Shapiro-Wilks, $n$ = 20, $p$ = 0.22), and summer (Shapiro-Wilks, $n$ = 37, $p$ = 0.52) but not the fall (Shapiro-Wilks, $n$ = 42, $p$ = 0.03). Fitting a normal distribution to the data for each season (Figure B-3) produced mean and standard deviation estimates that were used to randomly generate samples composing simulation data. See Attachment C for Quantile-Quantile plots of fits compared to real data.

Equation 1:

$$H' = -\sum_{i=1}^{R} p_i \ln(p_i)$$

*Where:*

*$p_i$ is the proportion of individuals belonging to taxa i in the dataset of interest*

*Interpretation: The greater the H’, the greater the richness and evenness.*

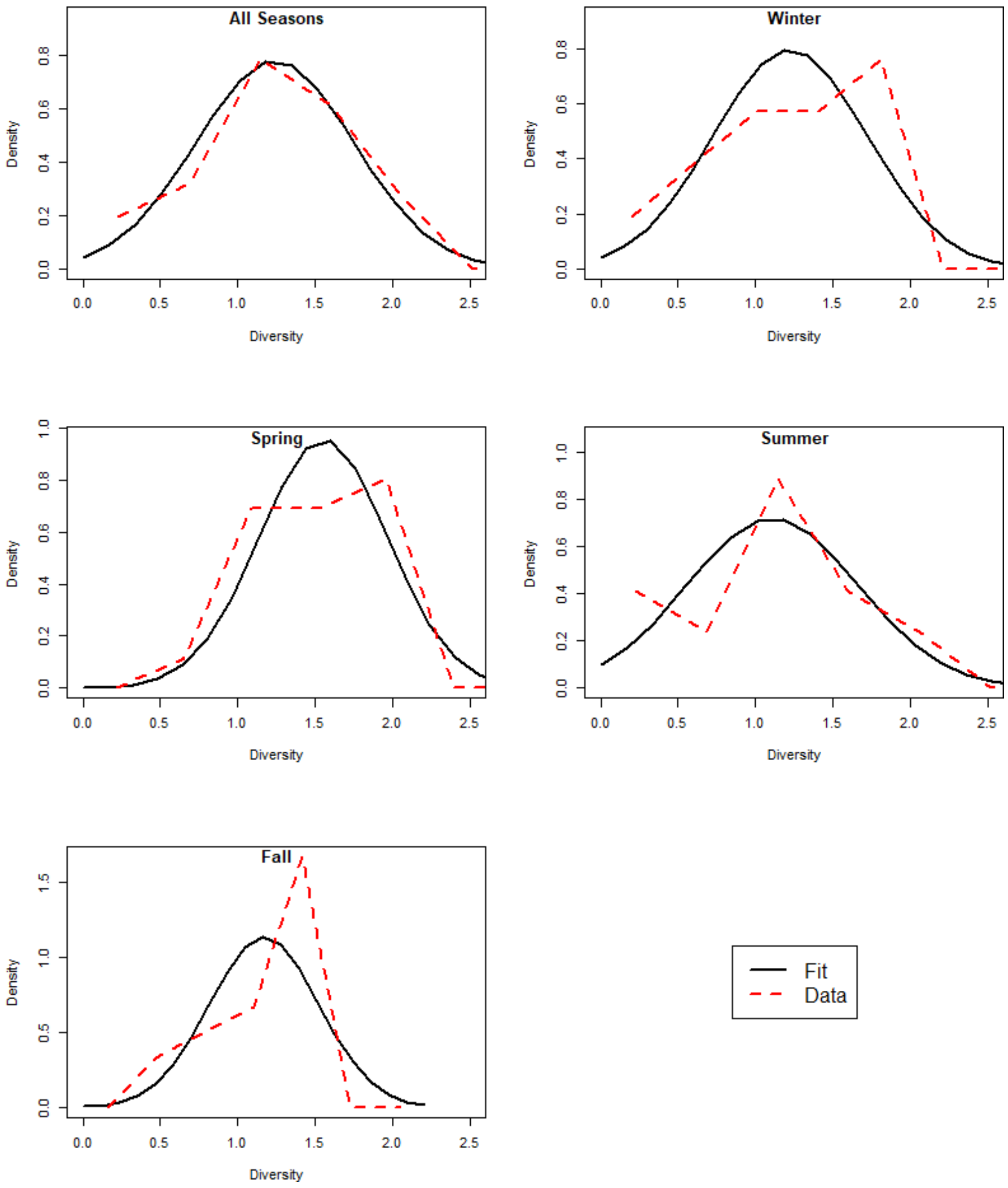

Figure B-3. Normal distribution (black) fitted to H' Diversity from NJDEP trawl data (red, dashed) collected within the Lease Area between 2009 and 2019. Fitted distributions for each season were used to generate datasets for the diversity power analysis simulation.

To conduct the power analysis with the correct degrees of freedom, the statistical model used to analyze the data was also chosen *a priori,* but other models could be fitted after data collection to investigate other questions. A GLM with a Gaussian conditional distribution will be used to assess the null hypothesis (as part of the BACI-style analysis) because it allows for incorporation of multiple categorical and continuous predictor variables and interactions.

Specifically, the GLM used "treatment" (i.e., before or after effects, but could be extended to include other years after effects), "location" (i.e., strata; effects site, close control, or far control), and “season” (i.e., winter, spring, summer, or fall) as categorical predictors and temperature (can be substituted for other environmental variables later) as a continuous predictor of diversity. The interactions between treatment:location and treatment:temperature were included and will provide the most valuable insight into whether the project affects diversity (Equation 2).

Equation 2:

$$DDDDDDDDDDDDDDDDDD = DDDDDDttDDttDDttDD + lllllttDDllltt + DDDDttDDlltt + DDDtttt + DDDDDDttDDttDDttDD : lllllttDDllltt + DDDDDDttDDttDDttDD : DDDtttt + \beta\beta_0$$

To test the effect of sample size on power, 13 datasets ranging from 24 samples to 312 samples in multiples of 24 were created for each iteration of a 2,000-iteration simulation. Each 24 additional samples contained 12 observations in each treatment (i.e., before and after effects), 6 observations in each of four seasons, and 8 observations allocated into each location (i.e., effects site, close control, far control).

The “before effects” treatment data were all selected from the same normal distribution for each season (Equation 3) while the “after effects” data were selected from one of three different distributions for each season depending on distance from effects. The “far control, after effects” data were selected from the same distribution as the “before effects” data while the mean of the “effects site, after effects” distribution was increased by 25% of the “before effects” mean (Equation 4) and mean of the “near control, after effects” distribution was increased by 10% of the mean (Equation 5). The increased diversity near the effects after they occurred assumed a localized colonization effect with neutral changes at farther sampling sites but a decrease of the same magnitude near the effects should be equally detectable as well (i.e., two-tailed). A 25% change in community indices has been used before in benthic monitoring studies with power close to 80% for most benthic taxa (Lambert et al. 2017). In this case, changing the mean of the “effects site” by 25% and the mean of the “near control” site by 10% is equivalent to completing a power analysis at each level of effect because both locations are compared to the “far control” location independently.

Equation 3:

$$\text{Winter: } \mathrm{N}(\mu\mu = 1.2\,, \sigma\sigma^2 = 0.5),$$

$$\text{Spring: } \mathrm{N}(\mu\mu = 1.6, \sigma\sigma^2 = 0.6),$$

$$\text{Summer: } \mathrm{N}(\mu\mu = 1.2, \sigma\sigma^2 = 0.4),$$

$$\text{Fall: } \mathrm{N}(\mu\mu = 1.2, \sigma\sigma^2 = 0.4)$$

Equation 4:

$$\text{Winter: } \mathrm{N}(\mu\mu = 1.25 * 1.2\,, \sigma\sigma^2 = 0.5),$$

$$\text{Spring: } \mathrm{N}(\mu\mu = 1.25 * 1.6, \sigma\sigma^2 = 0.6),$$

$$\text{Summer: } \mathrm{N}(\mu\mu = 1.25 * 1.2, \sigma\sigma^2 = 0.4),$$

$$\text{Fall: } \mathrm{N}(\mu\mu = 1.25 * 1.2 *, \sigma\sigma^2 = 0.4)$$

Equation 5:

$$\text{Winter: } \mathrm{N}(\mu\mu = 1.1 * 1.2\,, \sigma\sigma^2 = 0.5),$$

$$\text{Spring: } \mathrm{N}(\mu\mu = 1.1 * 1.6, \sigma\sigma^2 = 0.6),$$

$$\text{Summer: } \mathrm{N}(\mu\mu = 1.1 * 1.2, \sigma\sigma^2 = 0.4),$$

$$\text{Fall: } \mathrm{N}(\mu\mu = 1.1 * 1.2 *, \sigma\sigma^2 = 0.4)$$

Bottom temperature was also randomly selected for each tow from a normal distribution (Equation 6). Bottom temperature will be included in the real analyses but was generated from the same distribution for each season in the simulations to avoid incorrect assumptions. Instead, we assumed that the real CPUE data that the simulation CPUE were generated from reflects season effects of bottom temperature.

Equation 6:

$$\mathrm{N}(\mu\mu = 20°CC\,, \sigma\sigma^2 = 2°CC\,)$$

Once each dataset was generated, a GLM (Equation 2) was fitted in R with the “glm()” function and the *p value* for the “treatment:location” interaction terms were evaluated at an alpha level of 0.05 for significance as will be used to assess the null hypothesis ($H_{01}$) by determining if the diversity-location relationship was different after construction occurred. The pass/fail result was recorded for each of the 13 different sized datasets and then averaged over 2,000 simulations to determine the power of each sample size. Results indicated that 216 samples (108 before with 27 in each season and 108 after with 27 in each season) would have an 80% power in detecting the changes simulated here (i.e., <25% overall change in diversity; Table B-1 and was therefore selected as the sample size that will be applied within the survey design (Section 3.1.1). For final analysis, the significance of the interaction term “treatment:temperature” will also be assessed to test for evidence of underlying oceanographic characteristics that influenced results.

Table B-1. Estimated power at different sample sizes and effect sizes from 2,000 iterations of a simulation based on NJDEP Trawl diversity data. Bolded values are greater than 80% power.

| Total Sample Size | Samples per season per treatment | Power (10% change) | Power (25% change) |
|---|---|---|---|
| 24 | 3 | 0.06 | 0.13 |
| 48 | 6 | 0.07 | 0.23 |
| 72 | 9 | 0.09 | 0.36 |
| 96 | 12 | 0.12 | 0.46 |
| 120 | 15 | 0.14 | 0.54 |
| 144 | 18 | 0.15 | 0.62 |
| 168 | 21 | 0.17 | 0.69 |
| 192 | 24 | 0.17 | 0.74 |
| 216 | 27 | 0.20 | **0.80** |
| 240 | 30 | 0.22 | **0.83** |
| 264 | 33 | 0.24 | **0.87** |
| 288 | 36 | 0.25 | **0.89** |
| 312 | 39 | 0.27 | **0.91** |

### B.1.2 Biomass Power Analysis

As with the diversity power analysis, samples of biomass were generated based on the center and spread of distributions fitted to real data from 89 tows conducted between 2009 and 2019 by the NJDEP within the Lease Area. Tows from all years were pooled to create an adequate sample size. The distribution of all- species biomass CPUE appeared adequately lognormal after a log transformation produced a normal distribution for winter (Shapiro-Wilks, *n* = 13, *p* = 0.14), spring (Shapiro-Wilks, *n* = 20, *p* = 0.40), summer (Shapiro-Wilks, *n* = 37, *p* = 0.61), and fall (Shapiro-Wilks, *n* = 19, *p* = 0.51). Fitting a lognormal distribution to the data for each season (Figure B-4) produced log(mean) and log(sd) estimates that were used to randomly generate samples composing simulation data. See Attachment C for Quantile-Quantile plots of fits compared to real data.

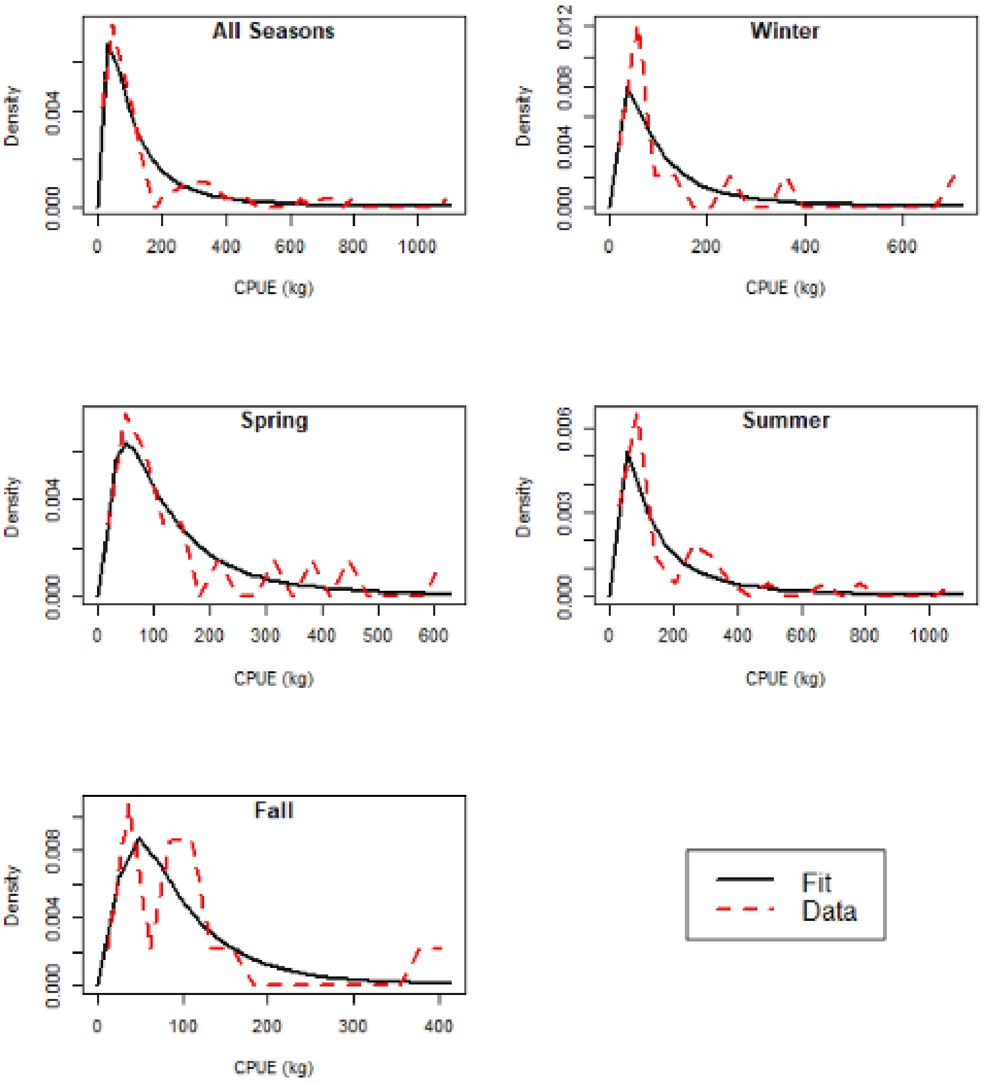

Figure B-4. Lognormal distribution (black) fitted to all-species biomass CPUE from NJDEP trawl data (red, dashed) collected within Lease Area OCS-A 0499 between 2009 and 2019.The fitted distributions from each season were used to generate datasets for the CPUE power analysis simulation.

To conduct the power analysis with the correct degrees of freedom, the statistical model used to analyze the data was also chosen *a priori,* but other models could be fitted after data collection to investigate other questions. A GLM with a Gaussian conditional distribution will be used to assess the null hypothesis because it allows for incorporation of multiple categorical and continuous predictor variables and interactions. Specifically, the GLM used “treatment” (i.e., before or after effects, but could be extended to include other years after construction), “location” (i.e., effects site, close control, or far control), and “season” (i.e., winter, spring, summer, or fall) as categorical predictors and temperature (can be substituted for other environmental variables later) as a continuous predictor of the log transformed biomass CPUE (Equation 7).

Equation 7:

$$\log(CCCCCCCC) = DDDDDDttDDttDDttDD + lllllttDDlllltt + DDDDttDDlltt + DDDDtttt + DDDDDDttDDttDDttDD: lllllttDDlllltt + DDDDDDttDDttDDttDD: DDDDtttt + \beta\beta_0$$

To test the effects of sample size on power, 13 datasets ranging from 24 samples to 312 samples in multiples of 24 were created for each iteration of a 2,000-iteration simulation. Each 24 additional samples contained 12 observations in each treatment (i.e., before and after effects), 6 observations in each of four seasons, and 8 observations allocated into each location (i.e., effects site, close control, far control).

The “before effects” treatment data were all selected from the same normal distribution for each season (Equation 8) while the “after effects” data were selected from one of three different distributions for each season depending on distance from effects. The “far control, after effects” data were selected from the same distribution as the “before effects” data while the mean of the “effects site, after effects” distribution was increased by 50% of the “before effects” log(mean) (Equation 9) and mean of the “near control, after effects” distribution was increased by 25% of the log(mean) (Equation 10). The increased diversity near the effects after they occurred assumed a localized colonization effect with neutral changes at farther sampling sites but a decrease of the same magnitude near the effects should be equally detectable as well (i.e., two-tailed).Greater percent changes were used for the biomass power analysis than the diversity power analysis because diversity is dependent on both the number of species present and their relative biomass whereas total biomass will not directly reflect changes in composition (i.e., biomass is less sensitive to ecosystem changes than diversity).

Equation 8:

Winter: $\text{Lognormal}(\mu\mu = 4.4, \sigma\sigma^2 = 1.0)$, Spring: $\text{Lognormal}(\mu\mu = 4.7, \sigma\sigma^2 = 0.9)$,

Summer: $\text{Lognormal}(\mu\mu = 4.7, \sigma\sigma^2 = 1.1)$, Fall: $\text{Lognormal}(\mu\mu = 4.4, \sigma\sigma^2 = 0.8)$

Equation 9:

Winter: $\text{Lognormal}(\mu\mu = LLllLL(1.5DD^{4.4}), \sigma\sigma^2 = 1.0)$,

Spring: $\text{Lognormal}(\mu\mu = LLllLL(1.5DD^{4.7}), \sigma\sigma^2 = 0.9)$,

Summer: $\text{Lognormal}(\mu\mu = LLllLL(1.5DD^{4.7}), \sigma\sigma^2 = 1.1)$,

Fall: $\text{Lognormal}(\mu\mu = LLllLL(1.5DD^{4.4}), \sigma\sigma^2 = 0.8)$

Equation 10:

Winter: $\text{Lognormal}(\mu\mu = LLllLL(1.25DD^{4.4}), \sigma\sigma^2 = 1.0)$,

Spring: $\text{Lognormal}(\mu\mu = LLllLL(1.25DD^{4.7}), \sigma\sigma^2 = 0.9)$,

Summer: $\text{Lognormal}(\mu\mu = LLllLL(1.25DD^{4.7}), \sigma\sigma^2 = 1.1)$,

Fall: $\text{Lognormal}(\mu\mu = LLllLL(1.25DD^{4.4}), \sigma\sigma^2 = 0.8)$

Bottom temperature was also randomly selected for each tow from a normal distribution (Equation 11). Bottom temperature will be included in the real analyses but was generated from the same distribution for each season in the simulations to avoid incorrect assumptions. Instead, we assumed that the real CPUE data that the simulation CPUE were generated from reflects season effects of bottom temperature.

Equation 11:

$$\mathrm{N}(\mu\mu = 20°CC, \sigma\sigma^2 = 2°CC)$$

Once each dataset was generated, a GLM (Equation 7) was fitted in R using the “glm()” function with a Gaussian error distribution and the *p values* for the “treatment:location” interaction terms were evaluated at an alpha level of 0.05 for significance, which will be used to assess the null hypothesis ($H_{o2}$) by determining if the biomass- location relationship was different after construction occurred. The pass/fail result was recorded for each of the 13 different size datasets and then averaged over 2,000 simulations to determine the power of each sample size. It was determined that the sample size selected from the biodiversity power analysis (216 samples, Section B.1.1) would have 27% power in detecting the 50% change in the effects strata simulated here (Table B-2). Larger changes in biomass would be more easily detectable at this sample size. A similar power analysis using data simulated based on 484 NEAMAP tows over 2 seasons (i.e., spring and fall) during the same 11 years found roughly twice the power for this sample size. For final analysis, the significance of the interaction term “treatment:temperature” will also be assessed to test for evidence of underlying oceanographic characteristics that influenced results.

Table B-2. Estimated power at different sample sizes and effect sizes from 2,000 iterations of a simulation based on NJDEP Trawl all-species biomass CPUE data.

| Total Sample Size | Samples per season per treatment | Power (25% change) | Power (50% change) |
|---|---|---|---|
| 24 | 3 | 0.06 | 0.06 |
| 48 | 6 | 0.07 | 0.10 |
| 72 | 9 | 0.07 | 0.14 |
| 96 | 12 | 0.08 | 0.16 |
| 120 | 15 | 0.09 | 0.18 |
| 144 | 18 | 0.10 | 0.21 |
| 168 | 21 | 0.10 | 0.23 |
| 192 | 24 | 0.11 | 0.26 |
| 216 | 27 | 0.12 | 0.27 |
| 240 | 30 | 0.13 | 0.31 |
| 264 | 33 | 0.14 | 0.33 |
| 288 | 36 | 0.15 | 0.37 |
| 312 | 39 | 0.16 | 0.40 |

### B.1.3 Other Analyses

A third GLM (Equation 12) with an appropriate link function will be fit to the data to test the third null hypothesis ($H_{o3}$). A power analysis was not conducted for this test because it was assumed that the sample size of 216 will be adequate to detect a change in the length of dominant fishes. This is due to rather than a single observation per tow in the case of CPUE and diversity, there is potential to catch hundreds or thousands of individuals at each station, greatly increasing sample size for length. As with the previous two GLMs, the significance of the interaction term “treatment:location” for each strata will determine if we reject the null hypothesis and the significance of the interaction term “treatment:temperature” will determine if there was evidence of underlying oceanographic characteristics that influenced results. For all

GLMs presented to this point, the “temperature” predictor could be substituted for other environmental variables (e.g., temperature, depth, dissolved oxygen, salinity) without changing the degrees of freedom and invalidating the power analysis

Equation 12:

$$LLDDttLLDDh = DDDDDDttDDttDDttDD + (ddDDDDDDttttllDD) + DDDDttDDlltt + DDDDtttt + DDDDDDttDDttDDttDD: ddDDDDDDttttllDD + DDDDDDttDDttDDttDD: DDDDtttt + \beta\beta_0$$

Power analyses only using NJDEP tows from within the WTA, rather than the entire Lease Area were considered. However, limiting tows to only within the WTA would decrease the available dataset to 32 tows. A comparison of diversity and all-species biomass CPUE demonstrated that the WTA subset ($n$ = 32) did not have a significantly different distribution from the other data within the entire Lease Area ($n$ = 57) for diversity (Wilcox, $p$ = 0.51) or biomass (Wilcox, $p$ = 0.59) and the distribution of observations from just the WTA was similar to the distribution of all observations in the Lease Area (Figure B-5 and Figure B-6).

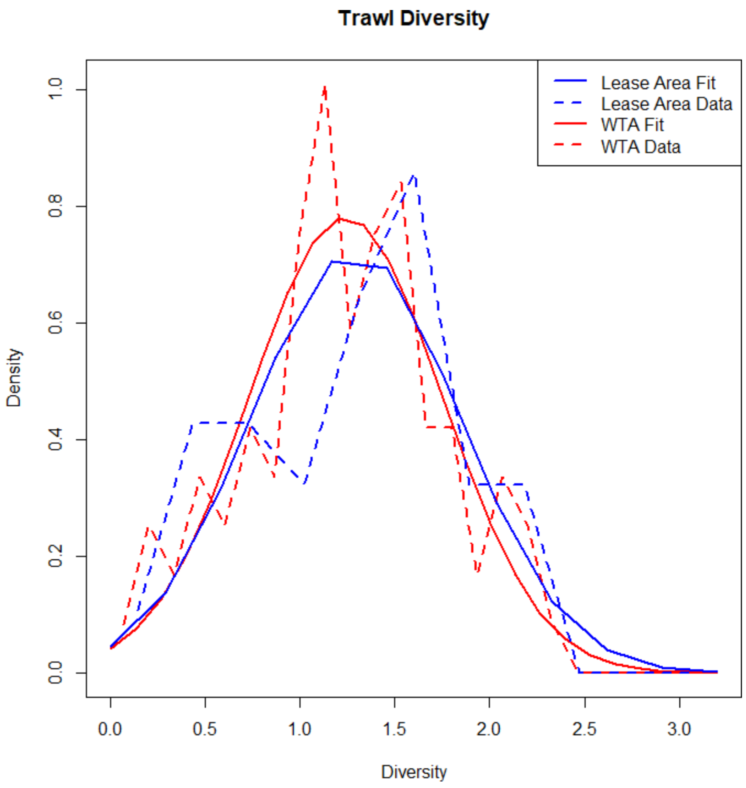

Figure B-5. Normal distributions (solid) fitted to diversity values from NJDEP trawl data (dashed) collected within the entire Lease Area OCS-A 0499 (blue) and just the WTA (red) between 2009 and 2019.

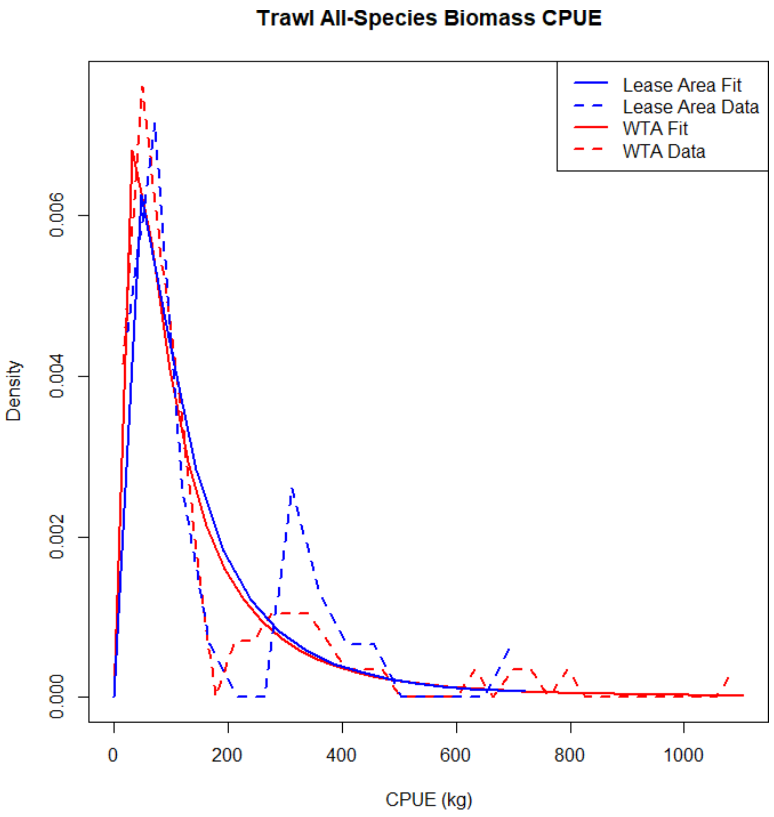

Figure B-6. Lognormal distributions (solid) fitted to all-species biomass CPUE from NJDEP trawl data (dashed) collected within the entire Lease Area OCS-A 0499 (blue) and just the WTA (red) between 2009 and 2019.

## B.2 Trap Survey Power Analysis

An *a priori* power analysis was conducted to determine the number of samples required to detect a change in the CPUE of commercially and recreationally important structure associated species (i.e., black sea bass, tautog, American lobster, Jonah crab, and rock crab). For this survey, CPUE refers specifically to the rounded up whole number of individuals caught after the standard 5-7 days of soak time. The power analyses were completed by generating datasets containing observations from multiple distances from the effects both before and after the effects and fitting a generalized additive model (GAM) with categorical and continuous variables and a smoothing parameter for distance. These power analyses used a conservative approach by assessing power using one year of baseline data compared to one year of post-effects data. Winter sampling was excluded from the trap power analyses because the NJDEP survey doesn’t cover this period. Instead, it was assumed that the same sample size for the other seasons would be sufficient for winter sampling efforts.

### B.2.1 CPUE Power Analyses

Samples of abundance were generated based on the center and spread of distributions fitted to real trap data from 2,977 trap fishing weeks between 2016 and 2020 funded by the NJDEP around artificial reefs along the New Jersey coast. Abundance data from all years were pooled to create a larger sample size. The CPUE distributions of the species of interest appeared adequately represented by negative binomial distributions in the spring, summer, and fall. Fitting a negative binomial distribution to the data for each season (Figure B-7 through Figure B-11) produced seasonal parameter estimates (Table B-3) that were used to randomly generate samples composing simulation data. See Attachment C for Quantile-Quantile plots of fits compared to real data.

Table B-3. Parameter values from negative binomial distributions fit to NJDEP ventless fish pot survey data. Size and µ are from the reparameterization of the negative binomial distribution as described in the ‘stats’ package in R (see details of NegBinomial).

| **Species** | **Spring** | | **Summer** | | **Fall** | |
|---|---|---|---|---|---|---|
| | $Size_{SP}$ | $\mu_{SP}$ | $Size_{SU}$ | $\mu_{SU}$ | $Size_{FA}$ | $\mu_{FA}$ |
| **Black Sea Bass** | 0.20 | 1.15 | 0.60 | 6.87 | 0.62 | 1.51 |
| **Tautog** | 0.14 | 0.20 | 0.15 | 0.39 | 0.21 | 0.59 |
| **American Lobster** | 0.30 | 0.28 | 0.30 | 0.94 | 0.31 | 0.58 |
| **Rock crab** | 0.32 | 1.56 | 0.15 | 0.90 | 0.14 | 0.72 |
| **Jonah crab** | 0.38 | 0.38 | 0.43 | 0.99 | 0.23 | 0.56 |

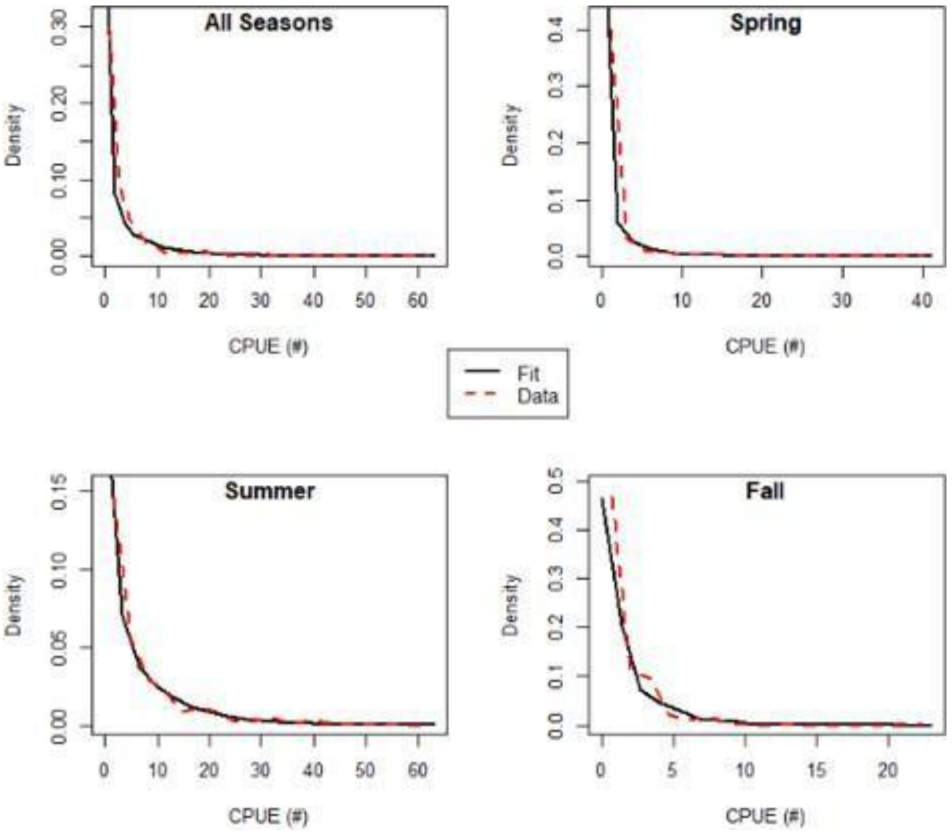

Figure B-7. Negative binomial distribution (black) fitted to black sea bass abundance CPUE from NJDEP trap data (red, dashed) collected around artificial reefs along the New Jersey coast between 2016 and 2020.The fitted distributions from each season were used to generate datasets for the CPUE power analysis simulation.

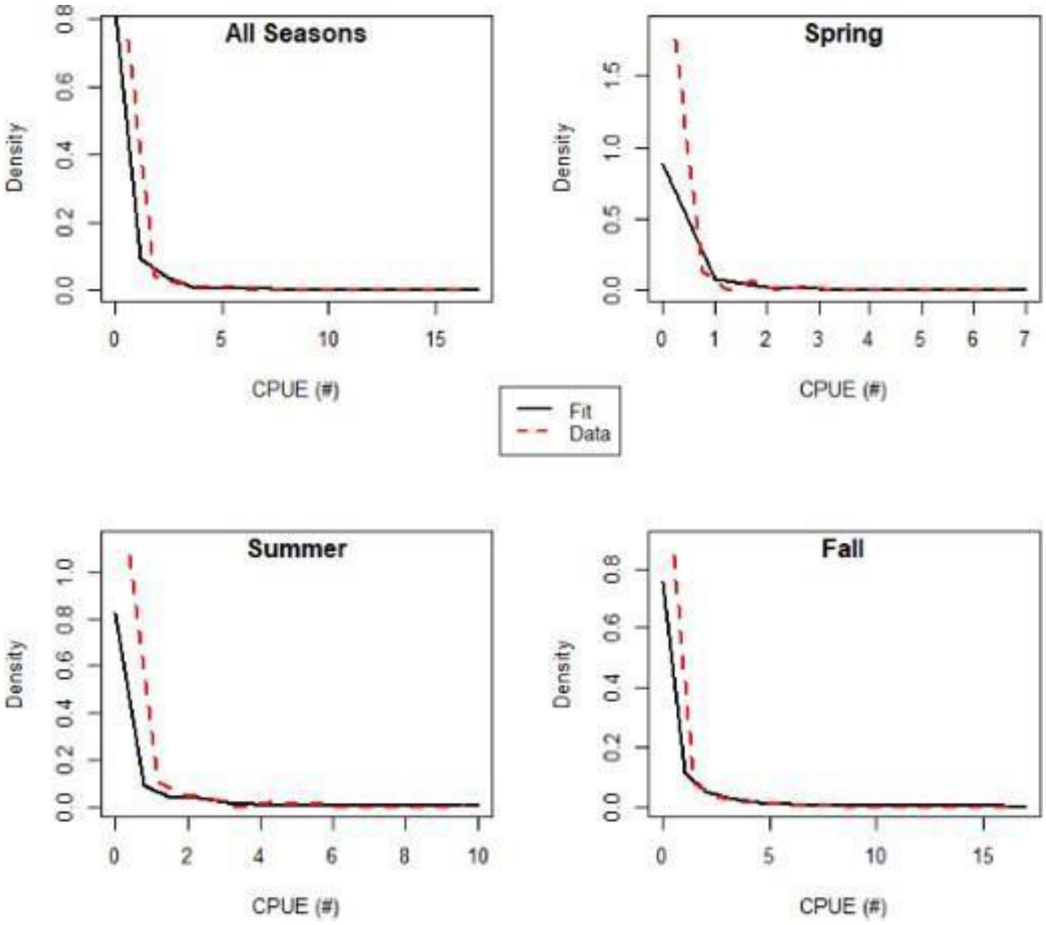

Figure B-8. Negative binomial distribution (black) fitted to tautog abundance CPUE from NJDEP trap data (red, dashed) collected around artificial reefs along the New Jersey coast between 2016 and 2020.The fitted distributions from each season were used to generate datasets for the CPUE power analysis simulation.

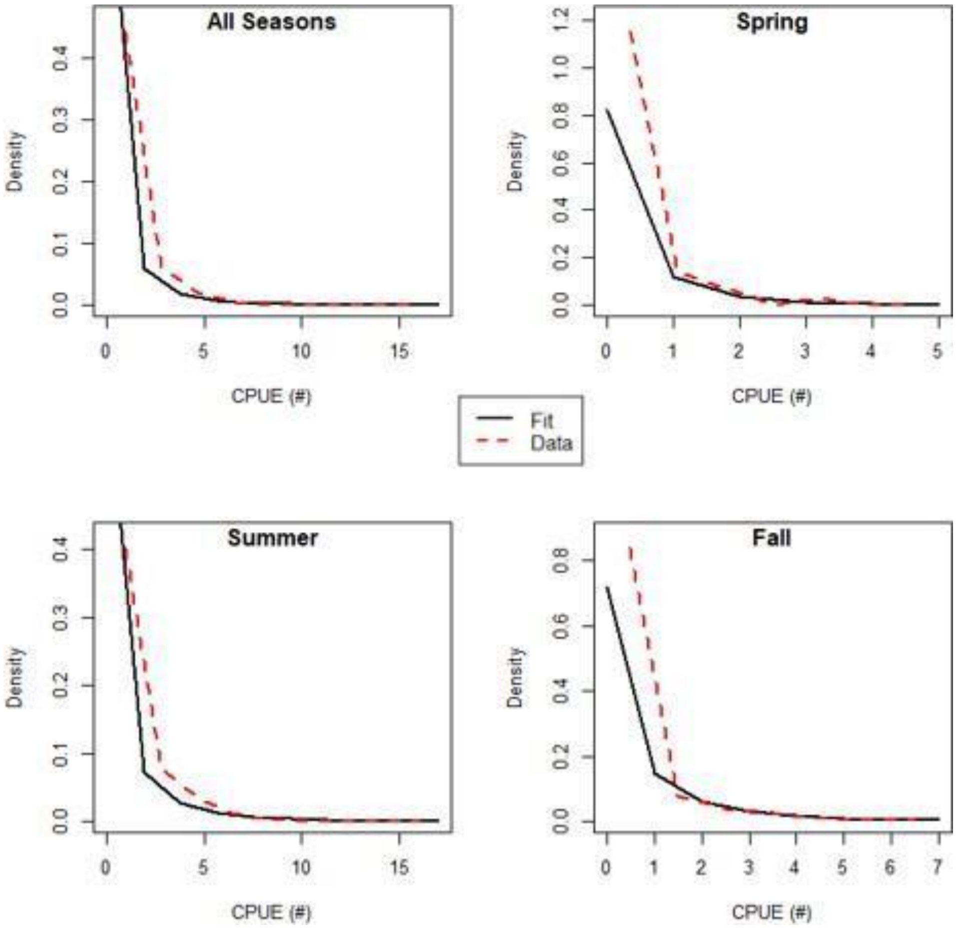

Figure B-9. Negative binomial distribution (black) fitted to lobster abundance CPUE from NJDEP trap data (red, dashed) collected around artificial reefs along the New Jersey coast between 2016 and 2020.The fitted distributions from each season were used to generate datasets for the CPUE power analysis simulation.

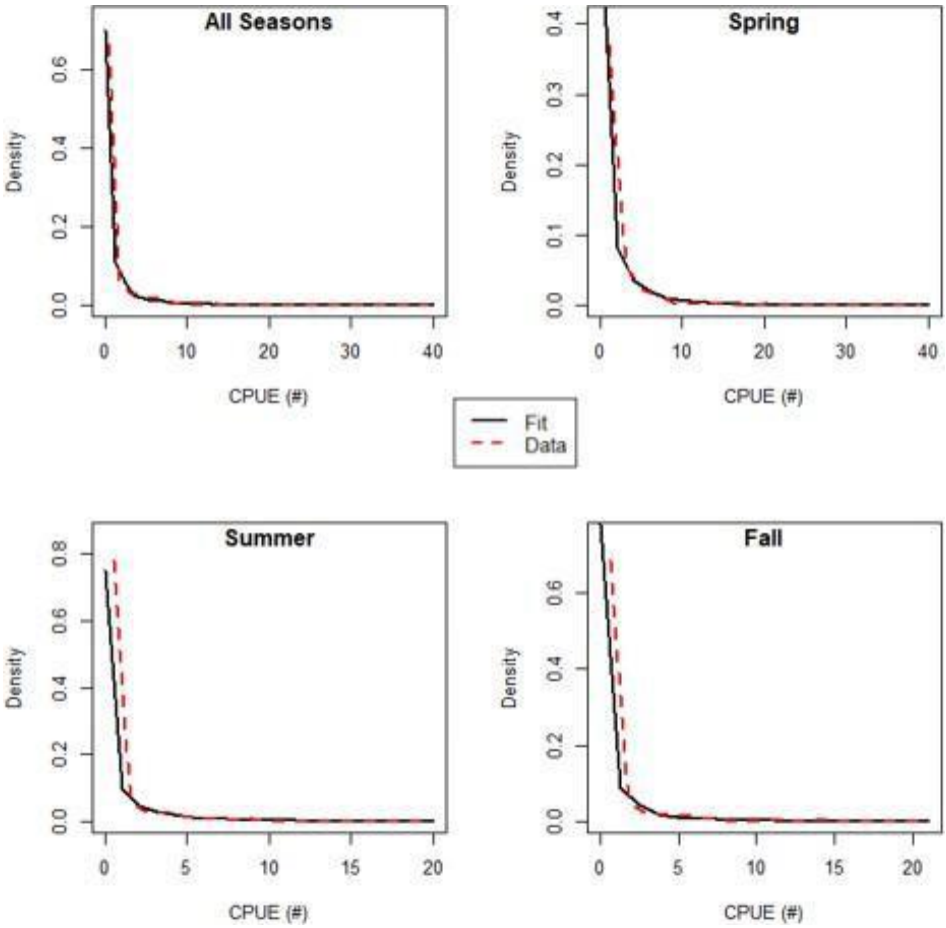

Figure B-10. Negative binomial distribution (black) fitted to rock crab abundance CPUE from NJDEP trap data (red, dashed) collected around artificial reefs along the New Jersey coast between 2016 and 2020.The fitted distributions from each season were used to generate datasets for the CPUE power analysis simulation.

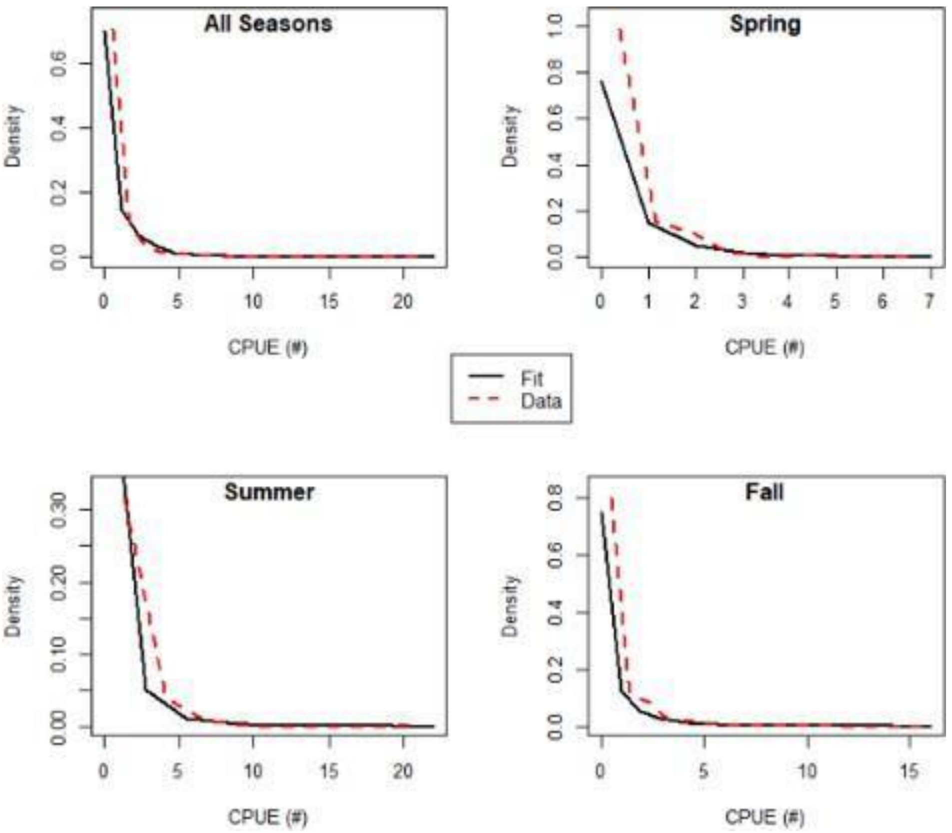

Figure B-11. Negative binomial distribution (black) fitted to Jonah crab abundance CPUE from NJDEP trap data (red, dashed) collected around artificial reefs along the New Jersey coast between 2016 and 2020.The fitted distributions from each season were used to generate datasets for the CPUE power analysis simulation.

A GAM or GAMM with a negative binomial conditional error distribution will be used to assess the null hypothesis for each species because it allows for incorporation of categorical and continuous predictor variables and enables the use of smoothing parameters to deviate from linear relationships and avoids making an assumption about a deterministic relationship between predictors and observations (Hastie & Tibshirani 1990). Specifically, the GAM in the simulation allowed for the application of a smoothing spline to the continuous “distance” (from effects) variable which is also accounted for in its interaction with a 2-level categorical predictor, “treatment”, while “temperature” and therefore the interaction between temperature and treatment were left linear (Equation 13).

Equation 13:

$$CCCCCCCC = DDDDDDttDDttDDttDD + DDDDttDDlltt + DDDDtttt + DDDDDDttDDttDDttDD: DD(ddDDDDDDttttllDD) + DDDDDDttDDttDDttDD: DDDDtttt + \beta\beta_0$$

To test the effect of sample size on power, 15 datasets ranging from 72 samples (i.e., trap fishing weeks) to 1080 samples in multiples of 72 were created for each iteration of a 2,000-iteration simulation. Each 72 additional samples contained 36 observations in each treatment (i.e., before and after effects) further allocated into 12 samples in each of three seasons, which correspond to 2 weeks of data from 1 transect of six traps spaced at semi-randomly selected distances from effects. The distances were not totally random to ensure adequate spatial coverage in line with the gradient survey design. Instead, one distance was generated from each of the following normal distributions (Equation 14).

Equation 14:

$$\mathrm{N}(\mu\mu = 0, \sigma\sigma^2 = 0), \mathrm{N}(\mu\mu = 15, \sigma\sigma^2 = 2), \mathrm{N}(\mu\mu = 50, \sigma\sigma^2 = 2), \mathrm{N}(\mu\mu = 150, \sigma\sigma^2 = 2), \mathrm{N}(\mu\mu = 400, \sigma\sigma^2 = 25),$$

$$\mathrm{N}(\mu\mu = 1{,}100, \sigma\sigma^2 = 25)$$

The “before effects” treatment catch data were all selected from the same negative binomial distribution for each season (Equation 15) while the “after effects” data were selected from one of five different distributions for each season depending on distance from effects. This process was repeated for each species twice to create two separate sets of simulations, one with a conservative overall change in catch probability distributions (34.6%) and one with a two times larger change (69.3%). The conservative set of simulations was based on results of a modelling study that detected a 35% increase in carrying capacity for a species of demersal fish after the installation of artificial reefs (Roa-Ureta et al. 2019). The less conservative set of simulations had double the change of the conservative simulation based on the assumption that larger changes are possible because there is limited structure in the WTA before construction and structure- oriented species are expected to be low in abundance. The increased biomass simulated near the effects after they occurred assumed localized aggregating/increased production effects with no change at the furthest two sampling sites, but an equal magnitude decrease near the effects should be equally detectable (i.e., two-tailed).

For the more conservative set of simulations, the “after effects” data $\mu$=400 m (1,312 ft) and $\mu$=1,100 m (3,608 ft) from effects were selected from the same distribution as the “before effects” data while the center catch of the $\mu$=0 m distribution was increased by 100% of the mean (Equation 16) center of the $\mu$=15 m (50 ft) distribution was increased by 50% of the mean (Equation 17), center of the $\mu$=50 m (164 ft) distribution was increased by 33% of the mean (Equation 18) and center of the $\mu$=150 m (492 ft) distribution was increased by 25% of the mean (Equation 19).

Equation 15:

$$\text{Spring: Negative binomial}(\mu\mu = \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Equation 16:

$$\text{Spring: Negative binomial}(\mu\mu = 2 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 2 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 2 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Equation 17:

$$\text{Spring: Negative binomial}(\mu\mu = 1.5 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 1.5 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 1.5 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Equation 18:

$$\text{Spring: Negative binomial}(\mu\mu = 1.33 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 1.33 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 1.33 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Equation 19:

$$\text{Spring: Negative binomial}(\mu\mu = 1.25 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 1.25 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 1.25 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

For the less conservative set of simulations, the “after effects” data $\mu$=400 m (1,312 ft) and $\mu$=1,100 m (3,608 ft) from effects were selected from the same distribution as the “before effects” data mean (Equation 15 while the center catch of the $\mu$=0 m distribution was increased by 200% of the mean (Equation 20) center of the $\mu$=15 m (50 ft) distribution was increased by 100% of the mean (Equation 21), center of the $\mu$=50 m (164 ft) distribution was increased by 66% of the mean (Equation 22), and center of the $\mu$=150 m (492 ft) distribution was increased by 50% of the mean (Equation 23).

Equation 20:

$$\text{Spring: Negative binomial}(\mu\mu = 3 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 3 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 3 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Equation 21:

$$\text{Spring: Negative binomial}(\mu\mu = 2 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 2 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 2 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Equation 22:

$$\text{Spring: Negative binomial}(\mu\mu = 1.66 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 1.66 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 1.66 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Equation 23:

$$\text{Spring: Negative binomial}(\mu\mu = 1.5 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Summer: Negative binomial}(\mu\mu = 1.5 * \mu\mu_{SSSS}, DDDDssDD = DDDDssDD_{SSSS}),$$
$$\text{Fall: Negative binomial}(\mu\mu = 1.5 * \mu\mu_{FFFF}, DDDDssDD = DDDDssDD_{FFFF})$$

Bottom temperature was also randomly selected for each set from a normal distribution (Equation 24). Bottom temperature will be included in the real analyses but was generated from the same distribution for each season in the simulations to avoid incorrect assumptions. Instead, we assumed that the real CPUE data that the simulation CPUE were generated from reflects season effects of bottom temperature.

Equation 24:

$$\mathrm{N}(\mu\mu = 20°CC\,, \sigma\sigma^2 = 2°CC\,)$$

Once each dataset was generated, a GAM (Equation 13) was fit in R using the mgcv package (Wood 2017) with a negative binomial error distribution function “neg.bin()“ and starting value for theta taken from the distribution of real catch data. The *p value* for the interaction term “treatment(after):distance” was evaluated at an alpha level of 0.05 for significance because it assesses the null hypothesis ($H_{o1}$) by determining if the biomass- distance relationship was different after construction occurred. This same analysis will be used on the real data after collection. The pass/fail result was recorded for each of the 15 different size datasets and then averaged over 2,000 simulations to determine the power of each sample size. The conservative simulation determined that a sample size of at least 576 would have 84% power in detecting the changes that were simulated for rock crab, but the power for detecting changes in the other species was much lower, failing to reach the 80% power threshold (Table B-4).

The larger changes in biomass simulated in the less conservative simulations were more powerful. Based on the less conservative simulations, a sample size of 864 will have at least 80% power to detect the provided changes for all tested species except for tautog, which had 53% power (Table B-5). However, tautog are highly structure-oriented, and are a strong candidate for having a larger effect size than even the less conservative change employed here. Therefore, 864 samples in the WTA, which corresponds to twelve transects of six traps fished for two weeks in three seasons was selected as the sampling effort for this survey. Additional winter sampling will further increase the sample size to 1,152 samples (576 per year) in the WTA, which corresponds to twelve transects of six traps fished for two weeks in four seasons in one year before and one year after construction

For final analysis, the significance of the interaction term “treatment:temperature” will also be assessed to test for evidence of underlying oceanographic characteristics that influenced results.

Table B-4. Results from conservative power analysis of trap abundance. Estimated power at different sample sizes from 2,000 iterations of a simulation based on NJDEP trap abundance data. Bolded values are greater than 80% power.

| Total Sample Size (trap fishing weeks both treatments) | 6-pot transects fished per season | Power | | | | |
|---|---|---|---|---|---|---|
| | | black sea bass | tautog | American lobster | rock crab | Jonah crab |
| 72 | 1 | 0.06 | 0.00 | 0.01 | 0.17 | 0.02 |
| 144 | 2 | 0.13 | 0.01 | 0.04 | 0.35 | 0.08 |
| 216 | 3 | 0.18 | 0.03 | 0.08 | 0.44 | 0.13 |
| 288 | 4 | 0.21 | 0.07 | 0.12 | 0.55 | 0.17 |
| 360 | 5 | 0.24 | 0.09 | 0.17 | 0.63 | 0.21 |
| 432 | 6 | 0.24 | 0.12 | 0.22 | 0.71 | 0.24 |
| 504 | 7 | 0.29 | 0.14 | 0.24 | 0.78 | 0.30 |
| 576 | 8 | 0.30 | 0.17 | 0.26 | **0.84** | 0.32 |
| 648 | 9 | 0.33 | 0.18 | 0.28 | **0.88** | 0.33 |
| 720 | 10 | 0.35 | 0.19 | 0.30 | **0.90** | 0.40 |
| 792 | 11 | 0.38 | 0.23 | 0.32 | **0.93** | 0.43 |
| 864 | 12 | 0.43 | 0.23 | 0.36 | **0.95** | 0.47 |
| 936 | 13 | 0.43 | 0.25 | 0.39 | **0.96** | 0.49 |
| 1008 | 14 | 0.43 | 0.25 | 0.43 | **0.97** | 0.53 |
| 1080 | 15 | 0.47 | 0.29 | 0.46 | **0.98** | 0.55 |

Table B-5. Results from less conservative power analysis of trap abundance. Estimated power at different sample sizes from 2,000 iterations of a simulation based on NJDEP trap abundance data. Bolded values are greater than 80% power.

| Total Sample Size (trap fishing weeks both treatments) | 6-pot transects fished per season | Power | | | | |
|---|---|---|---|---|---|---|
| | | black sea bass | tautog | American lobster | rock crab | Jonah crab |
| 72 | 1 | 0.11 | 0.00 | 0.01 | 0.21 | 0.05 |
| 144 | 2 | 0.25 | 0.03 | 0.12 | 0.34 | 0.20 |
| 216 | 3 | 0.32 | 0.09 | 0.25 | 0.47 | 0.33 |
| 288 | 4 | 0.41 | 0.17 | 0.34 | 0.54 | 0.42 |
| 360 | 5 | 0.46 | 0.24 | 0.41 | 0.64 | 0.53 |
| 432 | 6 | 0.53 | 0.30 | 0.48 | 0.73 | 0.61 |
| 504 | 7 | 0.61 | 0.37 | 0.54 | 0.79 | 0.68 |
| 576 | 8 | 0.63 | 0.38 | 0.61 | **0.83** | 0.73 |
| 648 | 9 | 0.68 | 0.43 | 0.65 | **0.88** | 0.77 |
| 720 | 10 | 0.74 | 0.48 | 0.71 | **0.89** | **0.84** |
| 792 | 11 | 0.77 | 0.51 | 0.76 | **0.92** | **0.87** |
| 864 | 12 | **0.81** | 0.53 | **0.80** | **0.94** | **0.90** |
| 936 | 13 | **0.85** | 0.58 | **0.83** | **0.96** | **0.91** |
| 1008 | 14 | **0.87** | 0.62 | **0.86** | **0.98** | **0.94** |
| 1080 | 15 | **0.89** | 0.64 | **0.88** | **0.98** | **0.95** |

## B.2.2 Other Analyses

Another GAM/GAMM (Equation 25) with an appropriate link function will be fit to the data to test the second null hypothesis ($H_{o2}$). A power analysis was not conducted for this test because it is assumed that the sample size determined by the CPUE power analyses will be adequate to detect a change in the length distributions of target species because the conditional error distribution (i.e., the lengths of fishes at given predictor inputs) will likely be Gaussian with parameters that make finding a significant determination of a reasonable effect size more powerful than over- dispersed abundance data. In other words, it should be easier to detect a localized change in length distributions than it will be to detect a change in population size. As with the previous GAM/GAMMs, the significance of the interaction term “treatment:distance” will determine if we reject the null hypothesis and the significance of the interaction term “treatment:temperature” will determine if there was evidence of underlying oceanographic characteristics that influenced results. For all GAM/GAMMs presented to this point, the “temperature” predictor could be substituted for other environmental variables (e.g., temperature, depth, dissolved oxygen, salinity) without changing the degrees of freedom and invalidating the power analysis. In addition, it would be possible to also analyze the data with a GLM by treating distance as a factor or applying a nonlinear function to transform the data.

Equation 25:

$$LLDDttLLDDh = DDDDDDttDDttDDttDD + (ddDDDDDDttttllDD) + DDDDttDDlltt + DDDDtttt + DDDDDDttDDttDDttDD: DD(ddDDDDDDttttllDD) + DDDDDDttDDttDDttDD: DDDDtttt + \beta\beta_0$$

## B.3 Hydraulic Clam Dredge Survey Power Analyses

Based on the existing data in the region, a hydraulic dredge survey will only be able to detect very large changes (i.e., effect size) in CPUE (of abundance for this section) without employing an unreasonable number of tows. It is possible that increased sampling resolution from the first year of sampling will provide better data that suggests smaller effect sizes will be detectable so an adaptive approach will be used to reevaluate the power analysis and sample size after the first round of sampling. The following section outlines the results of a few approaches to power analyses that were completed and a final power analysis that examines the power to detect a range of effect sizes given the proposed number of tows (48 per year).

A dual-analysis hybrid design applying BAG analyses to the BACI-style BOEM recommendations was selected in response to stakeholder comments about the likely non-independence of strata suggested in the BOEM (2019) guidelines. The power analyses for this survey were based on the BACI-style analyses.

### B.3.1 Atlantic Surf Clam Power Analysis

The first attempt at a power analysis explored data from 80 passing ~5 min tows conducted between 2011 and 2015 by the NEFSC as part of the clam dredge survey (Figure A-5). CPUE data from all years were pooled to create a larger sample size. Fitting a negative binomial distribution to the data (Figure B-12) produced size and μ parameter estimates that were used to randomly generate samples composing simulation data.

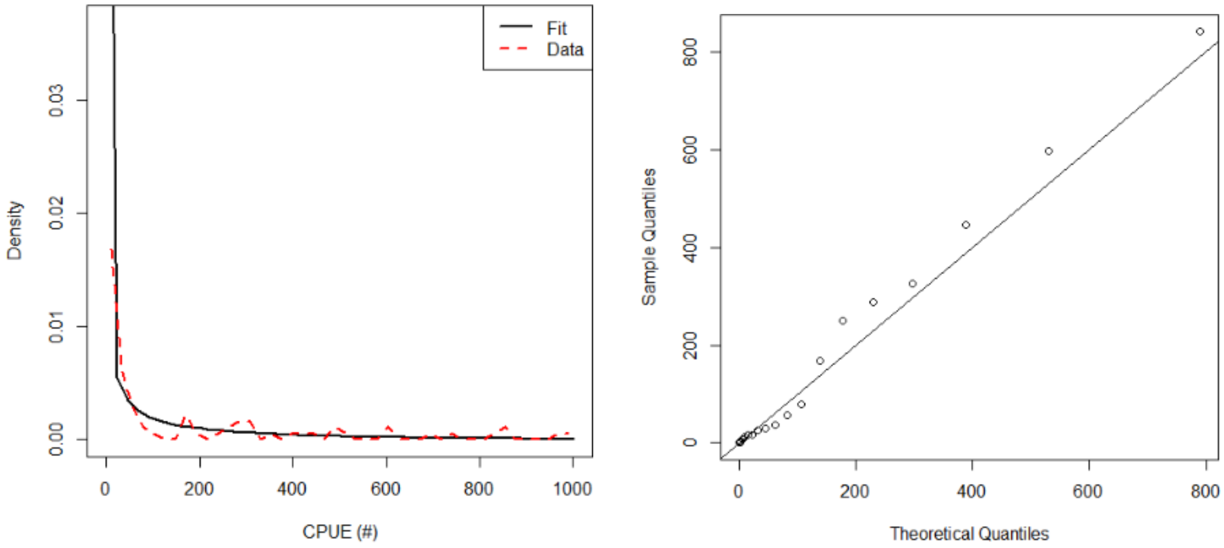

Figure B-12. Negative binomial distribution (black) fitted to Atlantic surf clam biomass from NEFSC dredge data (red, dashed) collected within and nearby the Lease Area between 2011 and 2015 (left) and the quantile-quantile plot (right). The fitted distribution was used to generate datasets for power analysis simulations.

To conduct the power analysis with the correct degrees of freedom, the statistical model used to analyze the data was also chosen *a priori,* but other models could be fitted after data collection to investigate other questions. A GLM with a negative binomial conditional distribution will be used to assess the null hypothesis because it allows for incorporation of multiple categorical and continuous predictor variables and interactions. Specifically, the GLM used “treatment” (i.e., before or after effects, but could be extended to include other years after construction), and “location” (i.e., strata; effects site, close control, or far control) as categorical predictors and temperature (can be substituted for other environmental variables later) as a continuous predictor of diversity. The interactions between treatment:location and treatment:temperature were included and will provide the most valuable insight into whether the project effects density (Equation 26).

Equation 26:

$$CCCCCCCC = DDDDDDttDD\mathbf{tt}DDttDD + llllllttDDllllltt + DDDDttDDlltt + DDDD\mathbf{tt}tt + DDDDDDttDD\mathbf{tt}DDttDD\mathbf{:}\ llllllttDDllllltt + DDDDDDttDD\mathbf{tt}DDttDD\mathbf{:}\ DDDD\mathbf{tt}tt + \beta\beta_0$$

To test the effect of sample size on power, 11 datasets ranging from 72 samples to 312 samples in multiples of 24 were created for each iteration of a 2,000-iteration simulation. Each 24 additional samples contained 12 observations in each treatment (i.e., before and after effects) with 3 observations allocated into each location (i.e., effects site, close control, far control).

The “before effects” treatment data were all selected from the same normal distribution (Equation 27), while the “after effects” data were selected from one of three different distributions depending on distance from effects. The “far control, after effects” data were selected from the same distribution as the “before effects” data while the mean of the “effects site, after effects” distribution was increased by 50% of the “before effects” mean (Equation 29) and mean of the “near control” “after effects” distribution was increased by 25% of the mean (Equation 28) occurred assumed localized colonization effects with no change at the furthest sampling sites, but a same magnitude decrease near the effects should be equally detectable (i.e., two-tailed). A 25% change in community indices has been used before in benthic monitoring studies with power close to 80% for most benthic taxa (Lambert et al. 2017). In this case, changing the mean of the “effects site” by 50% and the mean of the “near control” site by 25% is equivalent to completing a power analysis at each level of effect because both locations are compared to the “far control” location independently.

Equation 27:

$$\text{Negative binomial}(\mu\mu = 185, DDDDssDD = 0.37)$$

Equation 28:

$$\text{Negative binomial}(\mu\mu = 1.25 * 185, DDDDssDD = 0.37)$$

Equation 29:

$$\text{Negative binomial}(\mu\mu = 1.5 * 185, DDDDssDD = 0.37)$$

Bottom temperature was also randomly selected for each tow from a normal distribution (Equation 30).

Equation 30:

$$\mathrm{N}(\mu\mu = 20°CC\,, \sigma\sigma^2 = 2°CC\,)$$

Once each dataset was generated, a GLM (Equation 26) was fit in R with the “glm()” function with a negative binomial error distribution function “neg.bin()“ and starting value for theta taken from the distribution of real catch data. The *p value* for the “treatment:location” interaction terms were evaluated at an alpha level of 0.05 for significance, as will be used to assess the null hypothesis ($H_{01A}$) by determining if the abundance-location relationship was different after construction occurred. The pass/fail result was recorded for each of the 11 different sized datasets and then averaged over 2,000 simulations to determine the power of each sample size. Results indicated that there was a maximum of 18% power in detecting the changes simulated here (Table B-6). In addition, the GLM fit failed to converge in a small percentage of cases, especially when sample size was small.

Table B-6**.** Estimated power at different sample sizes and conservative effect sizes from 2,000 iterations of a simulation based on NEFSC Atlantic surf clam dredge abundance data.

| Total Sample Size (dredge tows) | Samples per year | Power (25% change) | Power (50% change) |
|---|---|---|---|
| 72 | 36 | 0.10 | 0.13 |
| 96 | 48 | 0.09 | 0.13 |
| 120 | 60 | 0.09 | 0.13 |
| 144 | 72 | 0.10 | 0.13 |
| 168 | 84 | 0.09 | 0.15 |
| 192 | 96 | 0.09 | 0.13 |
| 216 | 108 | 0.09 | 0.16 |
| 240 | 120 | 0.10 | 0.14 |
| 264 | 132 | 0.09 | 0.15 |
| 288 | 144 | 0.10 | 0.17 |
| 312 | 156 | 0.10 | 0.18 |

Next, we investigated the independence assumption to examine if we should be simulating sample sizes from a different sampling distribution that may require less power to detect effect size. Under the hypothesis that the large variance observed in the regional dredge data was the result of sampling patchy habitats/ populations, we might expect to see similar catch sizes at the same stations from year to year and therefore different (or less dispersed) sample distributions when sampling at a spatial scale equivalent to the survey design. Therefore, we examined the five sites that were sampled in more than one year between 2012 and 2015. However, these sites exhibited some very large differences between years (Table B-7) failing to support the idea that sampling at repeat locations might result in consistent abundances and higher power.

Table B-7. Multiyear Atlantic surf clam abundances at repeat sampling sites.

| | Abundance | | Absolute Difference |
|---|---|---|---|
| 2011 | 2012 | 2015 | |
| 0 | 5 | - | 5 |
| 12 | - | 856 | 844 |
| - | 440 | 0 | 440 |
| - | 604 | 20 | 584 |
| - | 510 | 0 | 510 |

Finally, we revisited the initial power analysis and used the probability distribution derived from the 80 passing tows to simulate data and test the power of 72 tows (36 per year) and 96 tows (48 per year) to detect various effect sizes (Table B-8). According to the simulations, 36 tows per year would have at least 80% power to detect a 1250% change in the mean CPUE and 48 tows per year would have at least 80% power to detect an 850% change in the mean CPUE. Based on these results, 96 samples (48 tows per year) will be used in the survey design because it should be able to detect at least an order of magnitude change and is at the reasonable edge of feasible effort for a monitoring survey.

Table B-8. Estimated power of 72 samples at different effect sizes from 2,000 iterations of a simulation based on NEFSC Atlantic surf clam dredge abundance data.

| Effect Size | Power (72 Samples) | Power (96 Samples) |
|---|---|---|
| 50% | 0.13 | 0.12 |
| 100% | 0.19 | 0.19 |
| 150% | 0.24 | 0.26 |
| 200% | 0.28 | 0.33 |
| 250% | 0.33 | 0.38 |
| 300% | 0.37 | 0.43 |
| 350% | 0.43 | 0.50 |
| 400% | 0.45 | 0.56 |
| 450% | 0.49 | 0.59 |
| 500% | 0.51 | 0.61 |
| 550% | 0.58 | 0.66 |
| 600% | 0.61 | 0.69 |
| 650% | 0.62 | 0.73 |
| 700% | 0.64 | 0.75 |
| 750% | 0.66 | 0.76 |
| 800% | 0.68 | 0.78 |
| 850% | 0.70 | **0.80** |
| 900% | 0.72 | **0.81** |
| 950% | 0.74 | **0.83** |
| 1000% | 0.75 | **0.84** |
| 1050% | 0.75 | **0.85** |
| 1100% | 0.76 | **0.86** |
| 1150% | 0.77 | **0.87** |
| 1200% | 0.79 | **0.88** |
| 1250% | **0.80** | **0.89** |
| 1300% | **0.81** | **0.91** |

## B.3.2 Other Analyses for Surf Clams

Another GLM (Equation 31) with an appropriate link function will be fit to the data to test the second null hypothesis ($H_{02A}$). A power analysis was not conducted for this test because it is assumed that the sample size determined by the CPUE power analysis will have more power to detect a change in the length (and length-at-age) distributions of surf clams because the conditional error distribution (i.e., the lengths of clams at given predictor inputs) will likely be Gaussian with parameters that make finding a significant determination of a reasonable effect size more powerful than over-dispersed abundance data. In other words, it should be easier to detect a localized change in surf clam condition than it will be to detect a change in surf clam population size. As with the previous GLMs, the significance of the interaction term "treatment:distance" will determine if we reject the null hypothesis and the significance of the interaction term "treatment:temperature" will determine if there was evidence of underlying oceanographic characteristics that influenced results. For all GLMs presented to this point, the "temperature" predictor could be substituted for other environmental variables (e.g., temperature, depth, dissolved oxygen, salinity) without changing the degrees of freedom and invalidating the power analysis.

Equation 31:

$$LLDDttLLDDh = DDDDDDttDDttDDttDD + (ddDDDDDDttttllDD) + DDDDttDDlltt + DDDDtttt + DDDDDDttDDttDDttDD: DD(ddDDDDDDttttllDD) + DDDDDDttDDttDDttDD: DDDDtttt + \beta\beta_0$$

## B.3.3 Ocean Quahog Power Analysis

No power analysis was fully completed for ocean quahogs because preliminary analyses found that the same issues (as surf clams) with overdispersion caused frequent failed model convergence and only enough power to detect large effects sizes. In addition, only six ocean quahogs were caught by the 5 tows within the WTA between 2012-2015. It was assumed that the planned number of tows based on the surf clam analyses will have adequate power to detect a large change in ocean quahog abundance or size. The same analysis process that will be applied to surf clams will also be applied to ocean quahogs with potential for a different error distribution based on the data.

# Attachment C - Quantile-Quantile Plots

## Quantile-Quantile Plots of Fits Compared to Real Data

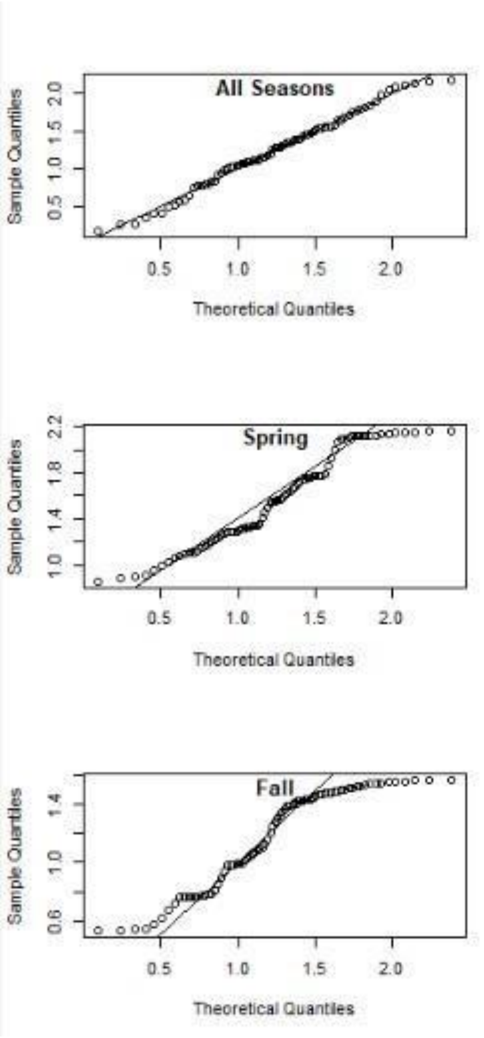

Figure C-1. Quantile-Quantile plots of normal distributions fit to diversity calculated from NJDEP trawl data.

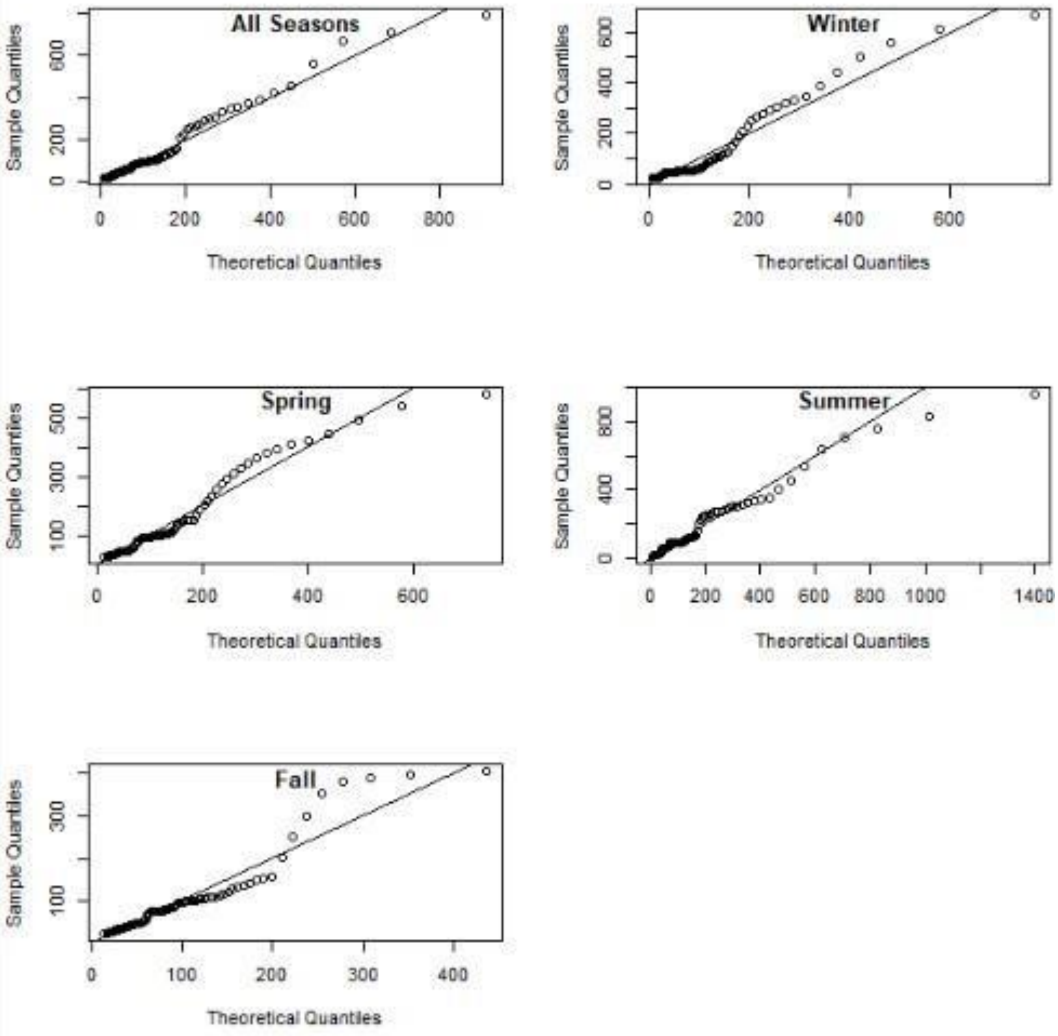

Figure C-2. Quantile-Quantile plots of normal distributions fit to all species biomass data calculated from NJDEP trawl data.

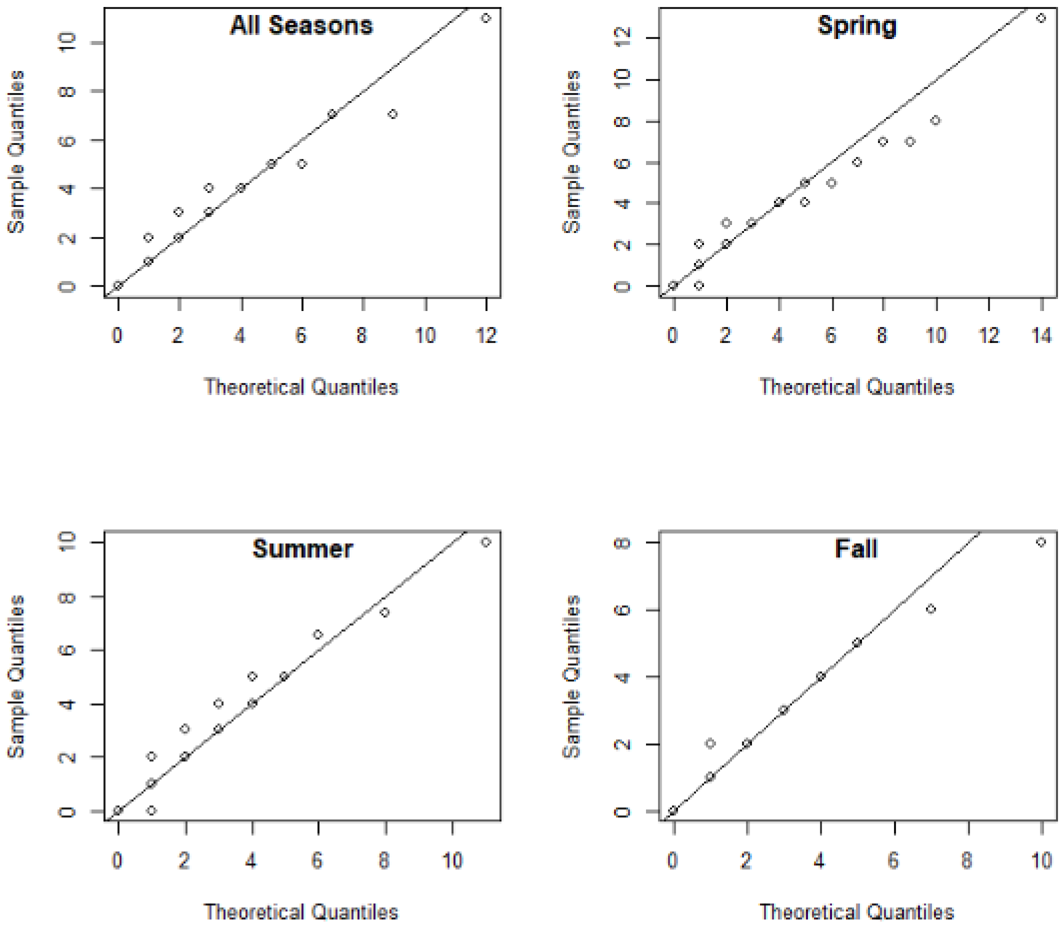

Figure C-3. Quantile-Quantile plots of negative binomial distributions fit to NJDEP fish pot rock crab catch data.

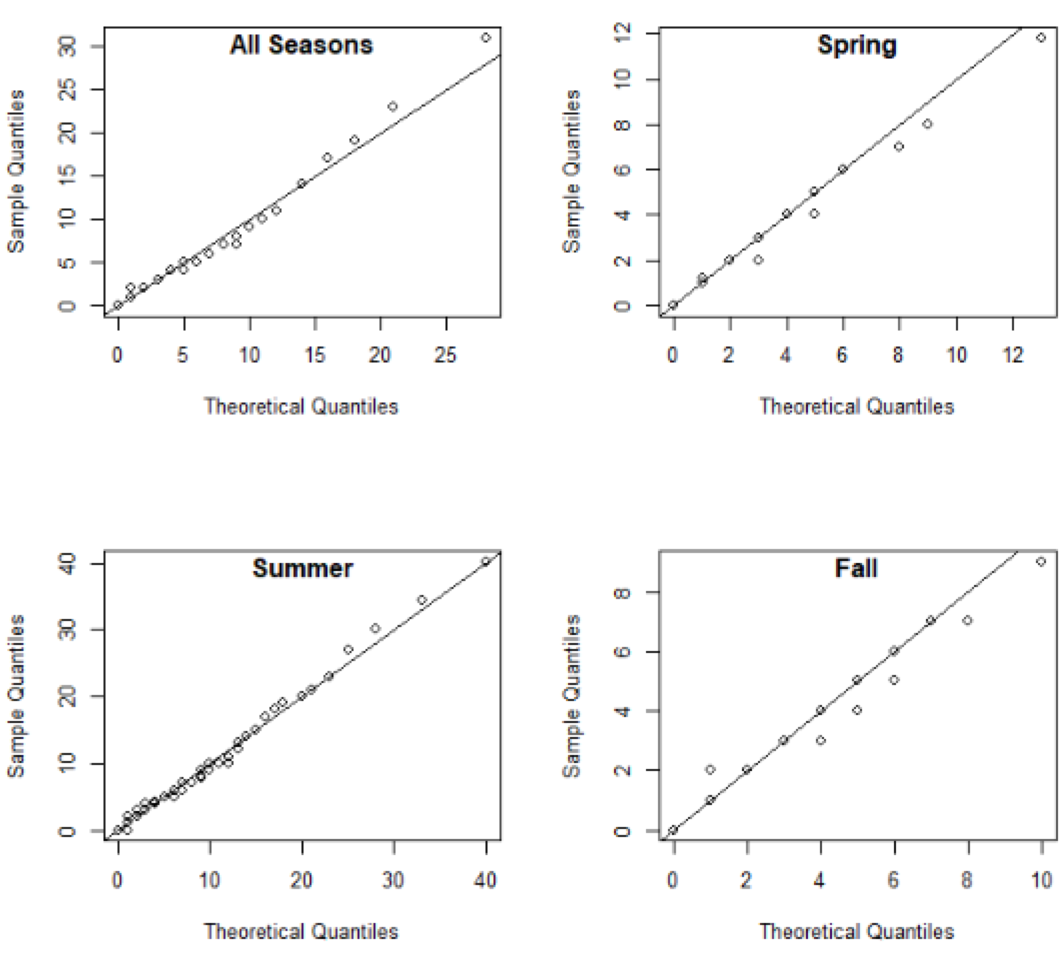

Figure C-4. Quantile-Quantile plots of negative binomial distributions fit to NJDEP fish pot black sea bass catch data.

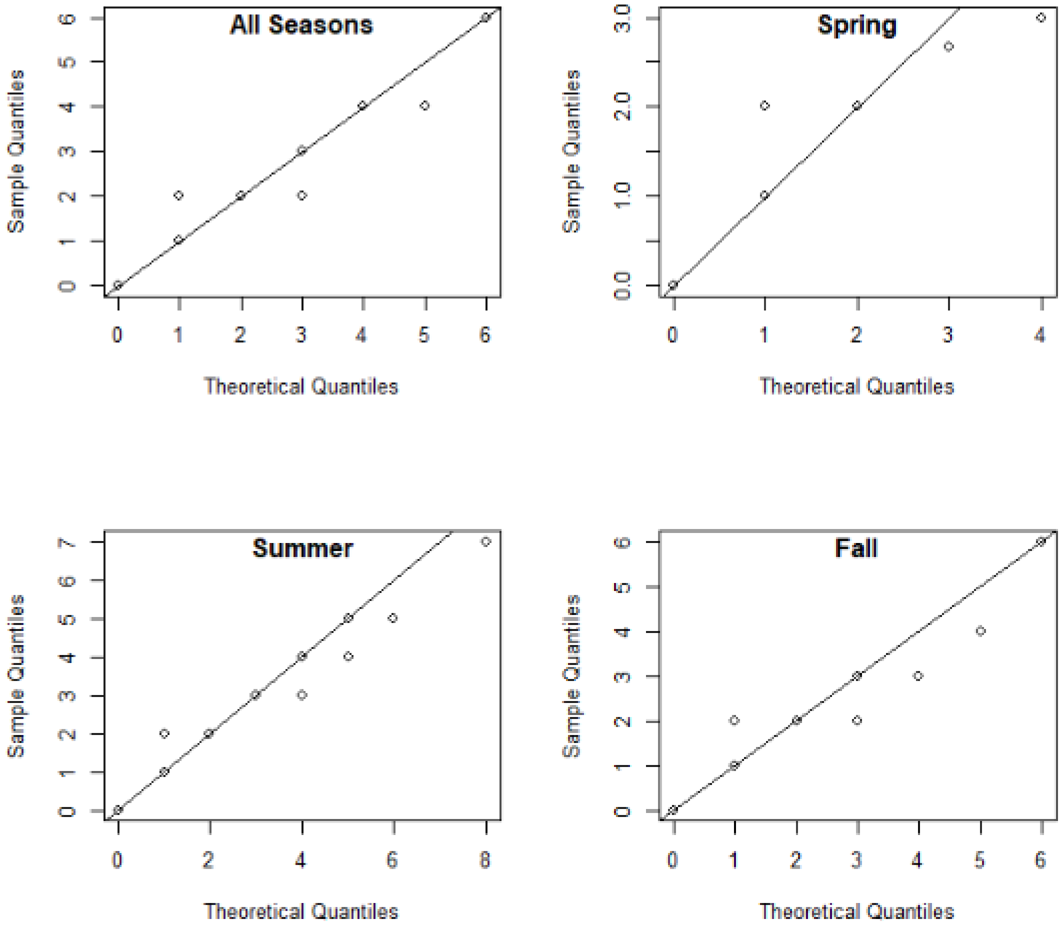

Figure C-5. Quantile-Quantile plots of negative binomial distributions fit to NJDEP fish pot Jonah crab catch data.

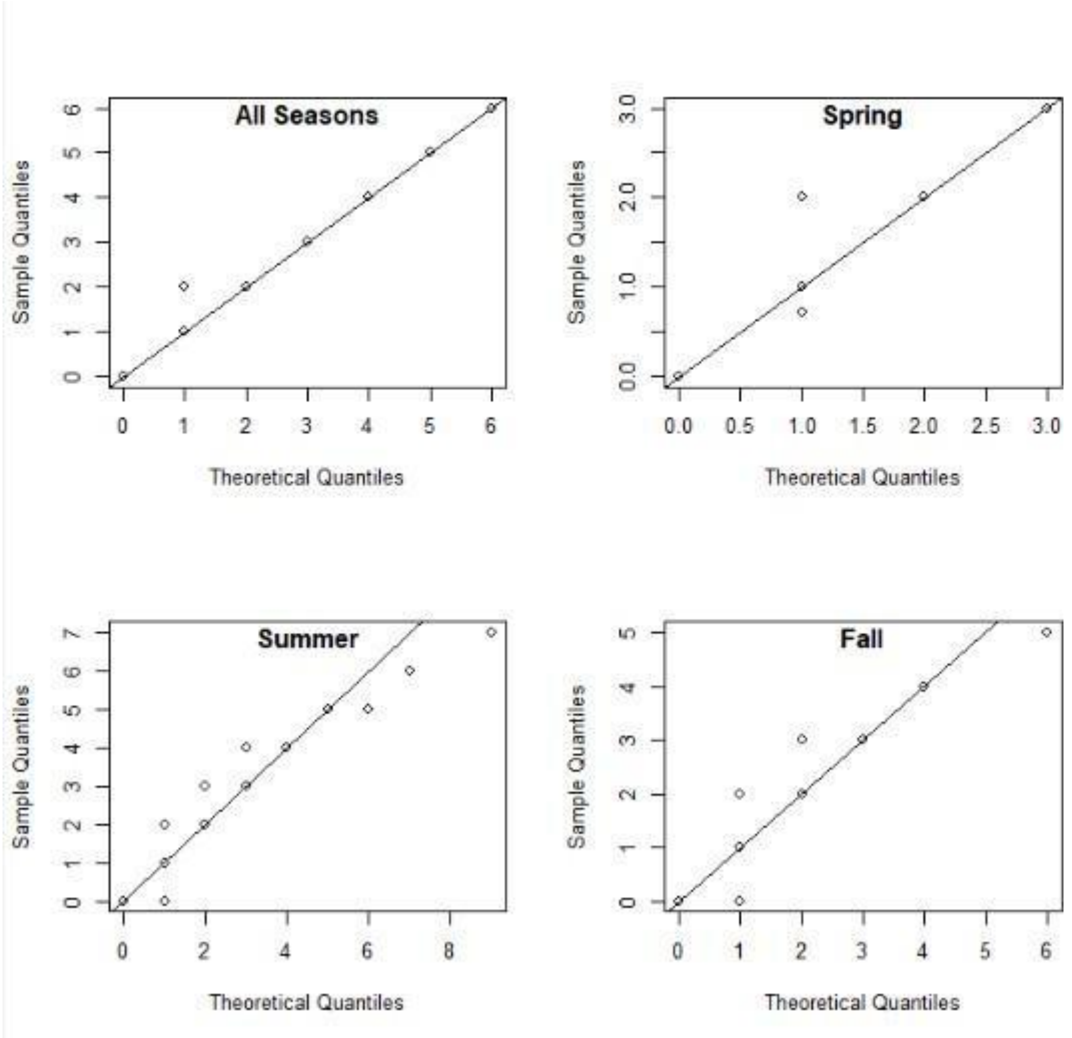

Figure C-6. Quantile-Quantile plots of negative binomial distributions fit to NJDEP fish pot lobster catch data.

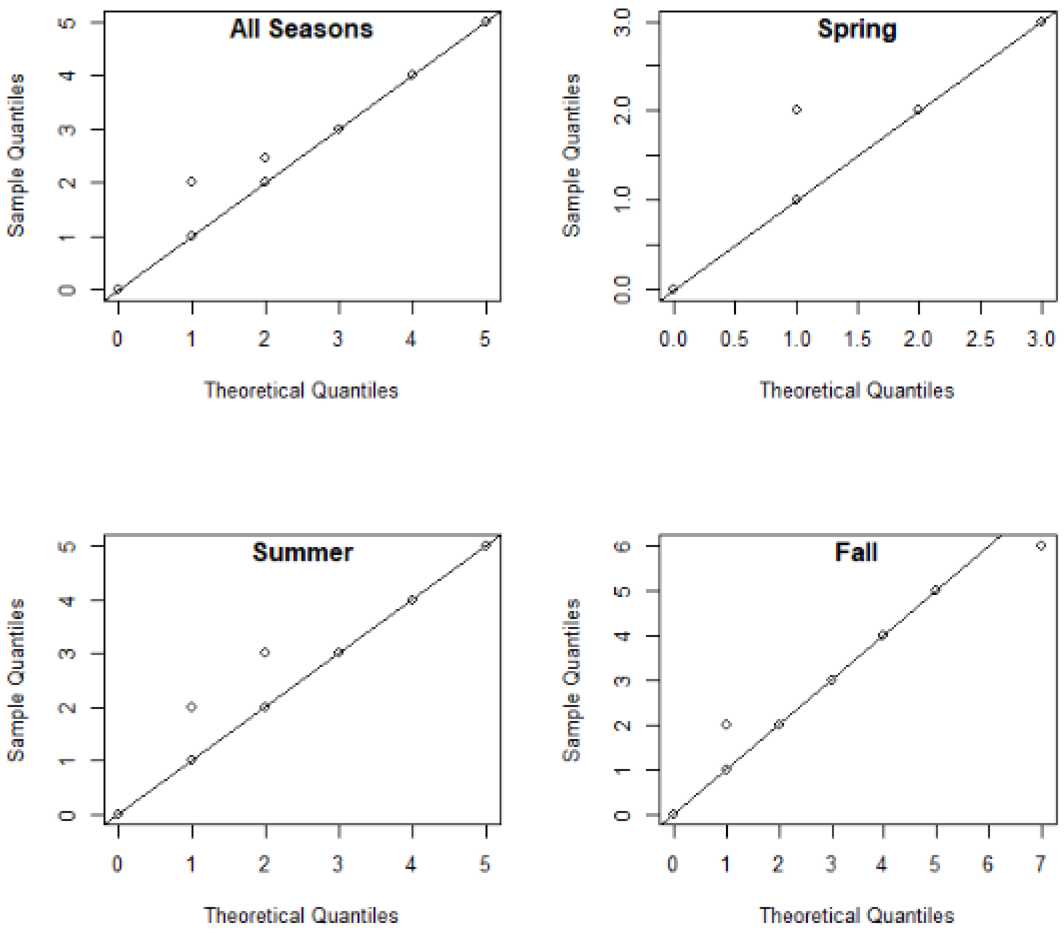

Figure C-7. Quantile-Quantile plots of negative binomial distributions fit to NJDEP fish pot tautog catch data.