Offshore Wind Planning in the New York Bight:

Environmental Sensitivity Analysis

New York State

NYSERDA
New York State Energy Research and Development Authority

NYSERDA Report 25-10
February 2025

NYSERDA's Promise to New Yorkers:

NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Our Vision:

New York is a global climate leader building a healthier future with thriving communities; homes and businesses powered by clean energy; and economic opportunities accessible to all New Yorkers.

Our Mission:

Advance clean energy innovation and investments to combat climate change, improving the health, resiliency, and prosperity of New Yorkers and delivering benefits equitably to all.

Cover Image Source: Getty Images

Offshore Wind Planning in the New York Bight: Environmental Sensitivity Analysis

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Prepared by:

Henningson, Durham & Richardson Architecture & Engineering, P.C.

New York, NY

NYSERDA Report 25-10 NYSERDA Contract 155561 February 2025

Notice

This report was prepared by Henningson, Durham & Richardson Architecture & Engineering, P.C., in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (hereafter "NYSERDA"). The opinions expressed in this report do not necessarily reflect those of NYSERDA or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, NYSERDA, the State of New York, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. NYSERDA, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

NYSERDA makes every effort to provide accurate information about copyright owners and related matters in the reports we publish. Contractors are responsible for determining and satisfying copyright or other use restrictions regarding the content of reports that they write, in compliance with NYSERDA's policies and federal law. If you are the copyright owner and believe a NYSERDA report has not properly attributed your work to you or has used it without permission, please email print@nyserda.ny.gov

Information contained in this document, such as web page addresses, are current at the time of publication.

Preferred Citation

New York State Energy and Research Development Authority (NYSERDA). 2025. "Offshore Wind Planning in the New York Bight: Environmental Sensitivity Analysis," NYSERDA Report Number 25-10. Prepared by Henningson, Durham & Richardson Architecture & Engineering, P.C., New York, NY. nyserda.ny.gov/publications

Abstract

A weighted sum overlay environmental sensitivity analysis was performed for 21 biota layers among four resource groups: marine mammals and sea turtles, birds and bats, fish and fisheries, and benthic habitat to assess the feasible potential for deepwater offshore wind development at or exceeding depths of 60 meters in the New York Bight. Layers were differentially weighted by collecting subject matter expert opinions, rationales, and input using the analytic hierarchy process, a structured multi-criteria decision analysis method for organizing and analyzing complex decisions. Relative sensitivity maps were created for each biotic layer, as well as aggregated by resource group and partitioned by 10 identified potential stressors and by four phases of offshore wind development. These sensitivity maps can help judge the relative suitability of potential offshore wind development within the area of analysis.

Keywords

offshore wind development, environmental sensitivity, weighted sum overlay, analytical hierarchy process

Acknowledgments

We thank the Project Advisory Committee (PAC), the New York State Environmental Technical Working Group (E-TWG), and all Environmental Sensitivity Analysis reviewers for volunteering their time toward providing advice on data sources and study reviews. We also acknowledge the data providers and authors cited whose research and effort contributed to this Environmental Sensitivity Analysis.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

2D	two-dimensional
AHP	Analytical Hierarchy Process
AoA	Area of Analysis
BMP	Best Management Practice
BOEM	Bureau of Ocean Energy Management
Climate Act	Climate Leadership and Community Protection Act
COP	construction and operations plan
CR	consistency ratio
CV	collision vulnerability
DFA	diurnal flight activity
DoN	Department of the Navy
DV	displacement vulnerability
E-TWG	New York State Environmental Technical Working Group
F-TWG	New York State Fisheries Technical Working Group
EA	environmental assessment
EFH	Essential Fish Habitat
EMF	electromagnetic field
ESA	Endangered Species Act
GIS	geographic information system
GW	gigawatt
HAPC	Habitats of Particular Concern
HMS	Highly Migratory Species
HRG	high-resolution geophysical
HVDC	High-Voltage Direct Current
Hz	hertz
IDW	inverse distance weighted
KDE	kernel density estimate
kHz	kilohertz
Master Plan	New York State Offshore Wind Master Plan
MCDA	multi-criteria decision analyses
MDAT	Marine-Life Data and Analysis Team
MW	Megawatt
NAD83	North American Datum of 1983
NARW	North Atlantic right whale
NCCOS	National Centers for Coastal and Ocean Science
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act

NFA	nocturnal flight activity
NJBPU	New Jersey Board of Public Utilities
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NYSERDA	New York State Energy Research and Development Authority
OBIS	Ocean Biogeographic Information System
OBIS-SEAMAP	Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
OMMSCS	Other Marine Mammals of Special Conservation Status
OSW	Offshore wind development
OWSP	Offshore Wind Strategic Plan
PAC	Project Advisory Committee
PiF	Partners in Flight
PTS	Permanent Threshold Shift
PV	population vulnerability
RI	randomness index
RSZ	Rotor Swept Zone
SEER	Synthesis of Environmental Effects Research
SME	subject matter expert
TNC	The Nature Conservancy
TTS	Temporary Threshold Shift
TWG	Technical Working Group
UME	unusual mortality event
U.S.	United States
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
UXO	unexploded ordnance
VMS	Vessel Monitoring System
WEA	Wind Energy Areas
WSA	Weighted Susceptibility Analysis

Executive Summary

In 2019, New York's historic Climate Leadership and Community Protection Act (Climate Act) was signed into law, requiring the State to achieve 100% zero-emission electricity by 2040 and to reduce greenhouse gas emissions 85% below 1990 levels by 2050. The law specifically mandates the development of 9,000 MW of offshore wind energy by 2035, building upon its previous goal of 2,400 MW of offshore wind energy by 2030. The New York State Energy Research and Development Authority (NYSERDA) is charged with advancing these goals.

Since the early 2000s, offshore wind development off New York's coast has advanced in relatively shallow areas in the New York Bight, on the Outer Continental Shelf (OCS). As offshore wind (OSW) development continues to mature and offshore wind leases are developed in deeper waters, the size and type of the offshore wind components are likewise expected to grow, and the project footprint will change as the use of floating offshore wind technology begins to be deployed. This may result in changes in the types of potential effects and interactions seen to date for fixed-bottom offshore wind projects. NYSERDA is conducting studies to investigate the implications of developing floating offshore wind in deeper waters. Findings from the studies will be used to support the identification of areas that present the greatest opportunities and least risk for siting deepwater offshore wind projects and will support other workstreams designed to help assure the continued responsible siting and development of offshore wind energy.

Five desktop environmental studies compile and analyze existing data on selected resources in the Area of Analysis (AoA) that may be sensitive to offshore wind development. Three zones comprise the AoA: Zone 1 is on the outer continental shelf (60 to 150 meters deep), Zone 2 is at the shelf break (150 to 2,000 meters deep), and Zone 3 includes the area beyond the shelf break (2,000 to 3,000 meters deep).

This Environmental Sensitivity Analysis used input data from four separate environmental spatial analyses conducted by NYSERDA (Benthic Habitat Study, Birds and Bats Study, Fish and Fisheries Data Aggregation Study, and Marine Mammals and Sea Turtles Study) to create sensitivity maps for respective biotic environmental resources (i.e., "receptors").

The environmental sensitivity was further evaluated based on potential stressors that could impact the resource groups during the typical OSW phases. Results indicated that new structures[1] were likely to be the most impactful stressor for birds, marine mammals and sea turtles, and fish and fisheries. Bottom disturbance[2] was the stressor identified as most likely to affect benthic habitat, and it was also likely impactful for fish and fisheries. Additionally, artificial light[3] was rated as having a potentially moderate impact on birds, and vessel traffic was assessed as having a potentially moderate impact on marine mammals. In general, sensitivity was potentially greater during the construction phase for marine mammals, sea turtles, and benthic habitat, while potentially greater during post-construction for birds and fish and fisheries.

Data gaps were evaluated for each receptor and quantified by how much reported data there was in the AoA for a given receptor across each zone of the AoA. Risk was not assessed in areas containing less than 50% data coverage as to only assess risk in areas with moderate data coverage. For benthic habitat and fish and fisheries receptors, risk could not be assessed in much of Zone 3. Consideration of the data gaps is an important qualification when interpreting risk and the sensitivity maps. Areas of higher risk for all four resource groups occurred in portions of Zones 1 and 2, with some areas of overlap, including areas of the continental shelf and shelf break. Areas of higher risk for marine mammals and sea turtles were in the northeast corner of Zone 1, along the shelf break, and within canyons in Zone 2. Higher-risk areas for birds were on the continental shelf and at the shelf break in Zones 1 and 2. For fish and fisheries, most of Zones 1 and 2 had moderate-to-high sensitivity. Sensitivity was high for benthic habitat in small areas of Zone 2 within canyons, with the rest of Zone 2 having areas of moderate and low sensitivity. Overall, sensitivities were lower in Zone 3, but this should be considered carefully as the data gaps were greater in this zone due to a lack of data for many receptors. Findings from the studies have been synthesized to determine environmental resource distributions within the AoA and which zones and areas within each zone present the greatest risk from OSW. This analysis and the set of environmental sensitivity maps represent one tool among several that could be used to inform future lease siting.

---

1 "New structures" is regarded as one of various stressors evaluated for each phase of offshore wind. The term defined in Section 2.4.

2 "Bottom disturbance" is regarded as one of various stressors evaluated for each phase of offshore wind. The term defined in Section 2.4.

3 "Artificial light" is regarded as one of various stressors evaluated for each phase of offshore wind. The term defined in Section 2.4.

1 Introduction

For more than a decade, New York State has been conducting research, analysis, and outreach to evaluate the potential for offshore wind energy. New York State Energy Research and Development Authority (NYSERDA) led the development of the New York State Offshore Wind Master Plan (Master Plan), a comprehensive roadmap and suite of more than 20 studies for the first 2,400 megawatts (MW) of offshore wind energy. The Master Plan encourages the development of offshore wind in a manner that is sensitive to environmental, maritime, economic, and social issues while addressing market barriers and aiming to lower costs. The Master Plan included spatial studies to inform siting of offshore wind energy areas. Now, NYSERDA is undertaking new spatial studies to review the feasible potential for deepwater offshore wind (OSW) development at or exceeding depths of 60 meters in the New York Bight and to support the future identification of additional lease areas in the region.

Planning processes considering the development of offshore wind in the deepwater areas examined in each of NYSERDA's spatial studies must consider these studies in the context of one another. Decision making must additionally consider different stakeholders and uses and will require further adjusted approaches and offshore wind technologies to ensure the best outcome. Globally, deepwater wind technology is less mature and primarily concentrated on floating designs at the depth ranges being assessed through the spatial studies, while deepwater fixed foundations are at their upper technical limit within the Area of Analysis (AoA). Therefore, floating designs were predominantly considered since most, if not all, of the AoA would likely feature floating offshore wind. NYSERDA, along with other states and federal agencies, is developing research and analysis necessary to take advantage of opportunities afforded by deepwater offshore wind energy by assessing available and emerging technologies and characterizing the cost drivers, benefits, and risks of floating offshore wind. Findings from these studies and available datasets will be used to support the identification of areas that present the greatest opportunities and least risk for siting deepwater offshore wind projects.

Offshore wind energy development is being introduced into a highly dynamic and human-influenced system. These reports seek to understand the potential interaction of offshore wind development and marine wildlife and habitats; however, it is important to consider these within the broader context of climate change and existing land-based and marine activities. The State will continue to conduct research through its established technical working groups (TWGs) concerning the key subjects of fishing, maritime commerce, the environment, environmental justice, jobs, and the supply chain. These TWGs were designed to inject expert views and the most recent information into decision making. Taken together, the information assembled in these spatial studies will help empower New York State and its partners to take the informed steps needed to capitalize on the unique opportunity presented by offshore wind energy.

1.1 Spatial Studies to Inform Lease Siting

- Benthic Habitat Study
- Birds and Bats Study
- Deepwater Wind Technologies–Technical Concepts Study
- Environmental Sensitivity Analysis
- Fish and Fisheries Data Aggregation Study
- Marine Mammals and Sea Turtles Study
- Assessment–Commercial and Recreational Uses Study
- Offshore Wind Resource Assessment Study Zones 1 and 3
- Technology Assessment and Cost Considerations Study

Each of the studies was prepared in support of a larger planning effort and shared with relevant experts and stakeholders for feedback. The State addressed comments and incorporated feedback received into the studies. Feedback from these diverse groups helps to strengthen the studies, and also helps ensure that these work products will have broader applicability and a comprehensive view. Please note that assumptions have been made to estimate offshore wind potential and effects using various methodologies across the studies. NYSERDA does not necessarily endorse any underlying assumptions in the studies regarding technology and geography, including but not limited to turbine location, turbine layout, project capacity, foundation type, and point of interconnection.

The Energy Policy Act of 2005 amended Section 8 of the Outer Continental Shelf Lands Act (OCSLA) to give BOEM the authority to identify OSW sites within the Outer Continental Shelf (OCS) and to issue leases on the OCS for activities that are not otherwise authorized by the OCSLA, including wind development. The State recognizes that all development in the OCS is subject to review processes and decision-making by BOEM and other federal and State agencies. This collection of spatial studies is not intended to replace the BOEM WEA identification process and does not commit the State or any other agency or entity to any specific course of action with respect to offshore wind energy development. Rather, the State's intent is to facilitate the principled planning of future offshore development off the coast of New York, provide a resource for the various stakeholders, and encourage the achievement of the State's offshore wind energy goals.

1.2 Study Area

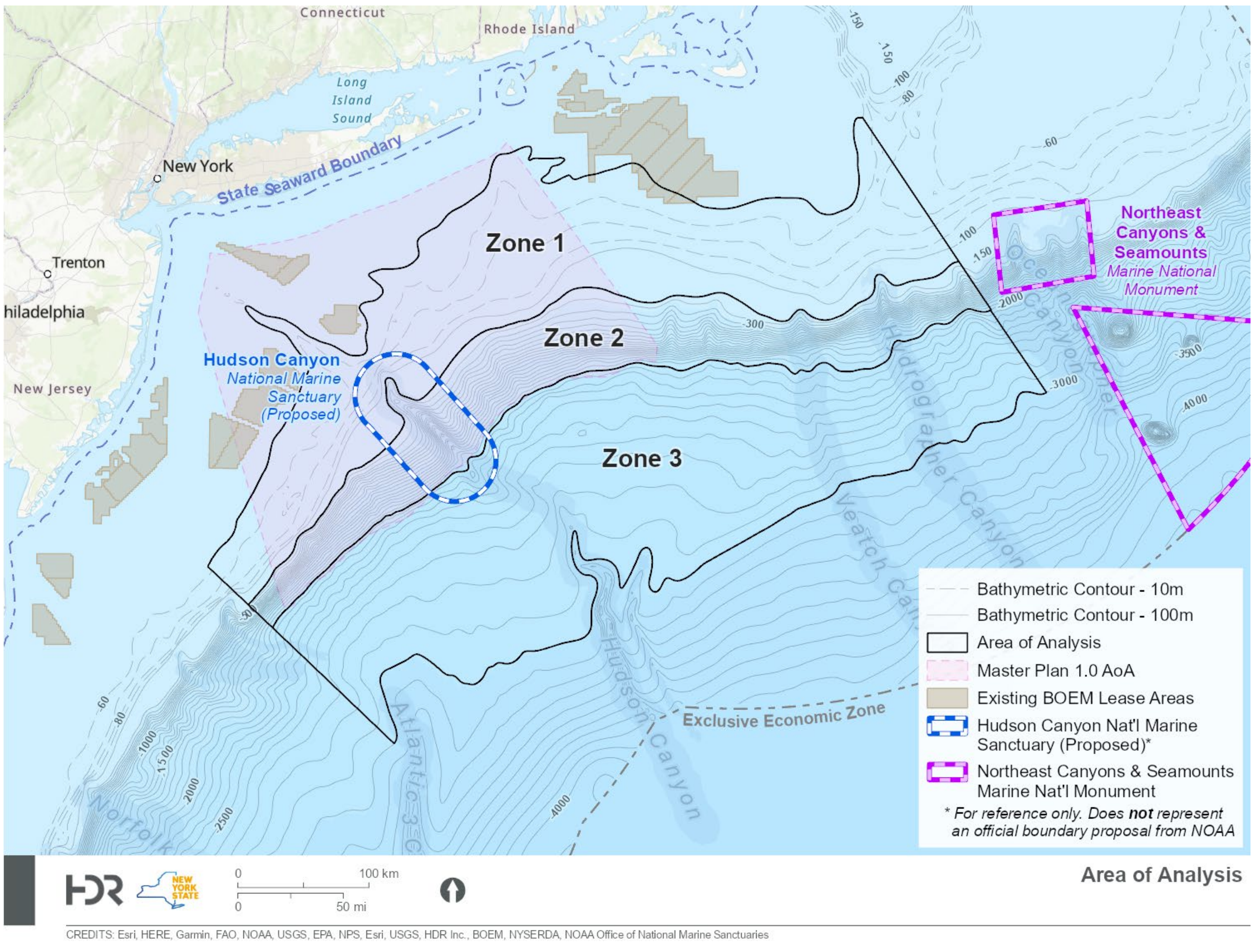
The spatial studies evaluate potential areas for deepwater OSW within a specific geographic AoA of approximately 35,670 square miles of ocean area, extending from the coast of Cape Cod south to the southern end of New Jersey (Figure 1). It includes three zones extending outward from the 60-meter depth contour, which ranges between 15 and 50 nautical miles from shore to the 3,000-meter contour, which ranges from 140 to 160 nautical miles from shore.

The eastern edge of the AoA avoids Nantucket Shoals and portions of Georges Bank, since those areas are well known to be biologically and ecologically important for marine mammals, fish and wildlife, fisheries, and maritime activity. The AoA does include areas such as the Hudson Canyon, which is under consideration to be designated as a National Marine Sanctuary and thus unlikely to be suitable for BOEM site leases. While offshore wind infrastructure will not be built across the entire AoA, the spatial studies analyze this broad expanse to provide a regional context for these resources and ocean uses.

- Zone 1 is closest to shore and includes a portion of the OCS. It extends from the 60-meter contour out to the continental shelf break (60 meters [197 feet)]to 150 meters [492 feet] deep). Zone 1 is approximately 12,040 square miles.
- Zone 2 spans the steeply sloped continental shelf break, with unique canyon geology and habitats (150 meters [492 feet] to 2,000 meters [6,561 feet] deep). Zone 2 is approximately 6,830 square miles.
- Zone 3 extends from the continental shelf break out to 3,000 meters (9,842 feet) depth. Zone 3 is approximately 16,800 square miles.

Zone 2, stretching across the steeply sloped continental shelf break with its distinctive canyon geology and unique habitats, is unlikely to host offshore wind turbines, but is still likely to be impacted by OSW activities through maritime traffic and/or cabling and was, therefore, included in this study. The underwater canyons in this region are distinctive and ecologically significant, making Zone 2 an area of particular interest for scientific research, conservation efforts, and fish and benthic habitats. Another crucial factor prompting this analysis is the presence of electrical cabling in the area, which can have several environmental implications, including electromagnetic fields that might disrupt marine life and the physical disturbance of the seafloor during installation. Lastly, maritime vessel activities throughout the zone could involve shipping traffic, fishing, and other recreational activities related to the sea, which can introduce pollutants, noise, and physical disturbances such as vessel strikes that may have adverse effects on the surrounding environment.

Figure 1. Area of Analysis



1.3 Study Objectives

The objectives of the Environmental Sensitivity Analysis were:

- Evaluate other existing spatially weighted risk assessment modeling techniques.
- Assess the potential for risk of adverse impacts on marine biota from OSW stressors in the AoA and develop a model to evaluate the temporal and spatial risks identified in the environmental studies on marine resources ("receptors") from the potential impacts ("stressors") and the level of risk associated with the stressors on a particular receptor during each phase of OSW.
- Assign risk scores for each receptor group for each phase of OSW.

- Provide geographic depictions of relatively high and low areas of potential conflict for OSW and associated stressors, based on the model, allowing for comparative analysis of the potential sensitivities to OSW for all four marine resource groups within the AoA.

To accomplish these objectives, this study developed a weighted sum model and map products that allowed for a comparative analysis of the potential sensitivities to construction and operation of offshore wind facilities for marine resources within the AoA. The Environmental Sensitivity Analysis considered activities that may occur during pre-construction, construction, and post-construction of offshore wind facilities.

This study is intended to serve as a planning level tool for identifying relative environmental sensitivity (also known as risk) spatially in the AoA. In other words, are marine resources in a particular region of the AoA more (or less) susceptible to OSW as compared to other regions? The resulting maps and data sets indicate areas of biological importance, to inform managers and developers and facilitate the identification of areas under consideration for OSW.

Although this study and associated figures are intended to provide technical insights into the anticipated sensitivity of marine biotic resources to OSW, it should be noted that this effort reflects a broad overview and is not a comprehensive or exhaustive study of all available scientific information. This study provides information regarding the potential relative sensitivity of certain marine resource groups to OSW in the defined AoA. Any specific project impacts that may be associated with potential OSW are not evaluated here and will be thoroughly evaluated as part of each project’s development cycle.

This study focuses on resources in the AoA. Section 1 describes the study area, study objectives, stakeholder engagement process, and report organization. Section 2 discusses the methods used for the literature review, data collection process, and geospatial analysis. Section 3 discusses data gaps and coverage of data for each resource group. Section 4 describes the results of the weights of the different layers, rationales for layer weighting, sensitivity results, and percent coverage of data. Section 5 provides summary conclusions.

This study is one of a series of environmental desktop studies that synthesize available and relevant existing data sets on four key resource groups: marine mammals and sea turtles; birds and bats; fish and fisheries; and benthic habitat. Each of these studies identifies potential stressors from all phases of OSW for each resource group, with a focus on deepwater technology. This report builds upon and compiles the results from the four studies into a single study and presents a series of figures showing areas of greatest (or least) risk from OSW.

1.4 Agency and Stakeholder Engagement

NYSERDA is committed to engaging with and incorporating stakeholder feedback in offshore wind planning processes. Prior to the development of this study, stakeholder comments from New York's Offshore Wind Master Plan were reviewed and incorporated into the study as applicable and practical. The State agency partners engaged in its the development and review, consist of the New York State Department of State, New York State Department of Environmental Conservation, New York State Office of Parks, Recreation, and Historic Preservation, New York State Department of Transportation, Empire State Development, New York Department of Public Service, New York State Office of General Services, and New York State Department of Labor.

To involve stakeholders in the development and analysis of the study, two stakeholder groups were consulted. A Project Advisory Committee (PAC), including subject matter experts (SMEs) from State, federal, and non-governmental groups, provided guidance for the identification of data sources, sensitivity receptors, rankings, and review of the draft and final reports. Conference call dates for the study PAC were May 4, 2022; May 30, 2022; July 14 and May 30, 2023.

Additionally, NYSERDA's Environmental Technical Working Group (E-TWG) provided a preliminary list of data sources used in the development of the study as well as reviewed the draft report. Comments from both groups were addressed and, as practical, incorporated into the final report. The State provided a first draft of the study for review by State and federal regulators, TWGs, and other stakeholders on August 22, 2023, and afforded these stakeholders the opportunity to submit written comments on the draft's contents. In addition, the E-TWG and NYSERDA's Fisheries Technical Working Group (F-TWG) hosted meetings in September 2023, in which the study authors gave an overview of the document and fielded questions and concerns from participating organizations. In total, the State received over

100 written and verbal comments. Several comments were about uncertainty and how risk was assessed or depicted with high uncertainty. To address these comments, sensitivity figures were revised to only include overall sensitivity rankings where data coverage was greater than 50%; all blocks with less coverage do not show a ranking. Additionally, the discussion of data coverage and uncertainty was moved ahead of the results to clearly define the uncertainty prior to presenting the results. Additional context was placed around the stressor rankings.

2 Methods

Given the primary objective of this study was to evaluate the relative risk of adverse impacts on marine resources from OSW stressors in the AoA, a weighted sensitivity model (i.e., a risk model) was developed. The model produced geographic depictions of relatively high and low areas of potential conflict for OSW with respect to marine resources. Development of the model incorporated the data sets, spatial data analyses, and results produced from the concurrent studies on the marine resources "receptors" (i.e., marine mammals and sea turtles, birds and bats, fish and fisheries, and benthic habitat) and identified the potential impacts ("stressors") on these resources and the level of risk associated with the stressors on a particular receptor during each phase of OSW. The stressors listed below were evaluated for each phase of OSW:

- Artificial lighting
- Bottom disturbance
- Changes in water quality
- Changes to atmospheric/oceanic dynamics
- Electromagnetic field (EMF)
- New structures
- Noise
- Scouring around seafloor structures
- Unexploded ordnance (UXO) detonation
- Vessel traffic

Refer to section 2.3 for a complete definition of terms used in the model framework. The model and associated map products allowed for a comparative analysis of the potential sensitivities to construction and operation of offshore wind facilities for marine resources within the AoA.

The remainder of this section provides details on each step of the sensitivity analysis and model development.

2.1 Data and Literature Review

Concurrently with this study, four separate studies focused on a specific marine resource group identified above (i.e., marine mammals and sea turtles, birds and bats, fish and fisheries, and benthic habitat). A desktop and literature review were conducted for each of these specific studies, and those data were used in this assessment (see section 2.5).

In addition, a comprehensive literature review was performed to identify and summarize similar studies done in the past, with a focus on those in connection with OSW. A summary of the most directly relevant reports (primary sources) is presented in the following subsections.

Additional literature besides primary sources was also reviewed; however, most of these sources were largely academic or conceptual and are, therefore, not summarized here. Nevertheless, these sources were broadly useful for the overall context. (Goodale and Milman 2016; Goodale and Stenhouse 2016; Goodale and Milman 2019; Croll et al. 2022; Cooperman et al. 2022; Díaz and Soares 2020, 2022; Southall et al. 2023).

2.1.1 NYSERDA Master Plan

In 2017, NYSERDA conducted a similar New York State Offshore Wind Master Plan Environmental Sensitivity Analysis (NYSERDA 2017a). The principal differences between this study and the Master Plan study include the following:

- Selected AoA
- Receptor groups and data sets used
- List of potential stressors
- Methodology for determining the weights between receptors, stressors, and phases

The AoA of the Master Plan Environmental Sensitivity Analysis focused on nearshore waters (e.g., western Zones 1–2) and was a 14,569-square-mile area of the ocean, extending from 15 nautical miles from the coast of Long Island and New York City to the continental shelf break, slope, and into oceanic waters to an approximate maximum depth of 2,500 meters (Figure 2).

As with this study, environmental sensitivity was defined in the 2017 study as the relative potential susceptibility to alteration or influence from activities associated with OSW. The marine resources were assessed as receptor groups (e.g., fish, benthic species, North Atlantic right whales [NARW, Eubalaena glacialis], phocid seals, and low-frequency cetaceans), where the members of each receptor group were expected to respond similarly to a particular stressor.

Studies appended to New York's Offshore Wind Master Plan and a study-specific literature review informed the risk assessment for this study. The Master Plan used existing seasonal and spatial data for marine species (i.e., predicted species density, core biomass, core abundance, essential habitat, and predicted habitat) to examine the sensitivity of these resources to potential stressors during the three phases of OSW (i.e., pre-construction, construction, and post-construction) within the Master Plan AoA. Data from the selected receptor groups and their associated weights were then combined via a weighted sum model.

The selection of the different receptor groups and data sets used to represent them were modified and/or updated from the Master Plan to reflect the latest available data and scientific understanding. In addition, the list of potential stressors from OSW was reviewed and modified, as needed, to reflect the current state of the industry and different technologies that might be employed due to the expanded AoA (e.g., floating turbines in deep waters). Lastly, the methodology for selecting the relative weightings among the selected receptors, stressors, and phases was updated. Details of all the changes are described in the remainder of this report.

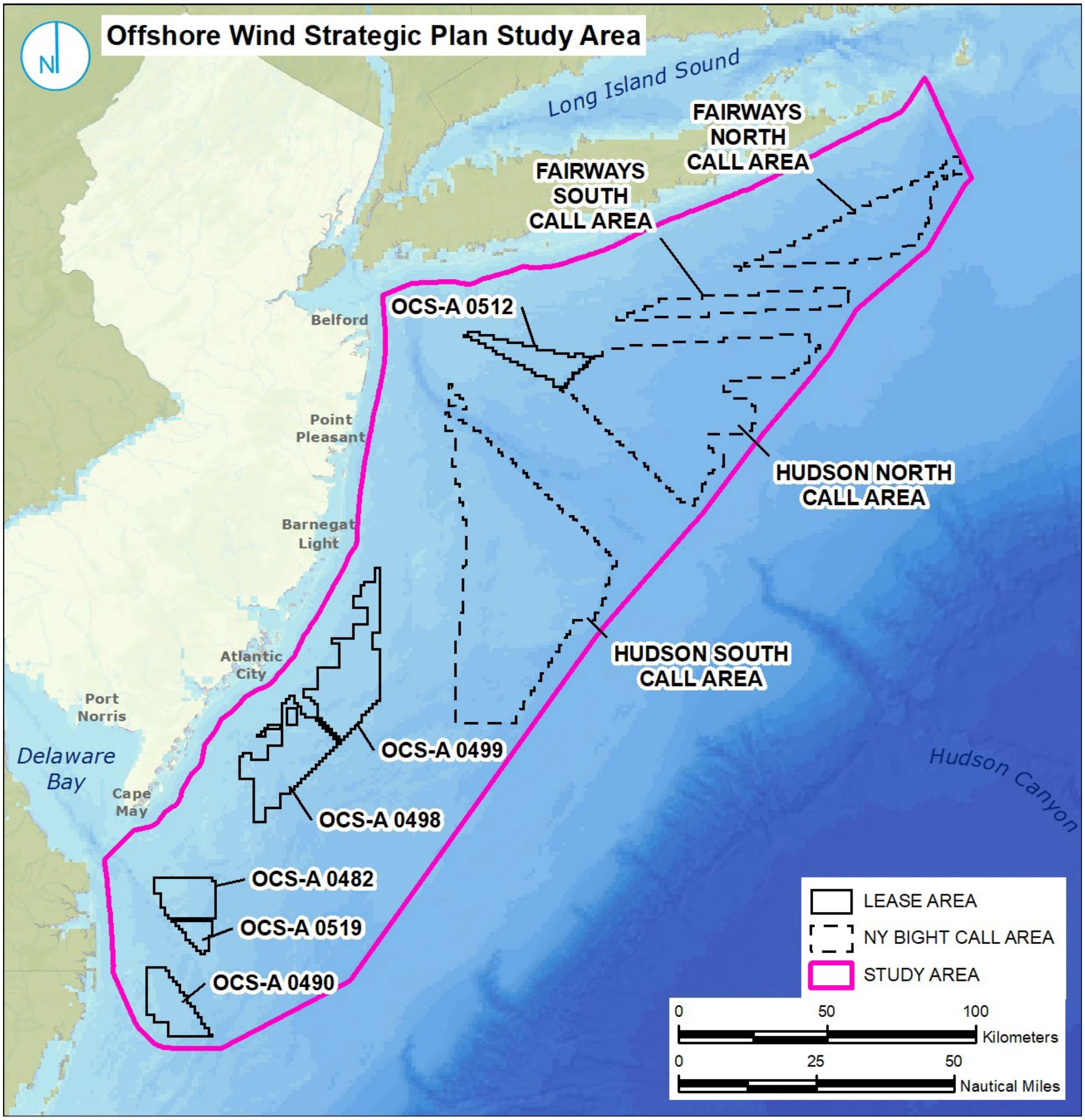
2.1.2 New Jersey Offshore Wind Strategic Plan

On January 31, 2018, New Jersey Governor Phil Murphy signed Executive Order No. 8 and Executive Order No. 92 (Murphy 2018, 2019), which directed the New Jersey Board of Public Utilities (NJBPU) to develop and implement the Offshore Wind Strategic Plan (OWSP). Like New York's Offshore Wind Master Plan, this plan included stakeholder input, scientific evaluations, and recommendations for a path forward.

The OWSP reflects a planning-level analysis and does not represent a comprehensive or detailed environmental impact analysis (New Jersey Board of Public Utilities and the Interagency Taskforce on Offshore Wind 2020). Rather, it provides information regarding the relative susceptibility of environmental and natural resources to OSW in and near existing planning areas off the coast of New Jersey. The AoA within New Jersey's coastal ocean for the OWSP is shown in Figure 2.

Figure 2. New Jersey Offshore Wind Strategic Plan Study Area

Source: New Jersey Offshore Wind Strategic Plan (July 2020 Draft)



The OWSP conducted a Weighted Susceptibility Analysis (WSA), which was applied to evaluate key biological resources and specific taxonomic groups (e.g., birds, cetaceans, sea turtles). It was intended to provide a broad overview and technical insights into the anticipated susceptibility of biota and fisheries activities to OSW. The OWSP analysis provided information regarding the potential relative susceptibility of certain taxonomic groups, important fisheries, and other ocean resources to OSW in the defined study area.

The OWSP considered the following groups of biotic receptors: birds, fish, cetaceans, sea turtles, habitat, and benthic invertebrates during the four phases of OSW (pre-construction, construction, operations, and decommissioning).

However, unlike New York's Offshore Wind Master Plan, no direct accounting was made for specific OSW stressors. The effects of potential stressors were implicitly considered during a similar weighting procedure and subsequent weighted sum overlay analysis. In the OWSP, weighting means the application of a numerical adjustment factor that reflects the relative susceptibility of the resource group represented in a particular data layer. Assigned weights were intended to capture the overall "risk" to the resource, which is a function of both vulnerability and likelihood of occurrence. The assignment of weightings holistically considered the preconstruction, construction, operations, and decommissioning activities associated with OSW and primarily focused on species conservation status and species general "vulnerability" to OSW as the two primary factors for determining the weights, but also considered species life history traits and various input from team experts. Based on this approach, the weights for each layer were then grouped into four general classes: limited, moderate, elevated, and high.

Lastly, like the New York Offshore Wind Master Plan, the WSA used a weighted sum spatial overlay analysis of the various taxonomic group data layers described above, each with individually weighted component layers.

2.1.3 National Centers for Coastal and Ocean Science Central Atlantic and Gulf of Mexico Wind Energy Areas

BOEM, in collaboration with the National Oceanographic and Atmospheric Administration's (NOAA) National Centers for Coastal and Ocean Science (NCCOS), developed an ecosystem-wide spatial suitability model to inform the selection of WEAs in U.S. federal waters for the Central Atlantic Draft WEAs and Gulf of Mexico WEAs (Randall et al. 2022a; BOEM 2015; Randall et al. 2022b).

While NYSERDA's aforementioned goals were similar, the BOEM spatial suitability model did not focus specifically on marine biotic resources, but included other factors (national security, industry, cultural, constraints, etc.) in addition to biotic factors. Moreover, the specific biotic receptors included fewer resources. Some specific examples of the similarities and differences are highlighted in the following paragraphs.

The BOEM siting suitability model was developed by expert marine spatial scientists, marine ecologists, project coordinators, policy analysts, and SMEs. Model development for both areas (Central Atlantic and Gulf of Mexico) used similar methodologies; therefore, only the Central Atlantic model is summarized here. The Central Atlantic is one of several regions where wind energy development in offshore federal waters is being considered to support the Biden-Harris Administration's goal of 30 gigawatts (GW) of offshore wind by 2030. In 2020, the Virginia Clean Economy Act was passed into law, which created the Commonwealth's first Clean Energy Standard, committing to transitioning the electric grid to 100**%** clean energy by 2050. BOEM received a letter from Virginia's governor requesting the formation of a renewable energy regional task force that could lead to a lease sale. BOEM agreed to create a Central Atlantic Intergovernmental Renewable Energy Task Force encompassing the area offshore Delaware south to Cape Hatteras, North Carolina.

A gridded relative suitability analysis, commonly used in multi-criteria decision analyses (MCDA) (Mahdy and Bahaj 2018; Abdel-Basset et al. 2021; Abramic et al. 2021; Vinhoza and Schaeffer 2021), was performed to identify the locations with the highest suitability for OSW in the area of analysis (Figure 3; note, the call areas shown in Figure 3 are as of the date of the NCCOS report and do not reflect BOEM's identification of lease areas). Spatial data layers included in the suitability analysis identified space-use conflicts and environmental constraints such as active national security areas, maritime navigation, ocean industries, and natural resource management.

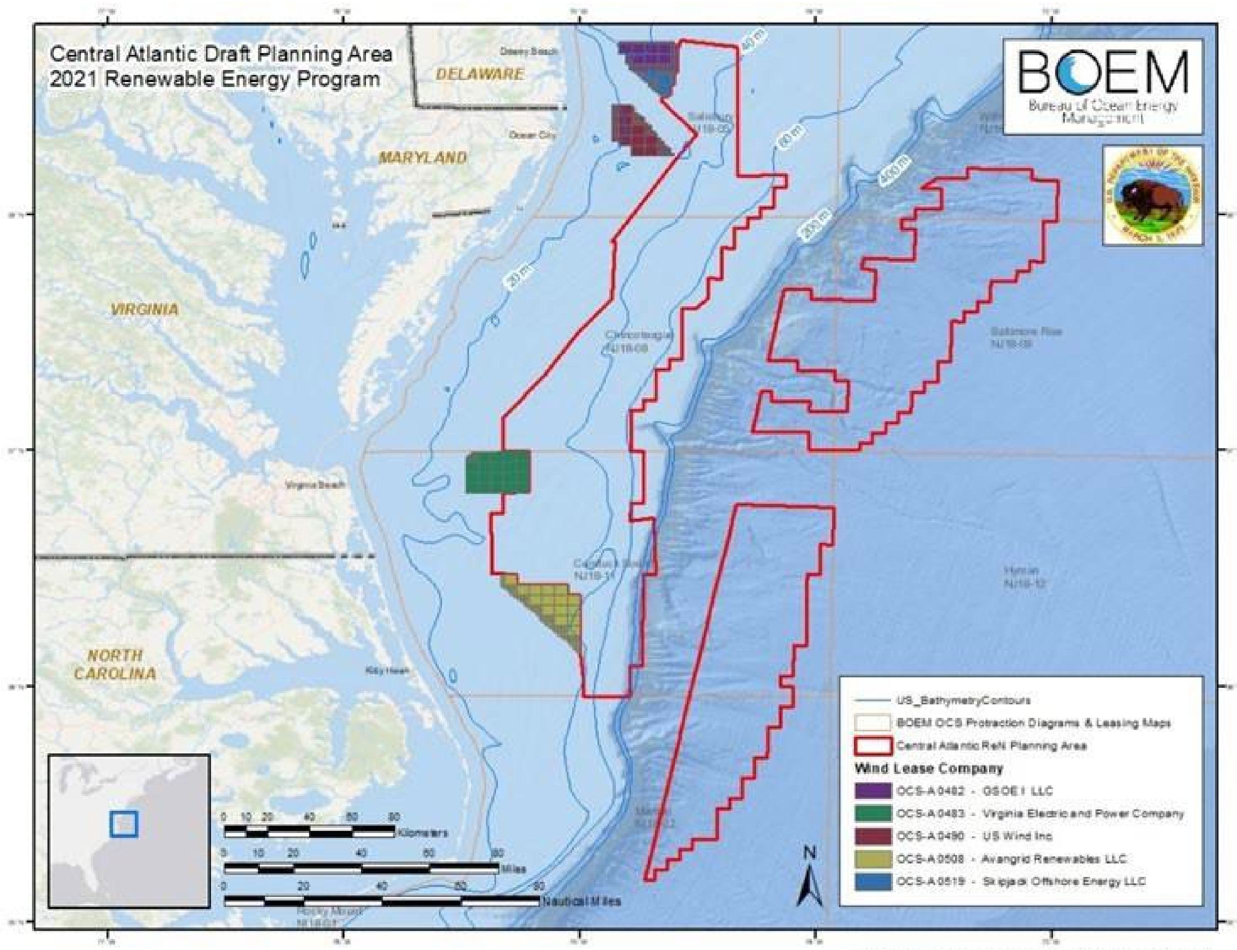
To develop the Central Atlantic suitability model, 54 data layers were selected from over 200 data layers that represent major ocean characteristics for the Central Atlantic Call Area. Data were organized into categories (sub-models) representing the major ocean sectors, including national security, natural and cultural resources, wind, fishing, and industry and operations. All data layers were assigned scores of relative compatibilities, allowing the calculation of an overall suitability score for each 10-acre grid cell of the study area.

Additionally, the BOEM spatial suitability model did not focus on identifying specific stressors or construction phases, as the other studies and each input layer was given equal weight when combined using a similar spatial overlay technique.

Finally, the BOEM model focused on *suitability,* which has an inverse relationship with *risk or sensitivity* (i.e., higher risk or sensitivity, less suitable the area is with respect to the given inputs).

Figure 3. BOEM Central Atlantic Call Area

Source: Randall et al. 2022b

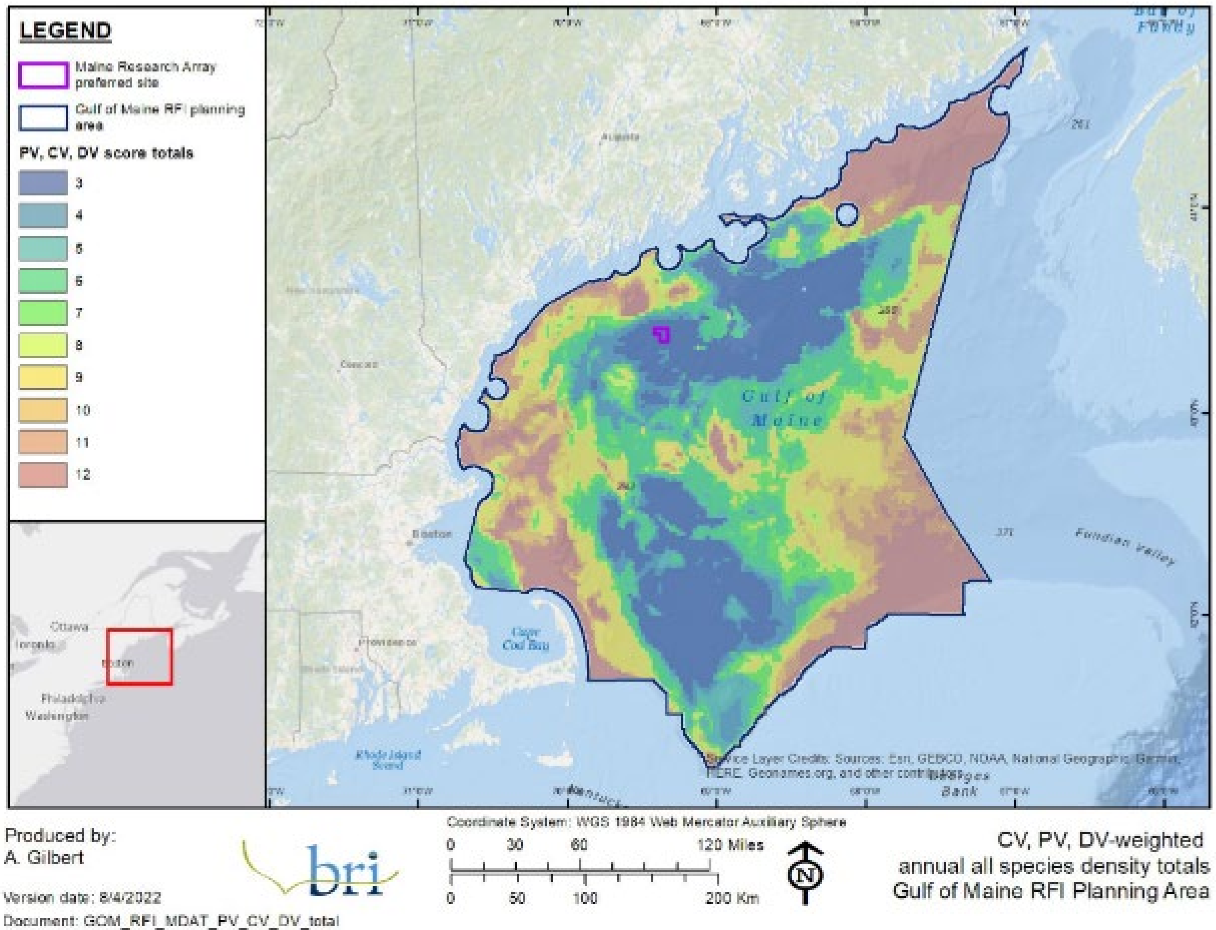


2.1.4 Gulf of Maine (Birds)

To support the State of Maine Department of Inland Fisheries and Wildlife during the offshore wind commercial planning process, The Biodiversity Research Institute conducted a desktop study and literature review to determine regions of importance for breeding and migrating marine birds in the Gulf of Maine to inform regions of higher and lower risk to marine birds (Figure 4). The study relied on three primary analyses: a buffer around colonial nesting marine bird islands during the breeding season based on the maximum foraging distance; a combined exposure and vulnerability assessment using regional marine bird models; and movement models of three diving bird species (Stepanuk et al. 2022).

Weighted density analysis of population vulnerability (PV), displacement vulnerability (DV), and collision vulnerability (CV) for all marine bird species built using Marine-Life Data and Analysis Team (MDAT) models (Curtice et al. 2019). Species included inhabitants of the Gulf of Maine region, including both species that nest and species that do not nest in this region.

Figure 4. Gulf of Maine Marine Bird Risk Analysis



2.2 Environmental Sensitivity Analysis

While each of the studies mentioned above differed slightly in their details, in general, the approach each employed was largely similar and broadly qualified as an MCDA, a sub-discipline in the field of operations research. In brief, the process of MCDA is to evaluate multiple (often conflicting) criteria with respect to a defined goal or metric to determine the best feasible solution.; by structuring complex problems well and considering multiple criteria explicitly, better-informed decisions result (Jahan and Edwards 2013; Díaz and Soares 2022).

Generally, all the spatial environmental sensitivity analyses and reports reviewed above followed this MCDA methodology and employed a common stepwise approach, outlined below.

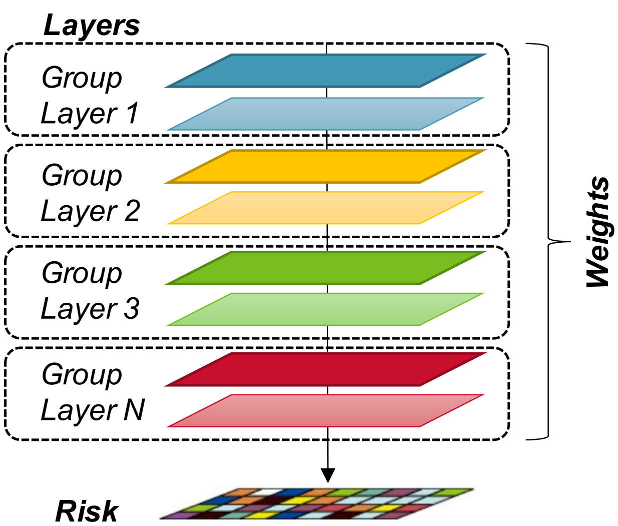
1. **Framework**: Establishing an overall conceptual framework.
    - Define the scope, goal, intended use, and audience.
    - Define an AoA (i.e., spatial extent).
    - Determine which input data are included (or excluded) from the analysis.
2. **Goal**: Defining the goal or metric.
    - Define the common metric all input data will be referenced to.
    - Example: “Risk / Sensitivity” or “Suitability.”
3. **Data**: Obtaining and evaluating input data sets
    - Identification of the individual components and data set(s) used to represent each component in the model.
    - For this study, the data sets are inherently spatial and cover most or all the AoA.
    - Determining if individual data sets are to be divided into subgroups and if so, how to group individual data sets into subgroups (e.g., marine mammal hearing groups).
    - Identify and address data gaps.
4. **Standardization and Rescaling**: Rescale input data to a common (dimensionless) scale.
    - Rescaling is often required as different data sets often have different units (e.g., weight in kilograms of bottom trawl fish catch, density in animals per square kilometer of marine mammals, etc.) and thus cannot be combined mathematically in a straightforward way without rescaling to a common scale.
    - Rescaling also often includes reprojecting and reshaping (standardizing) the data to a common geographic unit (e.g., raster grid dimension or polygons).
5. **Weighting**: Determine how (or if) the different receptor group layers should be differentially weighted.
    - When combining the various receptor group layers into an overall risk value, they can optionally be given different weights (i.e., preference) based on any number of factors relevant to OSW (e.g., Endangered Species Act [ESA] listing, population vulnerability, etc.).
    - Assignment of specific weighting values is often a subjective or semi-quantitative exercise based on expert judgment and consensus among stakeholders.
6. **Combine**: Determine how layers will be combined into an overall risk value.
    - Define the mathematical procedure and formulation to combine each of the prepared receptor data layers and apply their respective weights.

The remainder of this section provides detailed descriptions of each of these steps.

2.3 Framework

At a very high level, the process used to synthesize the respective spatial data sets into a common spatially explicit sensitivity model is a type of overlay analysis. Overlay analysis is a family of methodologies applied to identify optimal (or conversely, least optimal) site selection and is also known as suitability modeling. It is a technique for applying a common scale of values to diverse and dissimilar inputs to create an integrated output. Suitability models identify the best or least preferred locations for a specific phenomenon, goal, or metric (ESRI 2023). The schematic shown in Figure 5 illustrates the process of overlay analysis whereby a set of disparate layers representing the various marine resources considered are combined (possibly with differential weighting applied; see details in section 2.7) to generate an overall sensitivity output layer.

Figure 5. Conceptual Overview of a Weighted Overlay Model



For this study, the conceptual model for the sensitivity analysis is further subdivided into a hierarchical model shown in Figure 6. This model is a directed acyclic graph that subdivides the process into five distinct levels, as defined below. The boxes in the graph are called nodes, and the lines are called an edge. Each node (parent) is subdivided into the nodes below it (children) and the edges that connect them represent the set of weights that apportion the parent node to the children.

The weights used are determined by SMEs via an expert elicitation process described further below. The result of this process is that each child node is assigned a relative percent contribution to its respective parent and the sum of all these contributions is 100% for all the child nodes of each parent. In other words, the weights determine the overall "blending proportions" of all the child nodes to the parent nodes and this process repeats throughout the hierarchy.

A conceptual illustration of this parent-children relationship is shown in Figure 7, which highlights the top level of the hierarchy, but this concept is likewise applicable to all levels and all parent-children sets.

Level 1—Resource Sensitivity: This is the top level where all data are combined using a weighted overlay method to create a single sensitivity or risk layer for each resource group. A single sensitivity value is computed for each location in the AoA by combining the sub-levels together according to the corresponding data layers and weightings and depicts the relative environmental sensitivity on a common scale (e.g., 0–1 or low to high). Sensitivity has been calculated for each resource group separately, namely: marine mammals and sea turtles, birds & bats, fish & fisheries, and benthic habitat. The nodes at this level represent the combined sensitivity of the individual receptors described in Level 2.

Level 2—Receptor: This level subdivides the parent resource group into distinct receptor groups, each of which has a corresponding spatial data layer. Each receptor group represents an individual, or group of like individuals that could be impacted or otherwise stressed because of OSW. Details of each receptor and the source data layers used and how they were pre-processed and composited (as applicable) are provided in greater detail in the following sections.

Level 3—Stressor: This level subdivides the parent receptor nodes and represents the relative apportionment of each receptor to the 10 stressor categories identified above during OSW, namely: Artificial Lighting, Bottom Disturbance, Changes in Water Quality, Changes to Atmospheric and/or Ocean Dynamics, EMF, New Structures, Scouring around Seafloor Structures, UXO Detonation, Vessel Traffic and Noise. For example, low-frequency cetaceans (parent receptor) might be more impacted by UXO Detonation (child stressor) than by Artificial Lighting. These stressors are defined in section 2.4.

Level 4—Phase: This level subdivides the parent stressor nodes and represents the relative contribution or impact of each stressor during one of the four principal phases of OSW, namely: Pre-construction, Construction, Post-Construction/Operation, and Decommissioning. For example, Bottom Disturbance (parent stressor) might be more impactful or frequent during the Construction (child phase) than during Pre-Construction phase.

Figure 6. Hierarchical Framework for Sensitivity Analysis

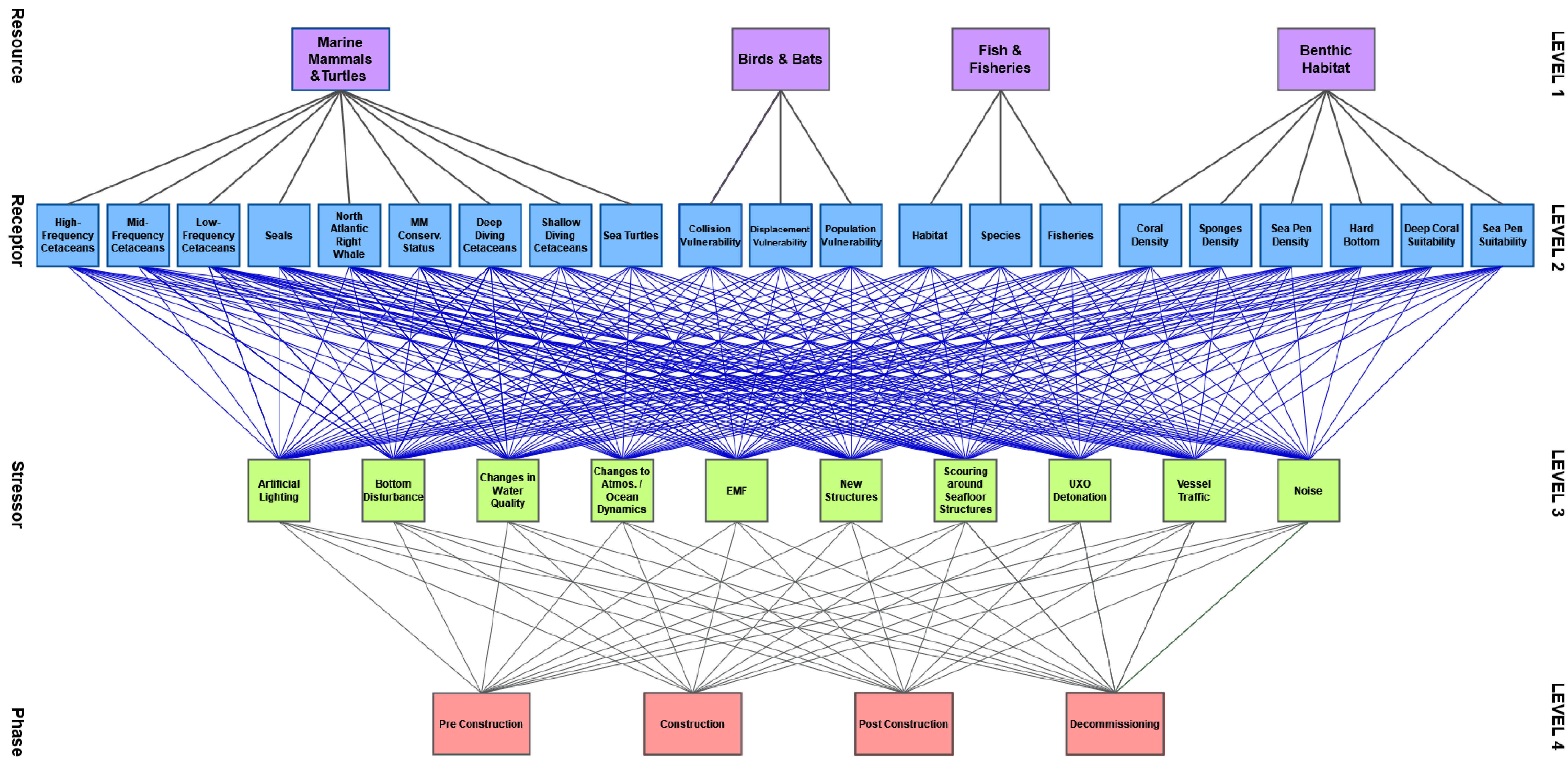
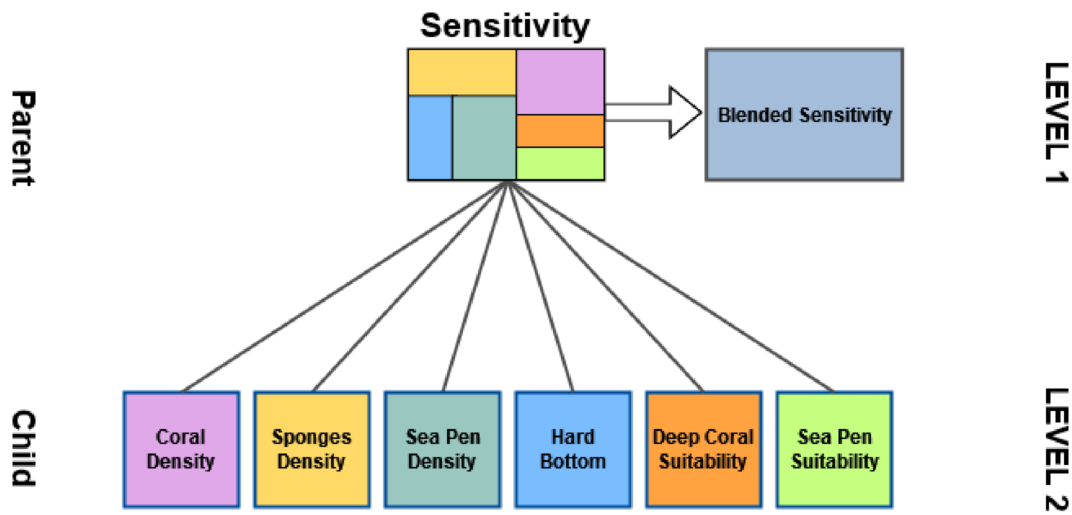


Figure 7. Conceptual Illustration of Parent-Child Relation and Relative Weight Contributions



One of the primary benefits of this framework and hierarchical approach is that it is very modular, hence, adaptable to future conditions. If additional receptor data sets need to be incorporated, or stressors evaluated, they can be added, and new results generated, thus, outputs are continuously improved as more information becomes available.

2.4 Stressor Definitions

The analysis framework uses 10 stressors, which were identified through a literature review and expert consultation as detailed in the corresponding environmental studies. A complete description and references for these stressors and their potential impacts marine resources can be found in the environmental desktop studies and in section 4.2.2 of this study.

Artificial Light: Artificial lighting for OSW is required for worker and navigational safety for vessels and aircraft on wind turbine decks, offshore substations, and construction or maintenance vessels. Lighting used during decommissioning activities, comparable to the lighting used during construction, will likely be slightly brighter, but more concentrated/localized to work areas than typical operations and maintenance activities. Lighting from turbine structures and project service platforms will likely produce light that is dimmer, less constant, but and more widespread than lighting from construction activities, which is then stronger than lighting from (mobile) pre-construction survey vessels (surface and underwater vessels).

Atmospheric & Oceanic Disturbances: Changes in ocean currents that may be caused by the placement of OSW platforms may influence the transportation and distribution of larval shellfish, alter coastal upwelling and water column mixing, and other oceanographic dynamics. Changes to atmospheric/oceanic conditions are most likely to occur during the operational phase due to the wind wave effect from the presence of turbines, resulting in long-term modulation of current and atmospheric dynamics. During pre-construction and construction, no structures will be present, thus changes to atmospheric/oceanic conditions are unlikely. The presence of structures during operations can result in long-term modulation of current and atmospheric dynamics and changes in oceanography. Decommissioning should bring the system back to pre-construction status, except for the new biological communities that were established during the post-construction stage. Effects are hypothetical and uncertain at this stage.

Bottom Disturbance: Bottom disturbance for OSW can be attributed to geotechnical surveys, site preparation and leveling, excavation and dredging, and anchoring and mooring of floating wind platforms and construction vessels. Pre-construction survey disturbance is expected to be less impactful than bottom disturbance from mooring lines during operations. Bottom disturbance during pre-construction is associated with trenching and site investigation surveys and is expected to be much less substantial than that caused by cable laying and pile/substation installation during the construction phase or during the deconstruction phase. Construction is expected to have the most bottom disturbance as it is associated with seabed preparation, anchoring, boulder removal and replacement, cable and scour protection and fixed foundation installation. Decommissioning includes not only mooring line bottom disturbance during operations, but also the removal of structures. The degree of disturbance depends heavily on the decommissioning methodology used.

Electromagnetic Field (EMF): In the context of OSW, the major source of EMFs is from power export cables carrying electricity to shore (Copping et al. 2020). EMFs are strongest immediately adjacent to the cable and decrease with distance from the cable; however, the strength of EMFs can depend on the type of cable used. Several marine species groups are known to be sensitive to electric and/or magnetic fields, such as elasmobranchs (skates, rays, and sharks), crustaceans, teleost (bony) fish, and sea turtles (Farr et al. 2021). These species use natural EMFs to support essential life functions such as locating predators or prey and migration. EMFs are present during operation, and are unlikely to occur during pre-construction, construction, and decommissioning. During phases prior to and after operations, electricity is not yet or no longer conducted through undersea cables, which create EMFs. The only risk is expected to be during post-construction when the cable is in place and in use.

New Structures: Several sub-stressors were considered under this stressor, including loss of fishing grounds and navigational complications, habitat conversion, entanglement, impingement, entrainment, and thermal stress from fixed high-voltage direct current (HVDC) substation platforms, collision with turbines, habitat displacement or loss, artificial reefs, and impacts on marine resources surveys. In-water structures are more likely to be present during operations, equally for construction and decommissioning, and least during pre-construction. While construction and post-construction introduce new structures, post-construction represents the most substantial impact of new structures, resulting in potential risks related to displacement of fishing effort, conversion of habitat, collision, displacement, and artificial reef effects. Decommissioning does not introduce new structures; however, the removal of structures may create risks, similarly to those that occur during construction. The degree of disturbance depends heavily on the decommissioning methodology used.

Noise: Underwater noise will be present in all phases of OSW. Pre-construction noise is typically associated with sonar from ongoing high-resolution geophysical (HRG) surveys and vessel traffic. The construction phase is likely to generate noise from pile-driving for anchor installation, HRG surveys, trenching for cable installation and vessel traffic. Post-construction noise can be caused by the operational noise from turbines and the cables, chains, wires, and anchoring devices tethering the floating platforms. Decommissioning noise may be attributed to the cutting/removal of structures and cables and vessel noise.

Scouring: Scouring around seafloor structures, such as foundations or anchors, is likely to occur most frequently during post-construction and decommissioning because scouring is caused by partially built turbine foundations, or incremental turbine installation. Additionally, the post-construction/operation phase likely generates the most scour of soft sediments over time, whereas decommissioning scour depends on techniques used (if structures are left in water, risk levels relate to structures being in place for a time). Scouring disturbances are not likely to occur during pre-construction.

UXO Detonations: UXO detonations are expected to only occur during the seafloor preparation phase of construction. Thus, UXO detonation is a pre-construction activity and does not occur during other phases of construction. Additionally, it can be assumed that fewer UXOs are available to be detonated during each subsequent phase.

Vessel Traffic: Increased vessel traffic from OSW development can lead to vessel strikes, cause navigational safety concerns for fisheries and other commercial vessels, impede fishing efforts, and displace marine species. Vessel traffic is expected to be most intense during construction and decommissioning, followed by post-construction, which was slightly higher than pre-construction. One reason vessel traffic is higher during construction and decommissioning than other phases is that it requires a larger number of barges and crew support vessels. For example, construction vessel traffic needed to remove equipment is much more intense than during pre-construction surveys and post-construction monitoring/maintenance. Vessel speed (in addition to the number of vessels) is also an important factor in assessing the risk to marine mammals, sea turtles and other marine species groups.

Water Quality: Changes in water quality related to OSW development can include the suspension of contaminants associated with bottom disturbance, the accidental release of fuel and oil, release of biocides to remove debris or biofouling, and the use of anti-corrosives on turbines and mechanical structures. Water quality impacts are much more likely during construction and decommissioning (increased vessel activity/likelihood of spills, discharge, turbidity, introduced chemicals, suspended solids, etc., from new structures in water) than during pre-construction and post-construction. Changes in water quality are more likely during the post-construction phase (biofouling treatments, vessel activity/likelihood of spills) than during pre-construction. Pre-construction survey water quality impacts are expected to be the same as impacts associated with maintenance. Resuspension of organic enrichment and sediment disturbance are likely to impact benthic communities during the construction phase to a greater degree than in pre-construction work such as surveys, etc., which have a smaller footprint.

2.5 Data Sets Evaluated

The selection of receptors identified for inclusion in the model framework (Figure 6) was based on a review of existing literature and similar reports (see section 2.1), PAC stakeholder engagement (see section 1.4), comments and feedback from the Master Plan, and other independent studies and regional agency environmental assessments (EAS) regarding OSW (NYSERDA 2015; Geo-Marine Inc 2010; Marine Management Organization 2013; BOEM 2016).

Individual receptors represent individual groups or data layers that are expected to respond similarly to OSW. If species were grouped, the grouping was based on similar permitting requirements, BOEM recommendations and requirements, protected species status or similar population concerns, or customary practice among similar studies and researchers. In general, only existing spatial data layers that substantially cover the AoA were used. Some layers did not have full AoA coverage but were used because they were important in showing presence of resources within the AoA, or in some cases, were the only data available for a particular receptor. Layers that were available in digital format and with substantially continuous and complete spatial coverage were considered for use in the study.

A summary of the selected receptors and data sets used is shown in Table 1, and a discussion follows of the data sets evaluated and used in the sensitivity analysis and data processing steps for each marine resource group. Refer to the corresponding environmental desktop studies that accompany this study for a detailed discussion of all data sources reviewed and the reasoning for their selection and representation in the sensitivity analysis.

Table 1. Environmental Sensitivity Analysis Receptors Data Summary

Resource Group	Receptor	Species Members/Description	Source(s)	Processing Summary	Notes
Marine Mammals & Sea Turtles	High Frequency Cetaceans	Harbor porpoise, dwarf and pygmy sperm whales	Curtice et al. 2019; Roberts et al. 2023	Sum of predicted abundance per 100 km^2 grid	
	Mid-Frequency Cetaceans	Sperm whales, beaked whales, dolphins: common dolphin, Killer whale, Northern bottlenose whale, Pygmy killer whale, false killer whale, Melon-headed whale, Risso's, Atlantic white-sided dolphin, white-beaked, Atlantic spotted dolphin, Pantropical spotted dolphin, striped dolphin, Fraser's dolphin, Rough-toothed, Clymene dolphin, spinner dolphin			
	Low-Frequency Cetaceans	Baleen whales—blue, sei, minke, fin, humpback			
	Seals	Harbor, gray, hooded, and harp seals			
	North Atlantic Right Whale (NARW)	North Atlantic right whale			Critically Endangered.
	Other Marine Mammals of Special Conservation Status	ESA-listed cetaceans (fin, sei, blue, sperm whales) and any marine mammals under UME designation (humpback whales, gray and harbor seals, minke whales).			
	Deep-Diving Cetaceans	Sperm whale, pygmy and dwarf sperm whale, beaked whales, pilot whales (both species), Northern bottlenose whale			Shallow versus deep-diving cetaceans were defined as Coastal (<200 m depth) and Oceanic (>200 m depth).
	Shallow-Diving Cetaceans	Dolphins not listed in "Deep-Diving Cetaceans," harbor porpoise, baleen whales (except NARW), common dolphin, Killer whale, Pygmy killer whale, false killer whale, Melon-headed whale, Risso's, Atlantic white-sided dolphin, white-beaked, Atlantic spotted dolphin, Pantropical spotted dolphin, striped dolphin, Fraser's dolphin, Rough-toothed, Clymene dolphin, spinner dolphin.			
	Sea Turtles	Green Sea Turtle, Kemp's Ridley Sea Turtle, Leatherback Sea Turtle, Loggerhead Sea Turtle	Sparks and DiMatteo 2023		
Birds & Bats	Collision Vulnerability (CV)	Ordinal scoring based on nocturnal flight activity, diurnal flight activity, avoidance, proportion of time within rotor swept zone, maneuverability in flight and percentage of time flying.	Curtice et al. 2019; Winship et al. 2018; Willmott et al. 2013	Ordinal score maps, see separate Birds & Bats report for detailed description.	Refer to Bird and Bat Study regarding low occurrence, low expected exposure risk and high uncertainty due to insufficient data on bats in the AoA.
	Displacement Vulnerability (DV)	Ordinal scoring based on 1) disturbance from ship/helicopter traffic and the wind facility structures and 2) habitat flexibility.			
	Population Vulnerability (PV)	Ordinal scoring based on Partners in Flight continental combined score, local state threatened and endangered species status and species of greatest concern need score, adult survival score and the regional population score.			
Fish & Fisheries	Habitat	Count of unique Essential Fish Habitat (EFH) species within the AoA; Atlantic sturgeon Section 7 range; Tilefish Habitats of Particular Concern (HAPC); juvenile Atlantic cod HAPC; Canyons/seamounts HAPC.	NOAA Greater Atlantic Region Section 7 mapper; NOAA EFH – Data Directory; NOAA EFH mapper (HAPC).	Sum of species habitat identified within each grid square; Presence/Absence of ESA Section 7 Sturgeon range or HAPC area.	Refer to Fish and Fisheries for EFH species summaries.

Table 1. continued

Resource Group	Receptor	Species Members/Description	Source(s)	Processing Summary	Notes
	Species	Demersal; Pelagic; Diadromous (Alewife, American eel, American shad, Atlantic sturgeon, Blueback herring, Hickory shad); AMFSC (American Lobster, Cobia, Atlantic Croaker, Black Drum, Red Drum, Menhaden, NK Sea Bass, NK Seatrout, Spot, Striped Bass, Tautog, Jonah Crab, and Pandalid Shrimp); Multispecies (Acadian redfish, American plaice, Atlantic cod, Atlantic halibut, Atlantic wolffish, Haddock, Ocean pout, Pollock, White hake, Windowpane, Winter flounder, Witch flounder, Yellowtail flounder); Small-mesh multispecies/Whiting (Silver hake, red hake, offshore hake); Consolidated Atlantic Highly Migratory Species Fishery; Atlantic Sea Scallop; Atlantic surfclam and ocean quahog; deep-sea red crab; mackerel, squid and butterfish; tilefish (golden, blueline, sand). Species list linked in notes.	NEFSC Bottom Trawl Survey Data (2013-2022); NEFSC Atlantic Surfclam and Ocean Quahog Survey Data (2013–2022); NEFSC Sea Scallop Dredge Survey Data (2013-2022) [includes Virginia Institute of Marine Science (VIMS) scallop dredge data].	Total bottom trawl catch weight from 2013-2022. Log transformed and gridded to 25 km^2 grids using Inverse Distance Weighted Interpolation.	Refer to Fisheries and Fisheries Study for species summaries.
	Fisheries	Northeast Multispecies (NMS), Sea Scallop (SES), Surfclam, Ocean Quahog, and Mussel (SCO), Highly Migratory Species (HMS), Squid, Mackerel, and Butterfish (SMB), Monkfish (MNK), and Declared Out of Fishery (DOF) plan permitted vessels. Total haul data for all fish species represented in NOAA Fisheries Observer data (as described in species above and for management plans). Note: DOF is a term used to identify all non-days-at-sea fisheries, such as whiting, summer flounder, scup, black sea bass, American lobster, and Jonah crab.	NOAA Fisheries Observer Data (2013–2022); NOAA Vessel Monitoring System (VMS) data (2013–2022).	Total Weight collected from 2013–2022. Log transformed and gridded to 25 km^2 using Inverse Distance Weighted Interpolation.	Refer to Fisheries and Fisheries Study for select Fisheries Management Plan (FMP) summaries and descriptions of species. Refer to Section 2.5.3.3 for discussion. Note: due to fishing industry confidentiality, NOAA provided Fisheries Observer data using a data selection method that excluded some vessel data and the exact location of collection; therefore, data gaps are evident in Zone 3 and not all fisheries and species that occur within the AoA may be represented in the data.)
Benthic Habitat	Coral Density	Occurrence Density (Corals / 100 km^2)	NOAA/OBIS	Spatial Kernel Density Estimator on 100 km^2 grid cells, and 25 km bandwidth.	
	Sponges Density	Occurrence Density (Sponges / 100 km^2)			
	Sea Pen Density	Occurrence Density (Sea Pen / 100 km^2)			
	Hard Bottom	Hard Bottom Likelihood, seabed forms, soft sediments.	USGS; Battista 2019 (Hard Bottom); NAMERA 2020 (Soft Sediments & Seabed Forms)	Seabed forms confined to Zone 2 of AoA, soft sediments used in Zones 1 and 3. Both reclassified to ranked likelihood of containing hard bottom.	
	Deep-sea Stony Coral Suitability	Ordinal score of Deep-Sea Stony Coral habitat suitability.	NOAA Office for Coastal Management 2018	Area-weighted mean predicted suitability.	
	Sea Pen Suitability	Ordinal score of Sea Pen habitat suitability.	NOAA/OBIS; Kinlan et al. 2013; 2020		

2.5.1 Marine Mammals and Sea Turtles

The primary data inputs for the **m**arine **m**ammals and sea turtles resource group were the habitat-based Marine Mammal Density Models for the U.S. Atlantic (Roberts et al. 2015, 2016a, 2016b, 2017, 2018, 2020, 2021, 2022, 2023; Roberts 2020; Roberts and Halpin 2022) and the East Coast Turtle Density Models (Sparks and DiMatteo 2023), hosted on the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) Model Repository (https://seamap.env.duke.edu/models/). These models are generally recognized as the best available information for these groups of species in the context of marine planning and permitting.

For the sensitivity analysis, the marine mammals and sea turtles resource group was subdivided into nine individual receptors (Figure 6, Table 1) that generally correspond to functional hearing groups, diving behavior, or conservation status. Thirty-nine species of marine mammals and four species of sea turtles were included in these groups. Models consisted of 10-kilometer by 10-kilometer raster grids of monthly (or in a few cases, annual) predicted species density for each of the species modeled. For each of the receptor groups identified, the constituent species model layers were added together for a total predicted abundance for that receptor group.

Because the purpose of this study was to evaluate the sensitivity of receptor groups in the context of specific OSW stressors, there was intentional redundancy among these receptor groups, as one species may fall into two or more receptor groups. The intentional redundancy allows for a more refined and representative approach to account for the affects OSW stressors across resource and receptor groups. For example, humpback whales (*Megaptera novaeangliae*) were evaluated for potential risk in the context of low-frequency noise, ship strikes as shallow divers, and overall sensitivity to OSW stressors because of their involvement in ongoing unusual mortality events (UMEs).

Refer to the corresponding Marine Mammal and Sea Turtle Study that accompanies this study for a detailed discussion of the individual species groups, data availability, seasonal distributions, and reasoning for receptor groupings.

2.5.1.1 High-Frequency Cetaceans

High-frequency cetaceans are defined as those that have a generalized hearing range of 275 hertz (Hz)–160 kilohertz (kHz) and are, therefore, sensitive to high-frequency sounds. Three species of high-frequency cetaceans are found in the AoA: dwarf (*Kogia sima*) and pygmy (*Kogia breviceps*) sperm whales, and harbor porpoise (*Phocoena phocoena*).

2.5.1.2 Mid-Frequency Cetaceans

Mid-frequency cetaceans are defined as those that have a generalized hearing range of 150 Hz–160 kHz and are, therefore, sensitive to mid-frequency sounds. Eighteen species of mid-frequency cetaceans are found in the AoA: sperm whale (*Physeter macrocephalus*), beaked whales, common dolphin (*Delphinus delphis*), killer whale (*Orcinus orca*), northern bottlenose whale (*Hyperoodon ampullatus*), pygmy killer whale (*Feresa attenuata*), false killer whale (*Pseudorca crassidens*), melon-headed whale (*Peponocephala electra*), Risso's dolphin (*Grampus griseus*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), white-beaked dolphin (*Lagenorhynchus albirostris*), Atlantic spotted dolphin (*Stenella frontalis*), pantropical spotted dolphin (*Stenella attenuata*), striped dolphin (*Stenella coeruleoalba*), Fraser's dolphin (*Lagenodelphis hosei*), rough-toothed dolphin (*Steno bredanensis*), Clymene dolphin (*Stenella clymene*), spinner dolphin (*Stenella longirostris longiristris*) and common bottlenose dolphin (*Tursiops truncatus*).

2.5.2 Low-Frequency Cetaceans

Low-frequency cetaceans are defined as those that have a generalized hearing range of 7 Hz–35 kHz and are, therefore, sensitive to low-frequency sounds. Other than the NARW, five species of low-frequency cetaceans are found in the AoA: blue whale (*Balaenoptera musculus musculus*), common minke whale (*Balaenoptera acutorostrata acutorostrata*), fin whale (*Balaenoptera physalus*), humpback whale, and sei whale (*Balaenoptera borealis borealis*).

2.5.2.1 Seals

As with other marine mammal species groups, habitat-based density models developed by Roberts et al. (2023) were used to create maps of predicted density of seals in and near the AoA. Gray seals (*Halichoerus grypus*) and harbor seals (*Phoca vitulina concolor*) were modeled together as a guild called "seals". This guild did not include harp (*Pagophilus groenlandicus*), hooded (*Cystophora cristata*), or ringed seals (*Pusa hipsida*) in density predictions because these species occur only occasionally in the region (Roberts et al. 2023).

2.5.2.2 North Atlantic Right Whale (NARW)

Recent estimates suggest that fewer than 350 NARW remain, and fewer than 70 of these individuals are breeding females (Hayes et al. 2022). Given the extremely small number of animals in the population, this species is particularly vulnerable to anthropogenic stressors, which, depending on the type and severity, have the potential to cause population-level effects. Given its critically endangered status, this species is considered a separate receptor group.

2.5.2.3 Other Marine Mammals of Special Conservation Status

Other than the NARW, several marine mammal species that occur in the AoA are listed as threatened or endangered under the ESA. These include the sperm whale, fin whale, blue whale, and sei whale (Hayes et al. 2022; NOAA 2023a). Other marine mammal species, such as humpback whales, minke whales, gray seals, and harbor seals, although not listed as threatened or endangered, are currently experiencing significant die-offs known as UMEs (NOAA 2023b). To the extent that they are understood, the causes of these UMEs vary, and may involve fishery interactions, vessel strikes, and disease outbreaks. In this analysis, ESA-listed species (other than the NARW) and those undergoing a current or recent UME are defined here as “Other Marine Mammals of Special Conservation Status” (OMMSCS) and considered a unique receptor group.

2.5.2.4 Deep-Diving Cetaceans

Along with generalized hearing groups and those of special conservation status, cetaceans were also analyzed in the context of the vertical habitat used by these species (i.e., dive depth). Deep-diving cetaceans are defined here as those that spend significant time in the mesopelagic zone (from 200 to 1,000 meters) and the bathypelagic zone (1,000 to 4,000 meters) (Braun et al. 2022; NOAA 2023f). The following deep-diving cetacean species are included in this analysis: sperm whale, dwarf and pygmy sperm whales, Cuvier’s beaked whale (*Ziphius cavirostris*), mesoplodont beaked whales (*Mesoplodon* sp., unidentified beaked whales, northern bottlenose whale, and pilot whales (*Globicephala* sp.).

2.5.2.5 Shallow-Diving Cetaceans

Shallow-diving cetaceans are defined here as those that spend significant time in the epipelagic zone (from the surface to 200-meter depth) (Braun et al. 2022; NOAA 2023f). The following shallow-diving cetacean species are included in this analysis: harbor porpoise, baleen whales (except NARW), killer whale, pygmy killer whale, false killer whale, melon-headed whale, common dolphin, Risso's dolphin, Atlantic white-sided dolphin, white-beaked dolphin, Atlantic spotted dolphin, pantropical spotted dolphin, striped dolphin, Fraser's dolphin, rough-toothed, Clymene dolphin spinner dolphin, common bottlenose dolphin.

2.5.2.6 Sea Turtles

Four species of sea turtle are expected to occur in the AoA: three "hardshell" species (green [*Chelonia mydas*], Kemp's ridley [*Lepidochelys kempii*], and loggerhead [*Caretta caretta*]) and the leatherback turtle (*Dermochelys coriacea*). Kemp's ridley and leatherback turtles are listed as endangered under the ESA, and green and loggerhead turtles are considered threatened. Density surface models for these species, developed by Sparks and DiMatteo (2023), were used to predict the seasonal density of sea turtles in the AoA. These models estimate long-term (2003–2019) monthly averages of density, abundance, and distribution for Kemp's ridley, leatherback, and loggerhead sea turtles (the green turtle models cover only 2010–2019).

2.5.3 Birds and Bats

For the birds and bats resource group, primary and secondary literature and data were compiled and reviewed with guidance from the bird and bat PAC and E-TWG. References were sourced from European literature, as well as precedent set in the U.S. National Environmental Policy Act (NEPA) process, including Construction and Operations Plans (COPs), and Section 7 consultations under the ESA.

The literature review identified birds and bats in the AoA, their stressors, and current mitigation practices. The data review identified 18 sources and additional published literature from Europe to inform the vulnerability of birds to deepwater OSW in the environmental sensitivity analysis. Due to lack of data on bats offshore, bats were not included in the data layers generated for the environmental sensitivity analysis.

A spatial risk assessment was conducted for birds and bats, based on avian risk assessments conducted for the Gulf of Maine and project-based COPs (e.g., Empire Wind in the New York Bight). Risks to bird and bat species from stressors across all phases of OSW included collision with turbines, avoidance, displacement, and attraction. The spatial risk assessment used Version 2 of the MDAT avian relative density and distribution models (Curtice et al. 2016; Winship et al. 2018) to produce a set of maps representing the exposure and vulnerability of 47 marine bird species to OSW. Species densities were combined across seasons and analyzed at the resolution of BOEM lease blocks (2304 hectares or 23 square kilometers per standard block).

Annual exposure scores for marine birds were calculated using quantiles of species densities within the AoA and were scaled up or down based on three criteria: Population Vulnerability (PV), Collision Vulnerability (CV), and Displacement Vulnerability (DV). Vulnerability scores were based on data such as flight heights from the Northwest Atlantic Seabird Catalog and sensitivity rankings derived from the literature review. A brief summary of these criteria is provided below; refer to the corresponding Bird and Bat Study that accompanies this study for detailed methods.

2.5.3.1 Population Vulnerability

An approach based on the methods used by (Kelsey et al. 2018; Fliessbach et al. 2019) was used to determine a PV score using various measures: the Partners in Flight (PiF) "continental combined score," a local "state status" using the maximum of threatened and endangered status and "species of greatest conservation need" score from states neighboring the AoA; adult survival score (Willmott et al. 2013); and the regional population score, which is an annual measure of the population using the study area and the MDAT models.

2.5.3.2 Collision Vulnerability

The CV assessment included scores for nocturnal flight activity (NFA), diurnal flight activity (DFA), avoidance, proportion of time within the Rotor Swept Zone (RSZ), maneuverability in flight, and percentage of time flying (Willmott et al. 2013; Furness et al. 2013; Kelsey et al. 2018). The assessment process conducted here followed Kelsey et al. (2018) and included the proportion of time spent within the RSZ (*RSZt*), a measure of avoidance (*Mac*), and flight activity (*NFA* and *DFA*).

2.5.3.3 Displacement Vulnerability

The DV assessment incorporated two factors: (1) disturbance from ship/helicopter traffic or wind facility structures (*Mad*); and (2) habitat flexibility (*HF*; Furness et al. 2013, Kelsey et al. 2018).

2.5.4 Fish and Fisheries

A comprehensive review of available fish and fisheries data sets was conducted to identify and select the most suitable data for this resource group within the AoA. For the sensitivity analysis, the fish and fisheries resource group were subdivided into three receptors: Habitat, Species, and Fisheries (Figure 6). A brief summary of the data selection and processing that was used to represent those receptors follows (refer to Table 1 and the corresponding Fish and Fisheries Data Aggregation Study that accompanies this study for a detailed description and reasoning).

Data sources for the sensitivity analysis receptor layers were evaluated spatially on geographic information system (GIS) map overlays and selected for the sensitivity analysis based upon total coverage within the AoA and the species surveyed. Following is a list of the data sources used for each Receptor Layer.

Habitat

- NOAA Atlantic Highly Migratory Species Essential Fish Habitat (EFH)
- NOAA New England and Mid-Atlantic Species EFH
- NOAA New England and Mid-Atlantic Habitats of Particular Concern (HAPC)
- NOAA Greater Atlantic Region ESA Section 7 range (Atlantic sturgeon [*Acipenser oxyrinchus oxyrinchus*])

Fish Species

- Northeast Fisheries Science Center (NEFSC) Spring and Fall Bottom Trawl Survey (2013–2022)
- NEFSC Sea Scallop Survey (2013–2022) (includes VIMS sea scallop dredge surveys)
- NEFSC Atlantic Surfclam and Ocean Quahog Survey (2013–2022)

Fisheries

- NOAA Fisheries Observer Data (2013–2022)
- Vessel Monitoring System (VMS) Data (2013–2022)

2.5.4.1 Habitat

To create the Habitat Receptor Layer, the NOAA Essential Fish Habitat (EFH) mapper was consulted and source layers from the Atlantic Highly Migratory Species Council and the New England/Mid-Atlantic Council were downloaded and combined to form a single layer (NOAA 2023b). This layer provides count data of designated EFH within a given grid square of the AoA. The NOAA EFH mapper was also used to include all HAPCs that occur within the AoA. These data are binary and represent the area coverage, or presence/absence, of HAPCs within the AoA.

The NOAA Greater Atlantic Region ESA Section 7 mapper was used to evaluate the presence of critical habitat for ESA-listed species within the AoA and it was determined that no critical habitat is present (NOAA 2023c). The only ESA-listed endangered species range or spatial extent that occurs within the AoA is the Atlantic sturgeon; therefore, this is the only ESA-listed species range that is included in the Habitat Receptor Layer. The potential for Atlantic sturgeon presence or absence within a grid square of the AoA is accounted for using these data. All habitat data were combined into one receptor layer.

- **Essential Fish Habitat**: EFH is defined as the habitat required by fish and other marine animals for survival, reproduction, and maturity. NOAA Fisheries works to protect EFH to sustain viable commercial and recreational fisheries, replenish declining fish stocks, and help support overall ecosystem health (NOAA 2023b). EFH layers for the NOAA New England/Mid-Atlantic EFH and Atlantic Highly Migratory Species (HMS) EFH (NOAA 2023b) were downloaded and was represented by calculating the total number of unique species across all life stages occurring throughout the AoA.
- **Habitats of Particular Concern**: HAPCs are subsets of EFH that contain rare species or habitat, help support the survival and reproduction of federally listed species, may be particularly vulnerable to impacts from human activities, or a combination of these traits (NOAA 2023b). HAPC layers for the Mid-Atlantic and New England areas, representing Tilefish HAPC, juvenile Atlantic cod HAPC, and Canyons/seamounts HAPC were combined and summarized as either presence or absence of HAPC within the AoA.
- **ESA Species**: The AoA falls under the jurisdiction of the NOAA Greater Atlantic Regional Fisheries Office and an evaluation of threatened and endangered species that occur within the AoA was done. Only one ESA-listed endangered species, the Atlantic sturgeon, has a range that overlaps the AoA according to the NOAA Section 7 mapper (NOAA 2023c). Given the importance of this ESA-listed species, and because the range covers the entirety of the AoA, the NOAA Section 7 Atlantic sturgeon range layer was downloaded and used to represent ESA species.

2.5.4.2 Species

The species receptor layer was created by downloading and compositing the most recent NEFSC Spring and Fall Bottom Trawl Survey Data (2013-2022); NEFSC Atlantic Surfclam and Ocean Quahog Survey Data (2013–2022); NEFSC Sea Scallop Survey Data (2013–2022). As discussed in the corresponding environmental desktop studies that accompany this study, the NEFSC surveys assess marine benthic fish and invertebrate populations in the Atlantic Ocean, from Cape Hatteras to the Canadian border (NEFSC 2023a, 2023b; NOAA 2023d), and are some of the longest running surveys in the world and provides researchers with time-series data on the distribution, abundance, and biomass of sampled fish and invertebrate populations (NOAA 2023d).

The NEFSC data sets consist of point data, as such, it was necessary to convert this into a two-dimensional (2D) surface in order to be used in the sensitivity analysis. To accomplish this, the individual point bottom trawl catch weight from 2013–2022 for the target species (see Table 1 for list) was summed for each trawl location and gridded to 25 square kilometer grid using an inverse distance weighted (IDW) interpolation model. Because the total weight collected over a 10-year period spanned several orders of magnitude resulting in a heavily asymmetrical distribution, the data were transformed using a $\log_{10}(w+1)$ transformation, where w is the total weight. It is very common for data sets to be naturally asymmetrical/skewed. In the case of skewed data, because many statistical methods rely on unskewed data, a common approach (if not *the most common*) is to take the log transformation, which has the effect of taking a skewed data set and making it more symmetrical.

2.5.4.3 Fisheries

To represent the Fisheries receptor layer, NOAA provided VMS data to inform fishing vessel usage of the AoA, particularly in Zone 3, where bottom trawl survey data are not available. VMS data use advanced technological systems to monitor commercial fishing vessels operating in the U.S. Exclusive Economic Zone and treaty areas (NOAA 2023a). VMS uses satellites to track over 4,000 vessels throughout their journeys and ensures operators remain in compliance with fishing permits and designated fishing zones (NOAA 2023a). The monitoring system sends hourly updates on vessel positions, which allows law enforcement to determine the location of potential violators (NOAA 2023a). VMS is a useful tool for agencies monitoring marine protected areas and provides information for data validation, catch share programs, and assists fishery observer program by supplementing data on fishing effort, targeted species, and fishing locations (NOAA 2023a). Due to the sensitive nature of VMS data, NOAA's strict confidentiality requirements for handling, processing, and reporting of these data were adhered to and, therefore, some data points have not been included.

Additionally, NOAA provided the NOAA Fisheries Observer Data from 2013 to 2022 (NOAA 2023e, NOAA Fisheries Northeast Fisheries Observer Data, available upon request from NOAA) and catch hail weight summaries for fishing vessels using the same species groupings as the species receptor layer was created. These data also addressed gaps in AoA coverage identified in the Bottom Trawl Survey data and

VMS data, particularly in Zone 3. Fishery Observer data generally account for only a small portion of all fishery trips; therefore, coverage is limited (GARFO 2023d). Nonetheless, these data provide a snapshot of fishing vessel usage of the AoA and offer additional coverage to the Fisheries receptor layer, especially in Zone 3 where data are limited. Like the species receptor layer, the summed Fisheries Observer point data were grided to a 25-square-kilometer grid using an IDW interpolation model and the same log transformation applied.

2.5.5 Benthic Habitats

A detailed desktop data review and gap analysis was conducted for benthic habitat data available within the AoA, using standard methods for identifying, downloading, and reviewing existing public data sources. These methods included reviewing data available on regional data portals (e.g., Northeast Ocean Data Portal), from federal and State agency-specific data providers (e.g., NOAA, U.S. Geological Survey [USGS], U.S. Coast Guard [USCG], and NYSERDA), and from other known regional data providers (e.g., The Nature Conservancy [TNC], the Ocean Biogeographic Information System [OBIS]).

The benthic habitat resource group was subdivided into six separate receptors as follows (refer to Table 1 and the corresponding Benthic Habitat Study that accompanies this study for a detailed description and reasoning).

2.5.5.1 Coral Density

Within the AoA, coral records obtained from NOAA and OBIS database searches represented at least 47 distinct species. Most (n = 8,493) of coral records were located within topographically complex canyon features along the continental shelf slope in AoA, where hard bottom substrate is present, along with high currents and significant depth gradients that interact with highly variable topography.

Because the occurrence data for corals only consisted of occurrence point data, it was necessary to create a 2D surface using the occurrence data to combine with the other receptor data sets for use in the sensitivity analysis. Therefore, the occurrence data were merged into a single data set and any duplicate records between the two data sources were identified and the record sourced from NOAA was retained over the duplicate OBIS record. A kernel density estimate (KDE) was conducted on this combined data set using a grid size of 10 kilometers by 10 kilometers and a bandwidth of 25 kilometers. The resulting density surface represented “species detection” of corals within the AoA.

Sampling effort was not included with this layer; therefore, it did not include absence data. Surveys most frequently occurred in topographically complex regions, such as canyons within Zone 2. Further undocumented surveys in the region were likely not captured by the two data sets used. This generally resulted in higher sampling and species detections in Zone 2 than in Zones 1 and 3.

2.5.5.2 Sponges Density

Data on deep-sea sponges were obtained from NOAA and OBIS databases and processed in a similar fashion to corals. Sponges within the region of the AoA are classified as demosponges, glass sponges, or calcareous sponges, accounting for 1,058 total sponge records. A KDE was conducted on this combined data set using a grid size of 10 kilometers by 10 kilometers and a bandwidth of 25 kilometers, with the goal of estimating sponge occurrence density within the AoA and providing a representation of "species detection" within this region.

2.5.5.3 Sea Pen Density

Data on sea pen occurrence were obtained from NOAA and OBIS databases and processed in a similar fashion to corals and sponges. At least 17 distinct species, found in 1,713 records of sea pen species, are present in the AoA. Sea pens appeared to be sparsely distributed within all AoA zones but are most common along the deep areas of the lower shelf break and within canyons of Zone 2, with a subset of records clustered along the upper mouth of Hudson Canyon. A KDE was conducted on this combined data set using a grid size of 10 kilometers by 10 kilometers and a bandwidth of 25 kilometers, with the goal of estimating sea pen occurrence density within the AoA and providing a representation of "species detection" within this region.

2.5.5.4 Hard Bottom

USGS created a model of substrate and sediment properties (Battista 2019) for much of the New York Bight, with coverage of most of the southern portion of Zones 1 and 2 of the AoA.

As this hard bottom layer does not cover much of the AoA in all three zones, it was supplemented with data from both TNC's Soft Sediment and Seabed Forms data layers (NAMERA 2020). The Soft Sediment and Seabed Forms data set report interpolated sediment grain size type and geoform, respectively, as geoforms can provide predictive information about seafloor sediment composition. Therefore, because they do not directly represent hard bottom likelihood as does the USGS model, these two layers were reclassified according to their respective likelihood of containing hard bottom substrate, as shown in

Table 2 and Table 3. The Soft Sediment data reclassified layer was applied to the missing areas (i.e., those without existing USGS Hard Bottom coverage) in Zones 1 and 3, and the reclassified Seabed Forms data were applied to the missing areas of Zone 2. The Seabed Forms data were used for Zone 2 because, in this region of high relief and canyons, they provide a better approximation of hard bottom likelihood than the Soft Sediment data, which are based on results from sediment grab samples, a tool that is not effective for sampling hard bottom habitats directly.

Table 2. Soft Sediment to Hard Bottom Likelihood Reclassification

Soft Sediment Type	Nominal Ranking (least to greatest) of Hard Bottom Likelihood
Mix of sand and mud	0
Sand with some mud	0
Mud with some sand	0
Majority sand	0
Majority mud	0
Sand with some gravel	2
Sand with some mud and gravel	2
Mud with some gravel	2
Mud with some sand and gravel	2
Mix of sand and gravel	3
Mix of mud and gravel	3
Mix of sand, mud, and gravel	3
Gravel with some sand	4
Gravel with some mud	4
Gravel with some sand and mud	4
Majority gravel	5

Table 3. Seabed Forms to Hard Bottom Likelihood Reclassification

Seabed Form Type	Nominal Ranking (least to greatest) of Hard Bottom Likelihood
Low Flat	0
Mid Flat	1
Upper Flat/bank	1
Upper Slope/peak	3
Valley Peaks	4
Depression/Valley	5

2.5.5.5 Deep-Sea Stony Coral Suitability

Deep-sea stony coral habitat suitability data was obtained from the NOAA Office for Coastal Management and represented the suitability for deep-sea stony corals within the AoA (NOAA Office for Coastal Management 2018). Habitat suitability models, also known as species distribution models, are increasingly used in science, conservation, and management, particularly for the study of species that are incompletely sampled (Vierod et al. 2014; Winship et al. 2020). These models work by quantifying the relationships that species have with environmental predictors and building a geospatial representation of potential habitat for the modeled species (Philips et al. 2006; Hirzel and Lay 2008; Elith and Graham 2009). For species such as deep-sea corals, habitat suitability models have become a primary tool, with assessments ranging from local (e.g., Rengstorf et al. 2013; Rowden et al. 2017), to regional (e.g., Guinotte and Davies 2014; Anderson et al. 2016a, 2016b; Kinlan et al. 2020) and even global scales (e.g., Davies and Guinotte 2011; Yesson et al. 2012, 2017a).

In the northeast U.S. region, Kinlan et al. (2020) reported on the development of high-resolution (370-meter grid size) regional scale models for deep-sea coral species that cover Zones 1 and 2 of the AoA and a portion of Zone 3. The Kinlan et al. model was bound in Zone 3 by the extent of the bathymetry used in their study, thus coverage in this Zone was not complete. Section 3 describes the data coverage for this and all receptors used in these analyses.

These data represented a predicted likelihood of the presence of deep-sea coral habitat and were already presented as a 2D surface (polygon areas), thus no additional pre-processing was required.

2.5.5.6 Sea Pen Suitability

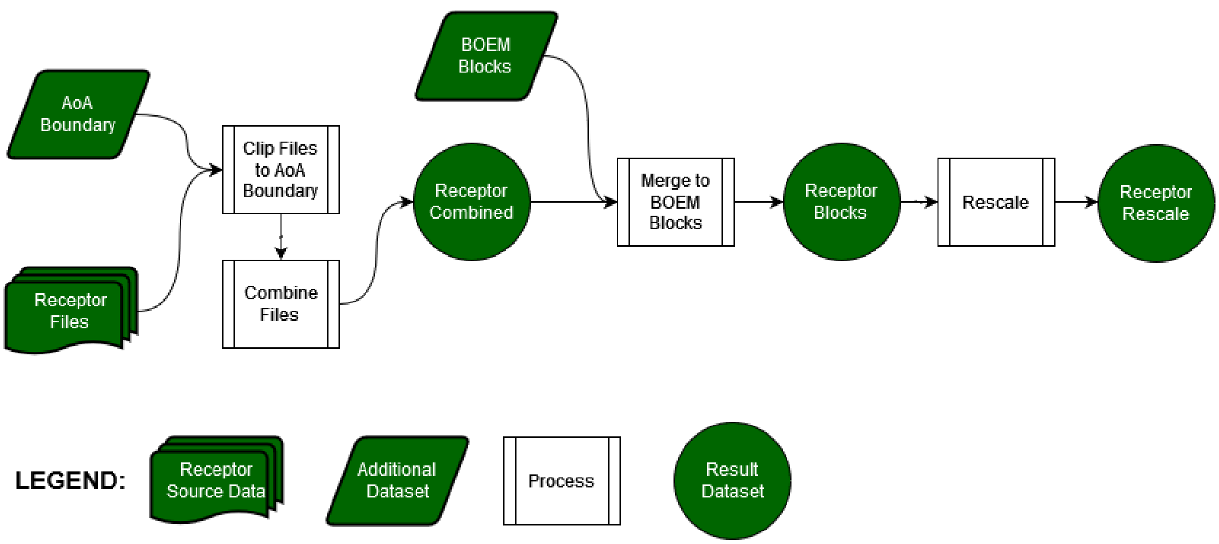
Similar to deep-sea corals, an existing layer of predicted habitat suitability for sea pens was obtained from NOAA/OBIS (Kinlan et al. 2013), which represented the likelihood of suitable sea pen habitat within the AoA as an ordinal scale from “Very Low” to “Very High.” Like deep see stony coral suitability, these data were already presented as a 2D surface (raster grid), thus no additional pre-processing was required.

2.6 Data Standardization and Rescaling

Once all the data sources were gathered and compiled as described above, the data were processed to conform to a mathematically comparable structure for the purposes of sensitivity calculations. This process consisted of two steps: data standardization and rescaling. As described in section 2.2, to be combined mathematically in a straightforward way, rescaling to a common scale is required between different data sets with different units (e.g., weight in kilograms of bottom trawl fish catch, density in animals per square kilometer of marine mammals, etc.). Similarly, the various data sets often have a different geographic representation (geometry, spatial resolution, format, etc.) and thus need to be reshaped into a common geographic unit to aid in combining them. The details of these two steps are described in detail in the following sections.

Data processing and analysis were done in the R statistical programming language (R Core Team 2021) and in ESRI ArcGIS Pro ("ESRI ArcGIS Pro" 2021) and orchestrated using the R targets package (Landau 2021), which is a set of pipeline tools to coordinate the pieces of computationally demanding analysis projects by creating a dependency graph of individual components. An example dependency graph for the processing steps of a generic receptor is shown in Figure 8, which illustrates how data standardization and rescaling steps integrate to create the receptor layer.

Figure 8. Example Dependency Graph for Data Processing for Example Receptor Layer



2.6.1 Data Standardization

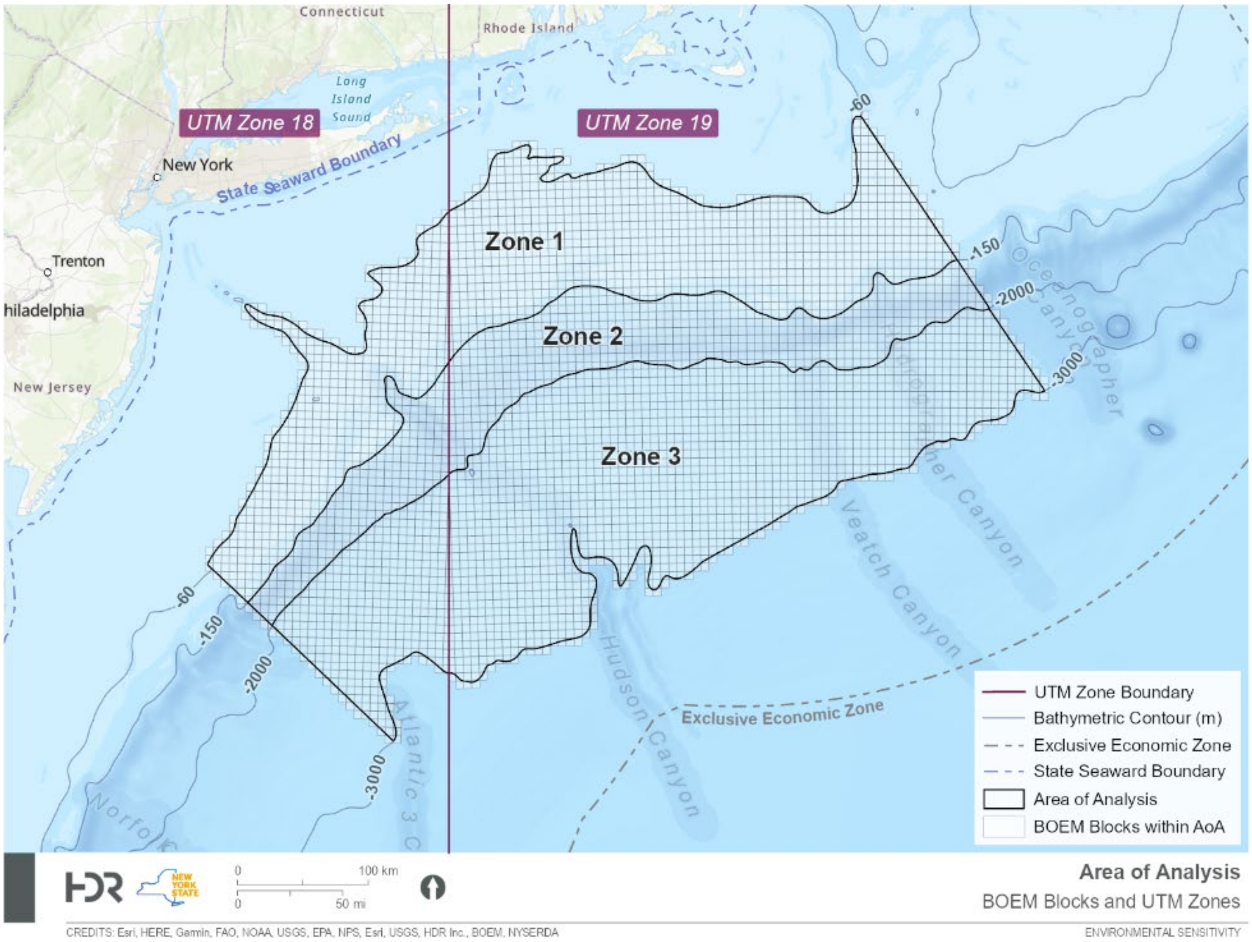
Standardization refers to the process of ensuring that all the data are reported on a standard geographic unit by transforming them to a common geometry and geodesy (i.e., datum, coordinate system, measurement units, and boundary extents). For the purposes of the sensitivity analysis, all receptor data sets in the AoA (Figure 1) were aggregated to the BOEM Lease Blocks network (Figure 9) as the standard geographic reporting unit. For reference, a BOEM lease block is defined as an area that typically varies between 20 and 24 square kilometers and is developed by the U.S. Department of the Interior's Minerals Management Service Mapping and Boundary Branch. Additional details on the Outer Continental Shelf Leasing Maps can be found in Boundary Development on the Outer Continental Shelf (U.S. Department of the Interior et al. 1999).

Spatial aggregation at the block level provided a convenient resolution relative to the size of the AoA and, moreover, is the standard spatial grid unit used by BOEM. All data were projected to the common map projection of Universal Transverse Mercator (UTM) Zone 19N (North American Datum of 1983 [NAD83], meters). UTM Zone 19N was selected because the majority of the AoA is within this zone. Individual data layers were resampled to the block layer using an area-weighted mean, using the exactextractr package in R (Baston 2023) in the case of raster data or sf package in the case of vector (polygon) data sets (Pebesma 2018; Pebesma and Bivand 2023). In total, there were 4,300 lease blocks (in their entirety) distributed amongst the three zones in the AoA, as shown in Table 4.

Table 4. BOEM Blocks Distribution within the Area of Analysis

Zone	Number of BOEM Blocks	% Of Total Blocks
Zone 1	1,568	36%
Zone 2	782	18%
Zone 3	1,950	45%
Total	4,300	100%

Figure 9. Area of Analysis with Bureau of Ocean Energy Management Lease Blocks



2.6.2 Rescaling

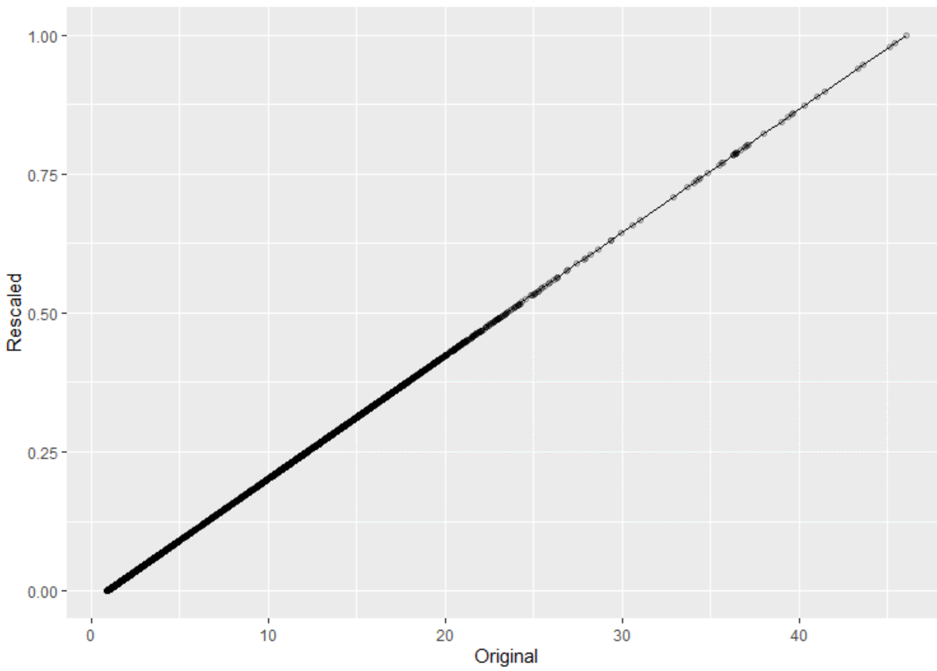
Rescaling data refers to the conversion of a set of values from one scale to another by employing a defined mathematical transformation. Rescaling is often necessary when disparate sets of data need to be combined (e.g., when variables span different ranges or have different units of measure). For this study, input data sets were rescaled to a continuous 0–1 scale (which should be interpreted as low sensitivity to high sensitivity) using the following linear rescaling function:

Equation 1.

$$v_i' = \frac{v_i - \min(\vec{v})}{\max(\vec{v}) - \min(\vec{v})}$$

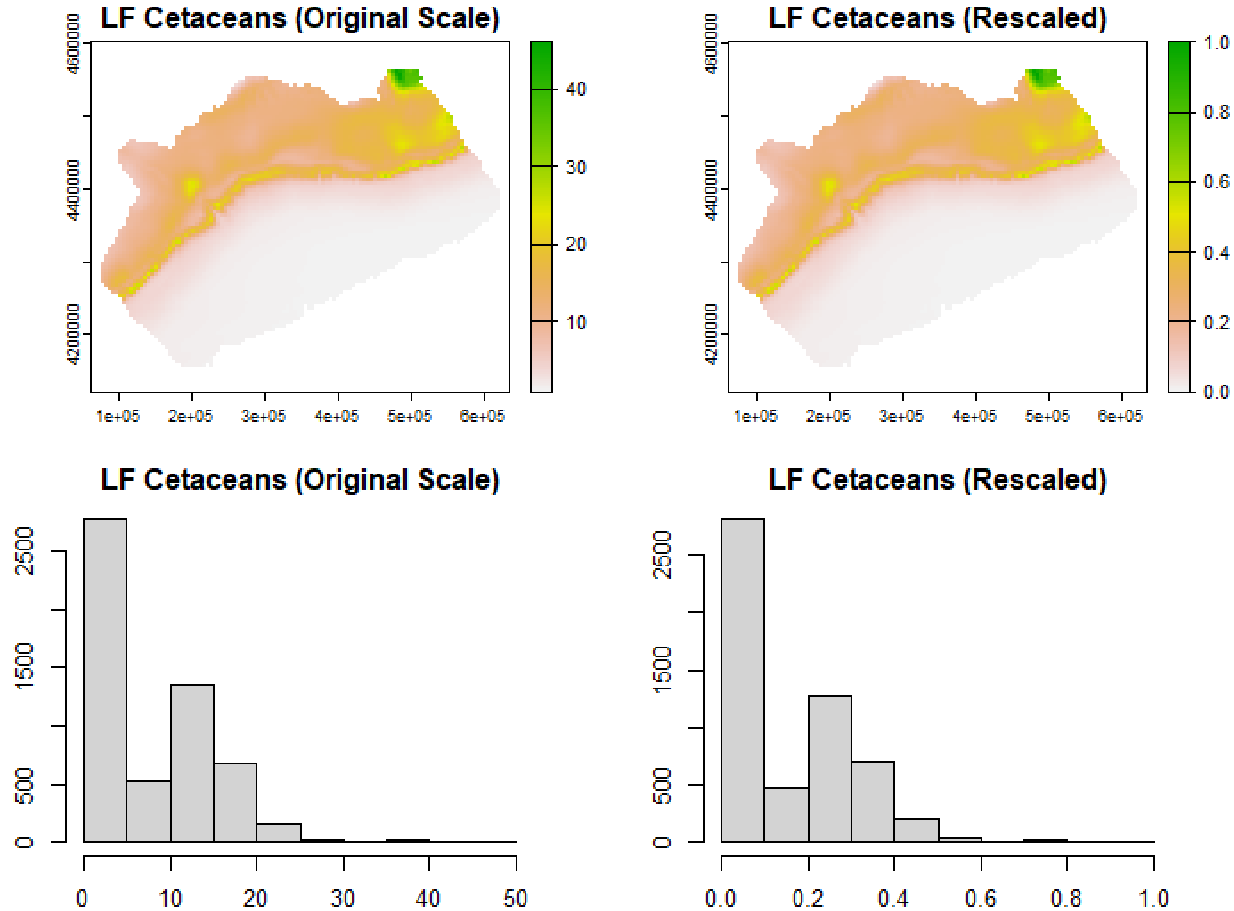
Where v_i' is the rescaled i^{th} element of a real vector $\vec{\boldsymbol{v}}$, and min and max of $\vec{\boldsymbol{v}}$ are the scalar minimum and maximum elements of $\vec{\boldsymbol{v}}$, respectively. It follows then that, if $\vec{\boldsymbol{v}} \in \mathbb{R}$ then $\vec{\boldsymbol{v}}' \in [0,1]$, which states that if a vector $\vec{\boldsymbol{v}}$ exists in the domain $\mathbb{R}$, then the rescaled vector $\vec{\boldsymbol{v}}'$ will exist in the domain [0,1]. An example of this function is shown in Figure 10, where a set of values on the original scale (x axis) are rescaled to a new range (y axis).

Figure 10. Example of Linear Transformation Function to Rescale Values



An important property of this rescaling function is that it only changes the range of the data and does not change the shape of its distribution or relative statistical attributes. Figure 11 illustrates the receptor data for the Low-Frequency Cetaceans density layer, both spatially (top) and in the histogram of values. Note how spatial variation in density and distribution remains unchanged and only the labels on the axis values change.

Figure 11. Example of Rescaled Data for Example Receptor Data (Low-Frequency Cetaceans)



By definition, the linear rescaling always rescales the *lowest* value to zero on the sensitivity scale, but zero sensitivity does not imply *no* sensitivity. It is just the lowest sensitivity *relative* to all other locations in the AoA. Similarly, one is the maximum relative sensitivity relative to other locations within the AoA.

2.7 Layer Weighting

The methodology used to combine the individual layers into an overall composite set of sensitivity maps consisted of a semi-quantitative process of expert elicitation among the SMEs to determine the weighting (i.e., the edges on the framework shown in Figure 6). The selection of a set of weights is inherently a subjective process as, for example, one expert might more heavily favor one or another component based on their unique background, biases, or expertise. Therefore, to minimize this effect and determine a set of weights as objectively and rigorously as possible, we used the Analytical Hierarchy Process (AHP) to survey the SMEs and calculate the weights.

The AHP is a general theory of group decision-making and a branch of operations research developed in the 1970s. It is a structured technique for organizing and analyzing complex decisions based on mathematics and psychology, and falls under the academic disciplines of MCDA and Theory of Decision Making (Saaty 1977, 1980, 1987, 2004; Zahedi 1986; Bernasconi et al. 2009). When used in group decision-making, instead of prescribing a "correct" decision, the AHP allows SMEs and decision-makers to collectively find the goal that best describes their mutual understanding of the problem and provides a comprehensive and rational framework for representing and quantifying its primary element. It is a versatile tool that allows individuals to rationally weigh attributes and evaluate alternatives presented to them, and therefore, minimize many of the drawbacks of a purely qualitative approach.

Layer weighting for this analysis was performed by SMEs from each study. Risk determinations were informed by the available subject literature as well as personal SME knowledge and experience. When information was lacking regarding the effects of specific OSW stressors, available information about similar anthropogenic activities was used to inform ratings. For OSW stressors that have little to no available information because of the evolving nature of these technologies, the best professional judgment was used by each resource SME. Best management practices (BMPs) and mitigation measures, while critical considerations in assessing the potential impacts of OSW on marine resources, were intentionally not taken into consideration in risk determination for this analysis. This is because BMPs evolve constantly with iterative OSW projects and changing agency guidelines as new information becomes available.

2.7.1 Analytical Hierarchy Process Methodology

The AHP methodology consists of preparing a series of survey questionnaires for each node (i.e., box) in the hierarchy (Figure 6) and asking each SME to systematically evaluate the elements below that node (child nodes). SMEs compare nodes to each other, two at a time, with respect to their impact on the node above them (parent node) in the hierarchy (e.g., comparing the relative effect of noise versus bottom disturbance with respect to a given receptor). Once this set of pairwise comparisons is completed, the set of rankings can be combined mathematically to produce an overall set of weights for each parent-children set in the hierarchy.

The primary benefits of using the AHP are that it provides more quantitative rigor by breaking down the decision space into smaller parts and focuses the effort of the SME to consider supporting evidence and rationale for each comparison. In making the comparisons, the SMEs can use concrete data about the elements, and they can also use their judgments about the elements' relative meaning and importance. Moreover, the method has additional functionality to ensure consistency among responses and provides an unbiased method to obtain rankings independently from each SME. Examples and details of the AHP are further described below.

2.7.2 Pairwise Rankings

When completing the pairwise rankings, each SME respondent is tasked with ranking the relative importance between each element of the pair according to the nine-point ordinal scale shown in Table 5, also known as the "Saaty" scale. The Saaty scale is composed of nine items on each end (17 options per pairwise comparison), where SMEs are asked to indicate how much element A is more preferred to B (or vice versa), based on the nine-point scale. Respondents are asked to select a score for each pairwise comparison and provide a rationale for each of them.

Table 5. The Fundamental Scale of Pairwise Comparisons

Scores of 2, 4, 6, and 8 can be used to express intermediate values.

Adapted from (Saaty 1987)

Intensity of Importance	Definition	Explanation
1	Equal	The two elements have equal importance relative to the parent.
3	Moderate	Experience and judgement determine that the preferred characteristic is moderately more important than the other.
5	Strong	Experience and judgement determine that the preferred characteristic is strongly more important than the other.
7	Very Strong	The preferred characteristic is very strongly more important over the other; its dominance is demonstrated in practice.
9	Extreme	The evidence for the preferred characteristic being more important over the other is of the highest possible order of affirmation.

To illustrate the survey process, a completed example of a survey questionnaire for the Level 3 Noise stressor is shown below in Figure 12, which compares each of the four Level 4 OSW phases. The number of pairwise comparisons (*P*) for each node with *k* child nodes follows:

Equation 2. $$\boldsymbol{P = \frac{k(k-1)}{2}}$$

As such, in this example for the four Level 4 phases, there are (4 x 3) / 2 = 6 pairwise comparisons to complete. Each comparison is scored using the scale defined in Table 5 and the individual respondent's rationale for why they chose this score is given. Thus, in the example shown in Figure 12, for the first comparison, the respondent (in this case, a marine mammal SME) indicated that Noise during the Construction Phase would be Very Strongly (score = 7) more important than Noise during the Pre-Construction Phase. This process is then repeated for each of the pairwise comparisons, which can be completed in any sequence.

Figure 12. Example of Completed AHP Survey for One Parent-Children Node Set

	Between:	Extreme		Very Strong		Strong		Moderate		Equal Risk		Moderate		Strong		Very Strong		Extreme	And:	Why?
Parent	Phase_1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phase_2	Rationale
Noise	Pre-Construction															✔			Construction	Underwater noise is much more likely to be present--and at levels that potentially affect marine mammal hearing and behavior--during the construction vs. preconstruction phase
Noise	Pre-Construction											✔							Post-Construction	Underwater noise is more likely to be present during operations (operational noise from turbines, sonar from ongoing HRG surveys, vessel noise) than during SI (sonar and vessel noise)
Noise	Pre-Construction													✔					Decommissioning	Underwater noise is more likely to be present (cutting/removal of structures, vessel noise, sonar from ongoing HRG surveys), and at potentially harmful levels, than during the pre-construction phase (SI surveys and vessel traffic)
Noise	Construction				✔														Post-Construction	Underwater noise is much more likely to be present--and at levels that potentially affect marine mammal hearing and behavior--during the construction vs. the operations phase. However, the operational noise of the larger (e.g. GE Haliade X) turbines is largely unknown
Noise	Construction							✔											Decommissioning	Underwater noise is more likely to be present during the construction vs. decommissioning phase, although decommissioning will also generate substantial noise via cutting/removal of structures
Noise	Post-Construction											✔							Decommissioning	Underwater noise is more likely to be present during decommissioning than operations

2.7.3 Weight Calculation

After a respondent has completed a survey questionnaire such as the one given in Figure 12, the AHP methodolgy requires that the set of responses be transposed into a reciprocal matrix (Saaty 1980):

Equation 3.

$$S_k = \begin{bmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,N} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,N} \\ \vdots & \vdots & a_{i,j} & \vdots \\ a_{N,1} & a_{N,2} & \cdots & a_{N,N} \end{bmatrix}$$

Where $\mathbf{S_k}$ is the reciprocal matrix for k children, $a_{i,j}$ represents the pairwise comparison score between the i^{th} and j^{th} children, $a_{j,i} = 1/a_{i,j}$ (i.e., the reciprocal), and $a_{ij} = 1$ when $i = j$.

For the example questionnaire shown in Figure 12, the resulting reciprocal matrix is shown in Figure 13.

Figure 13. Example of Reciprocal Matrix with Respect to Noise (parent) and Phase (children)

NOISE	Pre-Construction	Construction	Post-Construction	Decommissioning
Pre-Construction	1	1/7	1/3	1/5
Construction	7	1	6	3
Post-Construction	3	1/6	1	1/3
Decommissioning	5	1/3	3	1

The next step is to derive the scale of weights (or "priorities" in AHP parlance), which has been shown at this scale to be determined by solving for the principal right eigenvector of the matrix and then normalizing the result (Saaty 1980, 1987). By processing this matrix mathematically, the AHP derives priorities for the candidates with respect to the parent node (Noise, in this example case). The weights are measurements of their relative strengths, derived from the judgments of the SMEs as entered in the matrix. The result of the weight calculation for the example reciprocal matrix shown in Figure 13 is shown in Figure 14, which indicates that this respondent clearly indicated that Noise would be most impactful during the Construction phase (58**%** weight), followed by Decommissioning (26%), Post-Construction/Operation (11%), and finally Pre-Construction (5%). All the weights sum to unity, and in effect, the weights represent a partitioning of the sensitivy for a given element of the hierarchy with respect to its constituents (i.e., child nodes), or conversely, the contribution of each child to the parent.

Refer to (Saaty 1980) for a more detailed description of the methods and mathematics behind the AHP methodology.

Figure 14. Example Reciprocal AHP Matrix with Weights Calculated for Noise

	Pre-Construction	Construction	Post-Construction	Decommissioning	Weights
Pre-Construction	1	1/7	1/3	1/5	5%
Construction	7	1	6	3	58%
Post-Construction	3	1/6	1	1/3	11%
Decommissioning	5	1/3	3	1	26%
				Sum of Weights:	100%
				Inconsistency:	0.047

2.7.4 Measuring Consistency

One consequence of the AHP methodology is that the reciprocal matrix allows for a measure of consistency to be determined by computing the consistency ratio (CR):

Equation 4. $$CR = \left(\frac{\lambda_{max} - k}{k-1}\right)\left(\frac{1}{RI}\right)$$

Where:

λ_{max} is the maximum eigenvalue of the pairwise comparison weight vector computed above

k is the number of children compared.

The randomness index (RI) is determined based on the value of k and lookup from Table 6.

Table 6. Randomness Indices for Various Matrix Ranks

Source: Adapted from Saaty (1980)

k	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.53	0.88	1.11	1.25	1.34	1.41	1.45	1.49	1.51	1.54	1.55	1.57	1.58

By convention, if the CR is less than approximately 0.1, then the AHP matrix is said to be consistent (Saaty 1980; Hayrapetyan 2019). The CR is, in effect, a measure of how internally consistent (i.e., non-random) each respondent's answers are and if the transitive property for the comparison matrix mostly holds.

2.7.5 Aggregated Weights

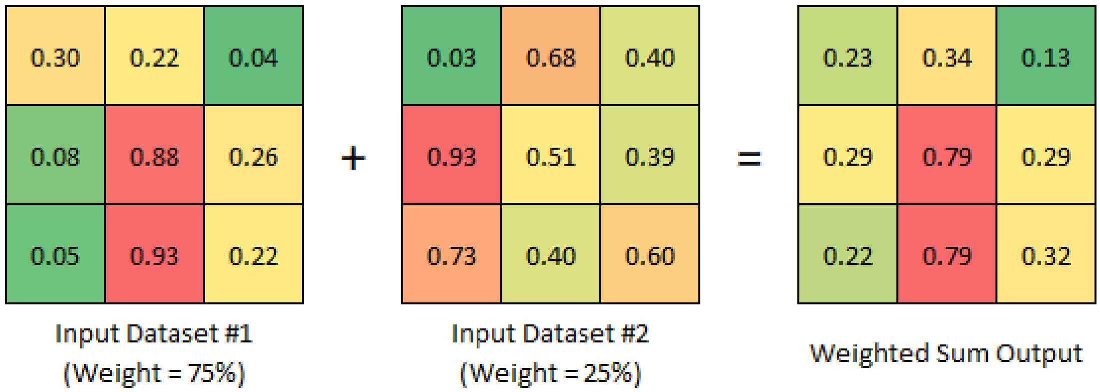
Another primary benefit of the AHP is that it allows multiple respondents to independently answer a given set of questions and subsequently combine the resulting weights in a natural way using straightforward statistics (for example, the mean weights across all respondents). This allows for a very flexible and democratic approach to decision-making that can be performed asynchronously across many respondents in both time and space and can help minimize common impediments and difficulties. Results of all AHP surveys and the resulting weights are summarized in section 3, Results.

2.8 Combined Weighted Overlay

As discussed in section 2.2, the final step in the processing once the data sets have been rescaled and standardized to the BOEM blocks, is to use the weights computed from AHP to perform a weighted overlay. This combines the individual receptor data sets with the weightings at each level of the framework by multiplying the standardized data values for each receptor by the corresponding layer-specific weightings. This process is illustrated in Figure 15, whereby the data are multiplied by their weights and added together.

Moreover, because all nodes in the hierarchy have a defined set of weights (i.e., the edges in the graph in Figure 6), the weight at any given node or aggregation of nodes can be computed by the product of the weights that connect in the given path of the hierarchy. For example, the combined sensitivity for each stressor in the fish and fisheries resource group can be calculated by multiplying the chain of weights under that resource group and adding them together.

Figure 15. Conceptual Illustration of Weighted Overlay



3 Data Gaps and Deficiencies

An important consideration to account for after the individual receptor data were compiled was the general issue of data gaps and deficiencies in the various input data sets. This is especially important when considering the interpretation of the sensitivity results, as underrepresentation of a receptor group (or groups) should be accounted for.

In this context, data gaps and data deficiency were reviewed based on two primary concepts:

- **Data Completeness:** Where and how much of the AoA had data reported for a given receptor? The absence of data should be considered carefully when reviewing the overall sensitivity results.
- **Data Confidence:** This is the overall degree to which the data accurately reflect the true receptor conditions. This generally is a property of the individual source data's provenance, methodology, caveats, limitations, etc. For a detailed discussion, refer to the corresponding environmental desktop studies that accompany this study.

Data completeness by resource group, receptor, and zone within the AoA is summarized in Table 7. Data gaps for each receptor and composited gaps are shown in the relevant subsections of section 4.3. Data completeness was calculated after the individual data layers were standardized and rescaled and was computed by tallying the number of blocks that had no data and expressed as a percentage of the total number of blocks within each AoA zone. Completeness was evaluated for each receptor data layer by block. For example, 41% of the blocks in Zone 1 had coral density data, likewise for 99% of Zone 2 blocks and 67**%** of Zone 3.

Table 7. Summary of Data Completeness by Resource, Receptor, and Zone within the Area of Analysis

Resource	Receptor	Zone 1	Zone 2	Zone 3
Marine Mammals & Sea Turtles	Deep-Diving Cetaceans	100%	100%	100%
	High-Frequency Cetaceans	100%	100%	100%
	Low-Frequency Cetaceans	100%	100%	100%
	Mid-Frequency Cetaceans	100%	100%	100%
	Marine Mammals Conservation Status	100%	100%	100%
	North Atlantic Right Whale	100%	100%	100%
	Shallow-Diving Cetaceans	100%	100%	100%
	Seals	100%	100%	100%
	Sea Turtles	100%	100%	100%

Table 7 continued

Resource	Receptor	Zone 1	Zone 2	Zone 3
Birds & Bats	Collision Vulnerability	100%	99%	79%
	Displacement Vulnerability	100%	99%	79%
	Population Vulnerability	100%	99%	79%
Fish & Fisheries	Habitat	100%	100%	100%
	Species	100%	70%	0%
	Fisheries	100%	99%	50%
Benthic	Coral Density	41%	99%	67%
	Deep-Sea Sony Coral Suitability	29%	95%	8%
	Hard Bottom	100%	100%	99%
	Sea Pen Density	62%	98%	47%
	Sea Pen Suitability	100%	100%	42%
	Sponge Density	46%	85%	22%

In general, the Benthic resource group had the lowest coverage of data. Deep-Sea Stony Coral Suitability was the scarcest, with 29% complete blocks in Zones 1 and 8% in Zone 3 and 95% coverage in Zone 2. Sponge, Sea Pen, and Coral Density were the next scarcest, with Zones 1 and 3 having lower data coverage percentages. Hard Bottom had nearly complete coverage of the entire AoA.

Fish and **f**isheries was the second scarcest receptor group, with the species receptor being the scarcest, having no data present in Zone 3, 70% coverage in Zone 2 and complete coverage in Zone 1. Fisheries data in Zone 3 had 50% coverage, Zone 2 had 99% coverage and Zone 1 had complete coverage. Fish Habitat had complete coverage across the AoA, but this was largely due to the inclusion of the ESA Section 7 Atlantic sturgeon range, as this range covered the entire AoA. EFH and HAPC data, the other contributors to this receptor group, were largely constrained to Zones 1 and 2 only.

The marine mammals and sea turtles receptor group had 100% data coverage across all three zones.

The Birds resource group had complete coverage in Zone 1, 99% coverage in Zone 2, and 79% coverage in Zone 3. All three receptor groups had this same pattern as they were derived from the same set of MDAT models (refer to the corresponding Bird and Bat Study for details on those procedures).

The set of coverage maps (by individual receptor layer, and resource group) are useful tools to employ as a “mask” over the sensitivity results, as they provide context on how much representation of the constituent data layers is present and, for example, can be used to screen out any locations that do not meet a given threshold of data deficiency.

Because there was an unequal representation of all data sets across all three zones, in particular Zone 3, generally had the least data coverage overall, sensitivity results for blocks that had less than 50**%** data completeness for each resource group were not displayed (i.e., masked) as being too data poor. The intention of this presentation is to prevent the misleading interpretation that some areas (example in Zone 3) are less sensitive than other areas when in fact, there is likely insufficient data available to draw such a conclusion.

4 Results

4.1 Rescaled Receptor Data Sets

The data sets discussed in section 2.5 were standardized to the BOEM block geometry layer and the numeric values were rescaled according to the methods discussed in section 2.6. This processing aligned all receptor groups to a common numeric sensitivity index that ranged from zero to one (i.e., low to high sensitivity). The results of this process are shown below by resource group in section 4.3.1.1 (Marine Mammals and Sea Turtles), section 4.3.2.1 (Birds and Bats), section 4.3.3.1 (Fish and Fisheries), and section 4.3.4.1 (Benthic Habitat).

4.2 Layer Weights

As discussed in section 2.7, for each parent-child level in the hierarchy framework (Figure 6), the survey comparisons of each respondent were collected, and the weights were calculated and aggregated. The following sections detail the responses from each level of the framework and the resulting weights and a summary of the rationales the respondents provided. For a detailed discussion of the individual receptors, associated stressors, and potential impacts, refer to the corresponding environmental desktop studies that accompany this study.

4.2.1 Level 1—Resource by Receptor Weights

The first level of the framework (Figure 6) allocates the relative contributions of each receptor group (Level 2) to each resource group (Level 1). Because each receptor is specific to a given resource group, only the respective SMEs of each particular resource group were asked to complete the survey (i.e., a bird SME would not be appropriate to determine how each of the nine marine mammal receptors should be allocated). Results of the Level 1 resource by receptor weights are shown in Table 8.

Table 8. Level 1—Weights Resource by Receptor

Data completeness values for birds and bats varies slightly from Table 7 because these calculations were made by area whereas Table 7 calculations were based on block.

Resource	Receptor	Level 1 Weight
Marine Mammals & Turtles	High-Frequency Cetaceans	7%
	Low-Frequency Cetaceans	15%
	Mid-Frequency Cetaceans	13%
	North Atlantic Right Whale	14%
	Seals	11%
	Turtles	12%
	Deep Diving Cetaceans	6%
	Other Marine Mammals Conservation Status	11%
	Shallow Diving Cetaceans	12%
	Marine Mammals & Turtles Total	**100%**
Birds & Bats	Collision Vulnerability	33%
	Displacement Vulnerability	33%
	Population Vulnerability	33%
	Birds & Bats Total	**100%**
Fish & Fisheries	Fisheries	33%
	Habitat	33%
	Species	33%
	Fish & Fisheries Total	**100%**
Benthic	Coral Density	30%
	Deep Coral Suitablity	30%
	Hard Bottom	3%
	Sea Pen Density	9%
	Sea Pen Suitability	8%
	Sponge Density	18%
	Benthic Total	**100%**

Among the marine mammal and sea turtle resource groups, low-frequency cetaceans and NARW had the highest weights (15**%** and 14%, respectively). Low-frequency cetaceans include humpback, common minke, sei, fin, and blue whales. Three of these low-frequency cetacean species are listed as endangered under the ESA. Low-frequency cetaceans are at potential risk of adverse impacts from certain OSW stressors, such as noise from piling and operations, auditory masking, and vessel strikes. Noise from vessel traffic and construction activities is audible to low-frequency cetaceans, and certain types of noise have the potential to cause temporary or permanent hearing loss, or "threshold shift."

Similarly, the main concerns for NARWs are their conservation status, vulnerability to vessel strikes, underwater noise, and entanglement. Noise from construction activities is audible to NARW and has the potential to cause a temporary threshold shift (TTS) or permanent threshold shift (PTS). However, mitigation measures such as the use of bubble curtains and implementation of clearance and shutdown zones during in-water construction will minimize this risk as well as risks of masking, avoidance, and other behavioral effects. Any associated missed foraging opportunities, and reduced body condition, given the special conservation status of this species, could potentially have population-level effects.

The receptors examined for birds included collision, displacement, and population vulnerability. The only threatened or endangered bird species included in the environmental sensitivity analysis was the roseate tern (*Sterna dougallii*). Bats were not included in this environmental sensitivity analysis due to insufficient data in the AoA. Bird receptors were rated equally. Collision vulnerability has immediate lethal consequences, though it may be less prevalent than displacement, which has delayed consequences. Displacement vulnerability is likely more prevalent, based on studies in Europe, though impact of low-visibility conditions on collision risk is not well documented.

For fish and fisheries, three overall risk receptor layers, habitat, fish species, and commercial and recreational fisheries, were given equal weighting during the analysis because they are all important and interrelated resources. Stressors that impact fish habitat (e.g., bottom disturbance) may directly or indirectly impact fish species. Similarly, negative impacts on fish species may directly or indirectly impact fisheries.

For benthic habitats, deep-sea coral occurrence density was ranked as equal risk with deep-sea coral habitat suitability, as these are representations of the same resource (deep-sea corals). Similarly, sea pen occurrence density was ranked as equal risk compared to sea pen suitability. All biological receptors were ranked as more sensitive than hard bottom habitat because hard bottom is often considered a geological feature rather than solely a biological habitat.

Deep-sea corals and deep-sea sponges were ranked as more sensitive than sea pens due to their general dependency on hard grounds for colonization over soft sediments, and their general inability to move and reattach, compared to the ability of some sea pens to re-embed in sediment following disturbance. For the purposes of this study, two pairs of receptors are discussed together: deep-sea coral occurrence density was paired with deep-sea coral habitat suitability, and sea pen occurrence density was paired with sea pen habitat suitability. This approach was chosen because these receptors are identical but differ in their data sources.

4.2.2 Level 2—Receptor by Stressor Weights

In contrast to the Level 1 weights, which serve to roll up each receptor group's data into a composite sensitivity, the second and third levels of the framework (Figure 6) partition each receptor group by the set of 10 stressor groups (Level 3). In turn, each of those stressors is further partitioned across the four phases of OSW (Level 4). Each resource group is discussed separately below.

4.2.2.1 Marine Mammal and Sea Turtle Stressor Weights

For marine mammals and sea turtles, new structures, noise, vessel traffic, and UXO detonation were the stressors that were consistently ranked the highest for potential impact across all nine receptor groups.

The Marine Mammal and Sea Turtle Study provides greater detail on stressors associated with both fixed and floating wind technologies and anticipated impacts on the marine mammal and sea turtle receptor groups. A summary of the rationale behind these rankings is presented below.

New Structures

New underwater structures put in place during construction or operation of an offshore wind farm are potential stressors to marine animals in their natural environment and can cause direct and indirect effects on these organisms. Within this stressor category, sub-stressors of particular importance are displacement (where animals avoid underwater structures and are, therefore, displaced from habitat otherwise available to them) and entanglement (where animals may be exposed to debris accumulated on underwater structures, such as derelict fishing gear). Because marine mammals and sea turtles are highly mobile marine species, they could, in theory, use other suitable areas to compensate for habitat loss and fragmentation. However, major barriers to migration or loss of critical habitat could affect species by requiring additional energy expenditures (Harwood 2001; Farr et al. 2021). If displacement does occur, marine mammals or sea turtles could experience reduced body condition and health if foraging time is increased, or migratory pathways are affected. Additionally, these species groups would have a heightened risk of vessel strikes if they moved into more heavily trafficked areas.

Entanglement may result in the severe injury or mortality, starvation, or drowning of an animal (Cassoff et al. 2011, as cited by Farr et al. 2022), and is considered a leading cause of UMEs for humpback whales and NARWs (in addition to vessel collisions) (NOAA 2023b, 2023c). It is unlikely that marine mammals would become directly entangled on the moorings themselves (primary entanglement) due to the large size of these cables and the tension involved (Benjamins et al. [2014], as described by Farr et al. [2021] and Maxwell et al. [2022]), but marine mammals and sea turtles would be at risk of secondary or tertiary entanglement. Secondary entanglement occurs when fishing gear becomes entangled in lines or cables, and this material subsequently entangles animals. Tertiary entanglement occurs when an animal is already entangled in gear, which becomes entangled in physical structures (Farr et al. 2021).

Studies show that baleen whales have the greatest risk of entanglement and toothed whales have the least risk due to their differing foraging habits; however, offshore wind farms functioning as hot spots of biological productivity can attract cetaceans, seals, and sea turtles for foraging, heightening the risk of entanglement for these species if snagged materials are present. Sea turtles, particularly juvenile sea turtles, become entangled in discarded fishing materials much more often than in land-based sources of debris (Duncan et al. 2017).

Species with large appendages, such as humpback whales or leatherback sea turtles, have a greater propensity for entanglement with ropes, lines, and cables that are used for fishing gear; increased biofouling of subsurface structures increases the likelihood of snagging of this fishing gear (Maxwell et al. 2022). Entanglement leading to mortality of marine mammals could pose a significant risk for population-level effects if highly endangered species are present in the areas around floating offshore wind farms. If floating wind farms were to have a larger spatial footprint than fixed-wind farms, this could increase the likelihood of displacement of marine mammals and sea turtles, as well as secondary and tertiary entanglement risk.

Noise

Noise from anthropogenic sources, such as the construction and operation of offshore wind turbines and increased vessel traffic, can result in the displacement or injury of marine organisms or otherwise affect their ability to communicate, forage, or interact with their environment (Bailey et al. 2010; Götz et al. 2009, as cited in Farr et al. 2021). Noise has the potential to physically injure marine mammals and sea turtles when reaching loud enough levels within the frequency hearing range for a certain amount of time to cause permanent harm caused by tissue damage or temporary injury caused by fatigue of cochlear hair cells and supporting structures (Southall et al. 2007). Marine mammals and sea turtles sensitive to noise may exhibit a stress response to loud noises. NARWs, as one of the world's most endangered species, likely experience chronic stress from continuous exposure to shipping noise; the cumulative effects of added anthropogenic noise sources could increase the chronic physiological stress levels in this species (Kraus et al. 2019). Chronic stress reduces immune and endocrine function, negatively affecting health and reproductive fitness and leaving them vulnerable to disease (Schick et al. [2013] and Rolland et al. [2017], as cited by Kraus et al. [2019]).

Behavioral responses of marine mammals to underwater noise can vary in severity, from no response at all to mild aversion, or panic, and flight (Southall et al. 2007). Humpback whales, green sea turtles, and loggerhead sea turtles have been reported to travel away from underwater seismic noise (McCauley et al. 2000). In feeding areas, avoidance can lead to reduced foraging time or the ability to find prey, resulting in reduced body condition and health (Kraus et al. 2019). Avoidance may cause marine mammals and sea turtles to move more frequently into areas of higher vessel traffic, such as shipping corridors. Depending on where and how far an animal displaces, it may be more susceptible to vessel strikes. Shallow-diving baleen whales, such as humpback whales and NARW, are at the highest risk of vessel strikes. These species have undergone a UME in the North Atlantic since 2016 and 2017, respectively, in which vessel strikes have been implicated as a major cause of mortality (NOAA 2023b). For NARWs, vessel strikes are considered a significant factor affecting the recovery of the species (Knowlton and Kraus 2001; Rolland et al. 2016; Pace et al. 2020). Vessel noise has also been shown to affect the foraging behavior of low-frequency cetaceans such as humpback whales, causing slower descent rates during foraging dives and fewer feeding events (Blair et al. 2016).

Because marine mammals rely on sounds for communication and for sensing their environment, marine noise has the potential to interfere with their ability to send and receive acoustic signals, and thus their ability to communicate, interact socially, forage, navigate, find prey or mates, and avoid predators (Clark et al. 2009). In the case of sea turtles, marine noise may interfere with the identification of appropriate nesting sites (e.g., David 2006; BOEM 2019). This type of interference is known as auditory masking. The susceptibility of a marine mammal to masking depends on the frequency bands in which they communicate and, on the frequency, loudness, and other attributes of the background noise (e.g., David 2006). For more information on potential risks to anthropogenic noise, refer to the Marine Mammals and Sea Turtles Study.

Vessel Traffic

Vessel strikes are a potential threat to a number of marine mammal and sea turtle species. Marine mammals and sea turtles are more likely to be struck and suffer mortality as a result of injuries when a vessel is large (i.e., 80 meters or longer) (Laist et al. 2001), traveling at high speed (13 to 15 knots or higher for cetaceans [Laist et al. 2001; Jensen and Silber 2004; Kite-Powell et al. 2007] and 10 knots for sea turtles [Hazel et al. 2007]), or located in a geographic bottleneck such as a narrow strait (Williams and O'Hara 2010). Additionally, vessels less than 65 feet (19.8 meters) in length accounted for 5 of the 12 documented lethal strike events in U.S. waters since 2008, demonstrating the significant risk this vessel size class can present to NARW (87 FR 46921). Travel speed restrictions of 10 knots or less have been shown to substantially reduce vessel strikes (Conn and Silber 2013; Crum et al. 2019), again indicating that speed is a major factor in the risk of vessel strikes. The risk of vessel strikes is positively correlated with a marine animal's behavior: the more time a species spends at the water surface, the higher the risk that animal has of interacting with vessels. Therefore, shallow-diving cetaceans and certain species and age classes of sea turtles may be more vulnerable to strikes than deep-diving cetaceans, for example, which spend less time at the surface.

The potential increase in vessel traffic to and from the port regions would also elevate the risk of ship strikes within the coastal regions. As mentioned above, humpback whales and NARW are particularly vulnerable to vessel strikes. Minke whales have also undergone an UME in the North Atlantic since 2017, in which vessel strikes have been implicated as an important cause, along with other human interactions (NOAA Fisheries 2023). Increased vessel traffic is also considered a threat to loggerhead, Kemp's ridley, and green sea turtles (NMFS and USFWS 1991; NOAA NMFS 2008; NMFS et al. 2011).

Unexploded Ordnance Detonation

In-water explosions, such as UXO detonation, produce a spherical shock wave that travels faster than the speed of sound in water (Popper et al. 2014). The extent of detonation and reach of effects depends on the size ("charge weight") of the UXO. The acoustic metrics and thresholds for effects depend on species and in some cases animal size and submersion depth (Hannay and Zykov 2022). No data is available regarding the effect of explosives on sea turtles, however the death of a small number of sea turtles resulting from the deconstruction of oil and gas structures in the Gulf of Mexico was reported, potentially related to rapid pressure changes on the air-filled lungs and other air-filled cavities such as the middle ear (Popper et al. 2014). Marine mammals are shown to be at the greatest risk of injury when at the same depth or slightly elevated above the explosion (Brand 2021). Injuries from the shock wave can include a sudden increase in cerebrospinal fluid pressure, middle and inner ear damage, and/or lung and intestinal hemorrhaging.

Most UXO along the U.S. coast are small, and locations of UXO disposal areas have already been excluded from potential OSW, significantly reducing the likelihood of identifying a UXO within the AoA (Middleton et al. 2021).

4.2.2.2 Birds and Bats Stressor Weights

For birds and bats, new structures and artificial lighting were the stressors that were consistently ranked the highest for potential impact across all three receptors. Introducing new structures and light sources poses long-term impacts on birds and bats due to the presence of offshore structures, which can affect their behavior, navigation, and breeding patterns. It can also potentially displace them from their preferred habitats. Population vulnerability is generally higher for rare species (e.g., endangered) but lower for abundant species. The severity of these impacts depends on the species and project characteristics.

New Structures

To be at risk of collision or displacement from new structures, bird and bat populations must be both exposed to OSW and vulnerable to collision or displacement (Goodale and Stenhouse 2016). Risk levels can vary both spatially and temporally. During operations and maintenance of the wind turbines and offshore substations, injury, and mortality from collision with new structures (turbines) represent the greatest potential risk to bats. Bats appear to be attracted to turbines for reasons that remain poorly understood, which could increase risk even if the number of bats offshore remains low (Guest et al. 2022). If bats occur in the AoA, they are expected to be migratory tree-roosting bats and are unlikely to be cave-hibernating bats. Migratory tree-roosting bats do not include federally- or State-listed species of concern.

The greatest potential risks to birds from new structures are collision and displacement. The siting of floating wind far offshore in the AoA may decrease risk to birds that use only coastal and nearshore environments, as compared to comparable wind facilities closer to shore (Garthe and Hüppop 2004; Farr et al. 2021). However, migratory seabirds and shorebirds may be displaced by offshore wind facilities under good visibility conditions, including some species listed as threatened and endangered under the ESA. Displacement has the potential to cause delayed but long-term indirect population impacts through habitat loss and/or increased energetic demands from diverting around facilities (Maxwell et al. 2022). Additionally, under poor visibility conditions (e.g., at night or during fog and adverse weather), collision risk increases for some species, including protected species.

It remains unclear whether increased perching opportunities for birds on offshore structures increases their risk of collision from the use of wind energy areas, or whether there is a benefit of resting locations in reducing energy expenditure (Ronconi et al. 2015; Maxwell et al. 2022). However, new above-water structures remain the primary direct stressor expected to affect birds negatively via collision with turbines (Maxwell et al. 2022) and questions remain about offshore wind infrastructure serving as a demographic sink (Delibes et al. 2001), that is, birds are attracted for an apparent advantage, but the attraction leads to higher fatality rates.

Entanglement (secondary) of birds with marine debris may also occur from the accumulation of derelict gear around new structures such as floating wind cables (Benjamins et al. 2014; Farr et al. 2021). These below-water stressors potentially have negative effects on birds, though they are not well documented.

Artificial Lighting

Above water, attraction to lighting during nighttime construction or vessel activities could temporarily increase collision risk or mortality resulting from exhaustion associated with light entrapment (Montevecchi 2006; Fox and Petersen 2019; Maxwell et al. 2022). The attraction of seabirds to light that results from their disorientation (i.e., “phototaxis”), can inflate collision rates when flux densities increase within the RSZ (Rodríguez et al. 2017; Deakin et al. 2022). Artificial lighting on wind turbine decks, offshore substations, and construction or maintenance vessels may serve as an attractant to bats, though significant uncertainty remains about bat use far offshore. Some turbines may be lit with aviation lighting; however, aviation lighting has not been found to influence bat collision risk at onshore facilities in North America (Arnett et al. 2008). Bats may also investigate the turbines for potential roosting opportunities or use lighting on structures for navigational purposes while migrating (Stantec 2016). If bats are present in the AoA, bats may more likely be attracted to wind turbines than displaced due to the presence of lighting.

4.2.2.3 Fish and Fisheries Stressor Weights

For fish and fisheries, new structures, bottom disturbance, and changes to atmospheric/oceanographic dynamics were the stressors that were consistently ranked the highest for potential impact across all three receptors. Risk, as defined in the Fish and Fisheries Data Aggregation Study, is the potential for fish and fisheries resources to experience negative impacts when exposed to specific stressors associated with deepwater OSW activities. At this level of the analysis, the relative degree of impact was assessed by considering the likelihood that the potential stressor and receptor might co-occur spatially and temporally, as well as the potential vulnerability of the receptor to the stressors.

New Structures

The Fisheries receptor was rated highest for this stressor. The commercial fishing community has expressed concern that the presence of floating offshore wind facilities may create areas of the ocean that cannot be fished. If this proved true, there could be financial loss to the commercial fishing industry and associated industries, including port communities, shoreline services, and the tourism industry. The placement of wind turbines and cable arrays has the potential to reduce the availability of fishing locations, especially with respect to mobile fishing gear (e.g., dredges) and long-line fishing gear (NOAA 2023a). Gear loss and damage due to entanglement or “hanging up” with offshore wind platforms and array cables may cause additional cost for fishing operations and leads to revenue losses. Fishing vessels may choose to avoid wind turbine platforms and cable arrays, which increases fishing pressure in other areas of the ocean (NOAA 2023a). Based upon stakeholder feedback, other major concerns of the fishing industry include potential collisions with wind turbines, decreased maneuverability when fishing and navigating around offshore wind facilities, leading to safety concerns, potential radar interference, the decreased availability of port space, reduced quotas, and the possibility of additional fishing regulations to mitigate impacts to fish and fish habitat potentially caused by OSW.

For fish species and habitat, studies have shown that structure-oriented marine species utilize the habitat provided by the foundations, moorings, and cables of wind platforms and are often found living on the submerged structure and within the surrounding environment (Farr et al. 2021; Roach et al. 2022; NOAA 2023a). The moorings and anchors used on floating offshore wind platforms provide attachment points for many invertebrate species and provide refuge and foraging opportunities for fish and shellfish (Farr et al. 2021; Roach et al. 2022). However, one study of blue mussels has shown that filter feeders consume bivalve larvae (LeBlanc et al. 2007). The impact of OSW on clam and scallop survival is currently unknown because no studies have focused on either group of shellfish (NOAA 2023a).

The addition of wind platforms and structural habitat in the offshore marine environment may cause fish communities to shift their preferred locations to new habitat provided by offshore wind platforms and create declines in fish abundance at locations they once preferred (Methratta et al. 2023). Small fish that prey upon invertebrates are often food for fish at higher trophic levels, so the increased availability of these forage species around offshore wind platforms can impact the health and survival of larger marine predators (NOAA 2023a).

The commercial fishing community has expressed concern that a greater abundance of predators within the vicinity of offshore wind platforms may pose additional risk to the survival of the early life stages of some species, such as juvenile lobsters (NOAA 2023a). Other concerns include increased predation of lower-trophic level fish that are concentrated around the submerged wind platform structure and increased fishing pressure on a variety of species that frequent the platforms (including predators) (Gill et al. 2020). Offshore structural habitat may attract some species, such as black sea bass, but reduce habitat availability for species requiring soft substrates, such as Atlantic surf clam (*Spisula solidissima*) (Farr et al. 2021; NOAA 2023a). Several of these species have been designated EFH within the AoA. One concern within both the scientific and fishing communities is the effect of offshore wind platforms on the survival and establishment of non-native species (Gill et al. 2020; Farr et al. 2021). Changes to the marine environment, including habitat conversion from soft-sediment to hard-bottom, could potentially allow non-native species to survive and become established (Viola et al. 2018; NOAA 2023a).

Recreational anglers have noted an increase in the diversity of fish species that occur within the vicinity of offshore wind platforms, noting that new species have been observed that were not present prior to construction of the turbines (ten Brink and Dalton 2018). For example, the presence of cod has been noted alongside the Block Island Wind Farm by anglers, which were generally uncommon in the fishing waters prior to the platform installation (ten Brink and Dalton 2018). Other species noted by anglers that appear to be attracted to the structural habitat provided by the Block Island Wind Farm include summer flounder (*Paralichthys dentatus*), black sea bass (*Centropristis striata*), striped bass (*Morone saxatilis*), tautog (*Tautoga onitis*), mahi mahi (*Coryphaena hippurus*), triggerfish (*Balistidae* spp.), and sea robin (*Triglidae* spp.) (Brink and Dalton 2018).

Bottom Disturbance

Demersal fish species are expected to be primarily impacted by benthic disturbances. Fish species living within the bottom water and benthic habitat will be subjected to changes in the seabed that occur during pile driving (fixed wind platforms), excavation and dredging, and the anchoring and mooring of floating wind platforms and construction vessels. Impacts to bottom habitat include physical disturbance of the seabed, sediment plumes or turbidity, and the release of toxins from the sediment generated from construction activities.

Additionally, the mooring lines used to secure floating offshore wind platforms to anchors on the seabed can be manipulated by currents, tide cycles, and waves, which may cause seabed scouring and sediment suspension into the water column (Maxwell et al. 2022). Demersal species that utilize benthic habitat that could be impacted by scouring and seabed disturbance include skate species, summer flounder, halibut, lobster, crab, and scallops.

Atmospheric/Oceanographic Dynamics

A recent study has shown that offshore turbine platforms can cause changes to hydrodynamics and potentially impact oceanic processes (Daewel et al. 2022). These changes to oceanographic dynamics could potentially impact the cold pool, a prominent seasonal stratification process. Changes to seasonal stratification could impact phytoplankton biomass, negatively affecting the survival of fish larvae, which depend upon phytoplankton for food. In turn, this could negatively impact the fisheries associated with those fish species. Stressors to fish on the local scale that could result from changes to hydrodynamic processes include temperature changes, nutrient availability, vertical mixing, and excessive turbulence; however, studies of these stressors specifically related to OSW are sparse and additional study is needed (van Berkel et al. 2020).

Changes to water column mixing have been noted within the vicinity of offshore wind platforms as eddies and turbulence occur downstream of turbines (van Berkel et al. 2020). Changes to upwelling can be localized or occur on regional scales, depending upon the size and location of the wind farm (van Berkel et al. 2020). Offshore wind platforms create changes to temperature and salinity within the water column and affect upwelling zones through changes to vertical mixing caused by wind wakes (van Berkel et al. 2020; Christiansen et al. 2022). Impacts on coastal upwelling can cause changes to primary production, which may affect the abundance of forage species at higher trophic levels. Recent research has suggested that water column mixing influences the aggregations of forage species that provide food at higher tropic levels (Goetsch 2023).

One study in the North Sea has indicated the potential for trophic cascades due to changes in phytoplankton biomass following the installation of offshore wind platforms and subsequent hydrodynamic alterations. This study additionally indicated that hydrodynamics play an important role in larval transport and the recruitment of some demersal species (Daewel et al. 2022, NOAA 2023a). Given the importance of hydrodynamics for larval transport, changes to hydrodynamics can result in larvae settling within habitat that is unsuitable for survival. According to NOAA (2023a), the study suggests that future OSW within the region could intensify the changes observed in larval dispersal.

4.2.2.4 Benthic Habitat Stressor Weights

For benthic habitat, bottom disturbance and new structures were the stressors that were consistently ranked the highest for potential impact across all six receptors, with changes in water quality and changes to atmospheric/oceanographic dynamics also being important. The greatest risk factor to benthic receptors, with many being slow-growing habitat formers, is likely to be impacts from bottom disturbance, as a result of activities such as trawling during pre-construction surveys, or direct impacts from anchors, chains, or seafloor infrastructure during or after construction. Bottom disturbance may also resuspend benthic sediments and potentially smother hard bottom substrates, resulting in their conversion to soft bottom habitats. Introduction of new structures may also represent a relatively moderate risk to corals due to the added potential impact of colonization by new organisms on the newly available hard bottom (the artificial reef effect), which may allow competitive or non-native species to invade existing communities.

Bottom Disturbance

As sessile organisms, the primary risk to the proposed benthic receptors is direct contact of installed structures and equipment with the seafloor (Halpern et al. 2007) during the placement of anchors, mooring systems, export and inter-array cables, and fixed structures (e.g., for substations within shallower depth zones). Direct contact with the proposed benthic receptors has long-term and habitat-wide implications that may persist for periods of up to a decade or more (Williams et al. 2010; Huvenne et al. 2016; Morrison et al. 2020) due to the fragility, structure-forming nature, limited recruitment, and slow growth rates of receptors such as deep-sea coral, deep-sea sponges, and sea pens (Hall-Spencer et al. 2002; Althaus et al. 2009; Neves et al. 2015).

Clark et al. (2016) reviewed multiple studies that reported significant damage, and in some cases, widespread loss of deep-sea coral fauna due to trawling, as well as impacts from resuspension of sediments and negative impacts on habitat quality and ecosystem function. In many severe cases, fishing gear caused seabed disturbances that resemble forest clearcutting (Watling and Norse 1998).

Cable arrays between wind turbines and onshore power stations also represent a sizable physical benthic footprint in addition to anchor and mooring systems, with distances between turbines of up to approximately one mile, and distances to shore that may exceed several hundred miles. These inter-array cables may also be weighted or buried between turbines, reducing potential for movement-based contact but increasing the overall footprint of the cable arrays. While these approaches may limit the movement of power cables, they can also increase the immediate impacts around cables by disturbing soft sediments during the digging of trenches, which can increase sediment suspension and turbidity, or by placing concrete mattresses over hardground sites, smothering benthic habitats.

New Structures

On the seafloor, introduced structures primarily include anchor systems, scour protection material (boulders or other material placed around anchors), export cables and cable protection (e.g., concrete mattresses), and fixed structures (e.g., fixed high-voltage direct current [HVDC] substation platforms). The placement of new structures would impart a direct bottom contact impact if placed in the general area of and/or directly upon benthic receptor species.

New structures (e.g., suction anchors, drag embedded anchors) have the potential for hydrodynamic scouring of the seafloor, resulting in erosion of pre-existing sediments and in faunal communities and the potential conversion to hard bottom grounds. Most anchor systems require soft substrates, such as clay or mud, and thus these anchor structures and/or their associated mooring systems (especially catenary moorings that can contact the seafloor) inherently present sediment scour risk to softbottom benthic habitats. Although scour protection structures such as boulders or concrete blocks are commonly placed around anchors and other seafloor structures to mitigate these effects, scour protection materials themselves will permanently convert softbottom habitats to hard bottom habitats and may exacerbate changes in faunal communities.

For all introduced structures, changes to existing benthic communities can occur via the colonization of organisms on the surfaces of structures. This colonization of anthropogenic structures, including pylons, anchors, and power cable structures, can act as an artificial reef supporting distinct assemblages of organisms throughout the water column, including mussels, macroalgae and anemones, as well as associated sessile macrofauna, which can serve to increase biomass at the new structure site by 4,000-fold (Rumes et al. 2013). As part of the increased settlement of these structures, they may also serve as islands for the introduction of opportunistic and non-native species that may outcompete local species, allowing them to "hop" between these islands, increasing the spread of invasive species into new ecosystems (e.g., Sammarco et al. 2004; Glasby et al. 2007; Meyer et al. 2017).

4.2.3 Level 3—Stressor by Phase Weights

The lowest set of weights partitioned the stressors (Level 3) into the four defined construction phases of OSW (Level 4). Like the Level 1 and Level 2 weights, because the relative potential impacts of each stressor vary between the different resource groups during each phase of OSW, the responses from each respective SME for each resource group have been summarized separately.

A summary description of each stressor relative to the construction phases is presented below, derived from the assigned weights, and interpreted from the rationales provided by SMEs that are informed by literature. Refer to the corresponding environmental desktop studies that accompany this study for a more detailed description of the stressors relative to each particular receptor and construction phase.

4.2.3.1 Marine Mammal and Sea Turtle Stressor by Phase Weights

For marine mammals and sea turtles, most of the potential stressors were accounted for in the construction phase, with the post-construction and decommissioning phases being important as well. The pre-construction phase was the least impactful, with a notable exception for UXO detonation, which is more likely to occur during this phase of OSW.

During the construction phase, the potential impacts on marine mammals and sea turtles were rated higher than in the post-construction phase. Construction noise, particularly from pile driving, can disturb marine mammals in the vicinity of the project. Pile driving, particularly impact pile driving, is one of the noisiest construction-related activities undertaken in marine environments today (Madsen et al. 2006; Erbe 2009). Piles for offshore wind turbine foundations (fixed-foundation offshore wind turbines) or anchors (floating offshore wind turbines; Maxwell et al. 2022) may be installed via impact hammer, vibratory hammer methods, or both.

Post-construction stressors that were rated higher were new structures, changes to atmospheric and oceanographic dynamics and scouring around seafloor structures. New structures can affect marine mammals and sea turtles by displacement, or potentially fragmenting their migratory habitat or critical habitat, which may require additional energy and a loss of fitness (Harwood 2001; Farr et al. 2021). If displacement does occur, marine mammals or sea turtles could experience reduced body condition and health if foraging time is increased, potentially heighten the risk of vessel strikes if marine mammals or sea turtles move into more trafficked areas or affect migratory pathways. New structures also pose a risk of entanglement to marine mammals and sea turtles, with the risk of secondary (entanglement with fishing gear or debris caught in cables) or tertiary entanglement (when an animal is already entangled in gear and becomes entangled on physical structures [Farr et al. 2021])—which is the greatest for floating structures, as described in section 4.2.2.1.

4.2.3.2 Birds and Bats Stressor by Phase Weights

For birds and bats, the potential stressors were generally evenly distributed across the four phases of development, with slightly more impact accounted for in the construction and post-construction phases, and the remainder more evenly distributed among the three other phases. Birds and bats have the potential to be adversely affected due to the presence of new structures during the post-construction (operational) phase. They are not likely to be adversely affected by the pre-construction phase; therefore, stressor weights within this phase have insignificant effects on overall sensitivity. Additionally, offshore wind projects situated away from the coast are expected to have a lower impact on birds and bats than nearshore projects. However, there is much uncertainty about the distribution of birds and bats in Zone 3 of the AoA, due to the lack of survey data collected there.

Noise may temporarily occur during all four phases of development, for example, from vessel traffic, construction activities, post-construction, and decommissioning; however, it is unlikely to substantially impact bats given its attenuation and limited propagation (Guest et al. 2022). Additionally, increased vessel traffic during all four phases of offshore wind energy development, particularly during high-volume construction activity, presents a risk of temporary displacement for rafting birds from foraging areas, such as loons and sea ducks (Schwemmer et al. 2011; Kelsey et al. 2018).

Bird species may be attracted to construction equipment, new structures, and/or artificial lighting during construction, post-construction, and decommissioning (Croll et al. 2022). Above water, attraction to lighting during nighttime construction or vessel activities could temporarily increase collision risk or mortality resulting from exhaustion associated with light entrapment (Montevecchi 2006; Fox and Petersen 2019; Maxwell et al. 2022). The attraction of seabirds to light that results from their disorientation (i.e., "phototaxis"), can inflate collision rates when flux densities increase within the RSZ (Rodríguez et al. 2017; Deakin et al. 2022).

4.2.3.3 Fish and Fisheries Stressor by Phase Weights

For fish and fisheries, phases that were rated as highest were construction, post-construction, and decommissioning.

The stressor ranked the highest in the pre-construction phase was UXO detonation. The noise generated by underwater explosions can cause physical injury and mortality to fish (Popper et al. 2014; Hannay and Zykov 2022). Damage to the swim bladder and gastrointestinal tract has been documented in the literature, and mortality can occur. However, most UXO along the U.S. coast are small, and locations of UXO disposal areas have already been excluded from potential OSW, significantly reducing the likelihood of identifying a UXO within the AoA (Middleton et al. 2021).

Stressors ranked the highest during the construction phase included bottom disturbances, changes in water quality, and vessel traffic. Bottom disturbances impacting fish and fisheries will vary depending upon the construction activity, time of year, and composition of substrate present at a particular construction site (Bergstrom et al. 2013; NYSERDA 2017b). Seabed preparation for cable installation (fixed platforms and substations) and dredging activities will physically alter benthic habitat by disturbing substrate and pushing or relocating boulders (BOEM 2022b). Boulder relocation can disturb fish and shellfish habitat, but it also may potentially impact fishing activities since boulders pose a risk for mobile fishing gear and could cause loss or damage to gear. Dredging activities can also be harmful to demersal fish species and the early life-stages of fish. To date, most studies on the impacts of dredging have focused on the risks associated with suspended sediments (e.g., reduced dissolved oxygen and burial).

Water quality can also affect fish, fish habitat, and fisheries during the construction of footings for fixed offshore wind platforms. The placement of anchors that are used to secure floating platforms, and the placement of underwater power cables can create sediment plumes and release toxins that were trapped within the sediment (Wegner et al. 2017).

Vessel traffic/vessel strikes during the construction phase are a concern for marine species that spend time at or near the surface and primarily impact marine mammals because fish exhibit faster reaction times or tend to avoid moving vessels entirely (NYSERDA 2017b; Maxwell et al. 2022). The Atlantic sturgeon is one fish species of concern regarding vessel strikes; however, most documented vessel strikes of Atlantic sturgeon occur within rivers and estuaries and are expected to be more common in narrow waterways, with shallow water, where the species has difficulty avoiding vessels (Brown and Murphy 2010; Balazik et al. 2012; NYSERDA 2017b). Potential impacts to fisheries from vessel traffic include short-term travel delays and congestion, given the increased presence of marine vessels that are necessary for the construction phase of the project. Fishing and non-fishing vessels will be restricted to specific travel routes to avoid OSW construction. Delays and congestion will be temporary and presumably localized. The number of marine vessels associated with the OSW project will decrease when construction is completed. Construction of floating offshore wind platforms and cable arrays is also expected to create complications with fishing operations (Maxwell et al. 2022).

As described in section 4.2.2.3, the fishing industry is concerned about the presence of offshore wind structures. The post-construction phase would have the highest impact on the fisheries receptor, with post-construction impacts also anticipated for the other two receptors. Layer weighting did not take into consideration where potential lease areas could be, nor did it consider offshore wind configuration, layout, or particular technologies. All of these factors are important and may affect the feasibility of fishing and result in greater or less risk to fisheries.

All types of fishing gear are expected to be limited by floating offshore wind technology due to entanglement risk; however, complications with mobile gear such as trawl nets and dredges is a primary concern (Maxwell et al. 2022). Fishing vessels are likely to avoid floating wind turbines and cable arrays to prevent hangups, entanglement, and gear loss. For this reason, OSW has the potential to create areas of the ocean that cannot be fished; depending upon the location and spacing of wind turbines and cable arrays, portions of historical fishing grounds could be lost. As the siting of future offshore wind platforms takes place and the use of specific technologies is refined during future steps of development, the risk to fisheries could increase or decrease.

Alternatively, post-construction phase in-water structures provide various species of fish, shellfish, and other invertebrates with complex habitat; some of those species (e.g., bivalves) filter water and provide forage to other marine species (Raoux et al. 2017; ten Brink and Dalton 2018; Roach et al. 2022). The "reef effect," documented in the literature, has been shown to increase habitat availability for a wide range of species such as scup, cod, black sea bass, and shellfish (Raoux et al. 2017; ten Brink and Dalton 2018; Roach et al. 2022). However, food web functionality can be impacted by the artificial reef effect produced by the introduction of submerged structures into the marine environment. Researchers have noted that high concentrations of filter feeders can lead to an increase in benthic organic matter as individuals excrete waste, die, and decompose (Aurore et al. 2017). More research is needed to understand the long-term impact of habitat conversion on marine species as OSW takes place (NOAA 2023).

Additional impacts during the post-construction phase include hydrodynamic processes potentially impacting oceanic processes (Daewel et al. 2022). Changes to oceanic processes (e.g., upwelling) can be localized or occur on regional scales, depending upon the size and location of the wind farm van Berkel et al. 2020). It is unclear how prey species aggregations may be impacted by changes to water column mixing and subsurface processes that are caused by the addition of wind platforms to the marine environment.

Stressors to fish and fisheries that could occur during the decommissioning phase of offshore wind facilities include potential habitat conversion related to the removal of new structures, noise, vessel traffic and changes in water quality.

As discussed above for the post-construction phase, the addition of hard structure to the marine environment will create habitat for structure-oriented species (Lindeboom et al. 2011; Aurore et al. 2017; ten Brink and Dalton 2018; Farr et al. 2021 NOAA 2023a). As temporary in-water structures are removed during the decommissioning phase of offshore wind projects, the new habitat that was created by these structures is disturbed and, in some cases, entirely disappears (Miller et al. 2013; Synthesis of Environmental Effects Research [SEER] 2022). Partial decommissioning is one option that leaves some in-water structures intact and preserves the “artificial reef effect” created by these structures (SEER 2022). The net effect of offshore wind structures should be evaluated during decommissioning to assess the positive and negative impact of structure removal on fish and fisheries.

4.2.3.4 Benthic Habitat Stressor by Phase Weights

For benthic habitat, most of the potential stressors were accounted for in the construction and post-construction phases, generally associated with bottom disturbance, new structures, changes in atmospheric/oceanographic dynamics, and changes in water quality.

OSW projects require large-scale introduction of myriad structures, which will unavoidably impact benthic communities. Impacts in the form of habitat disturbance might occur during the pre-construction phase due to seabed preparation techniques, including sand-wave leveling or boulder/debris removal prior to installation of mooring systems, although no studies have examined the direct impacts of these procedures on benthic fauna. However, impacts from vessel anchors are expected to be most severe during construction and decommissioning phases due to the anticipated larger number of vessels and extended period of anchoring during these phases.

Bottom disturbance from vessel anchoring is anticipated to be minimal during the post-construction/ operational phase, due to the ability of vessels to tie off to offshore wind energy platforms, reducing the requirement for bottom anchoring by vessels.

The long timescales suggested for the recovery of deep benthic receptors must be kept in mind, as any damage because of offshore wind energy development and operation may persist throughout the operational life of the platform, with further potential for contact-mediated damage to recovering reef sites during decommissioning further extending recovery periods.

4.3 Sensitivity Results

Once all the receptor data sets were prepared and the weights determined, as described in the foregoing sections, the data and weights were combined to produce a set of standard map sets that visualize the sensitivity results in the AoA from a variety of different perspectives.

The following sub-sections are generally organized by the framework hierarchy shown in Figure 6, whereby the overall (Level 1) sensitivity across the entire AoA is presented first for all resource groups. Then, sensitivity maps are provided for each resource group in a standard presentation:

- Receptor: The sensitivity map of each receptor in the resource group.
- Resource:
  - Total sensitivity map for the resource group (i.e., all receptors in the resource group combined with weights applied).
  - The percent data coverage map for the resource group.
- Stressor: The sensitivity map for the resource group for each stressor.
- Phase: The sensitivity map for the resource group for each phase.

This standardized presentation facilitates review and comparison between resource groups and focuses on the key objectives of the study.

4.3.1 Marine Mammals and Sea Turtles

4.3.1.1 Sensitivity by Receptor

Figure 16 depicts the sensitivity of the high-frequency cetacean receptor group. Areas of higher risk were identified in the northern portion of Zone 1, with comparatively less risk in Zone 2.

Figure 16. High-Frequency Cetaceans Sensitivity

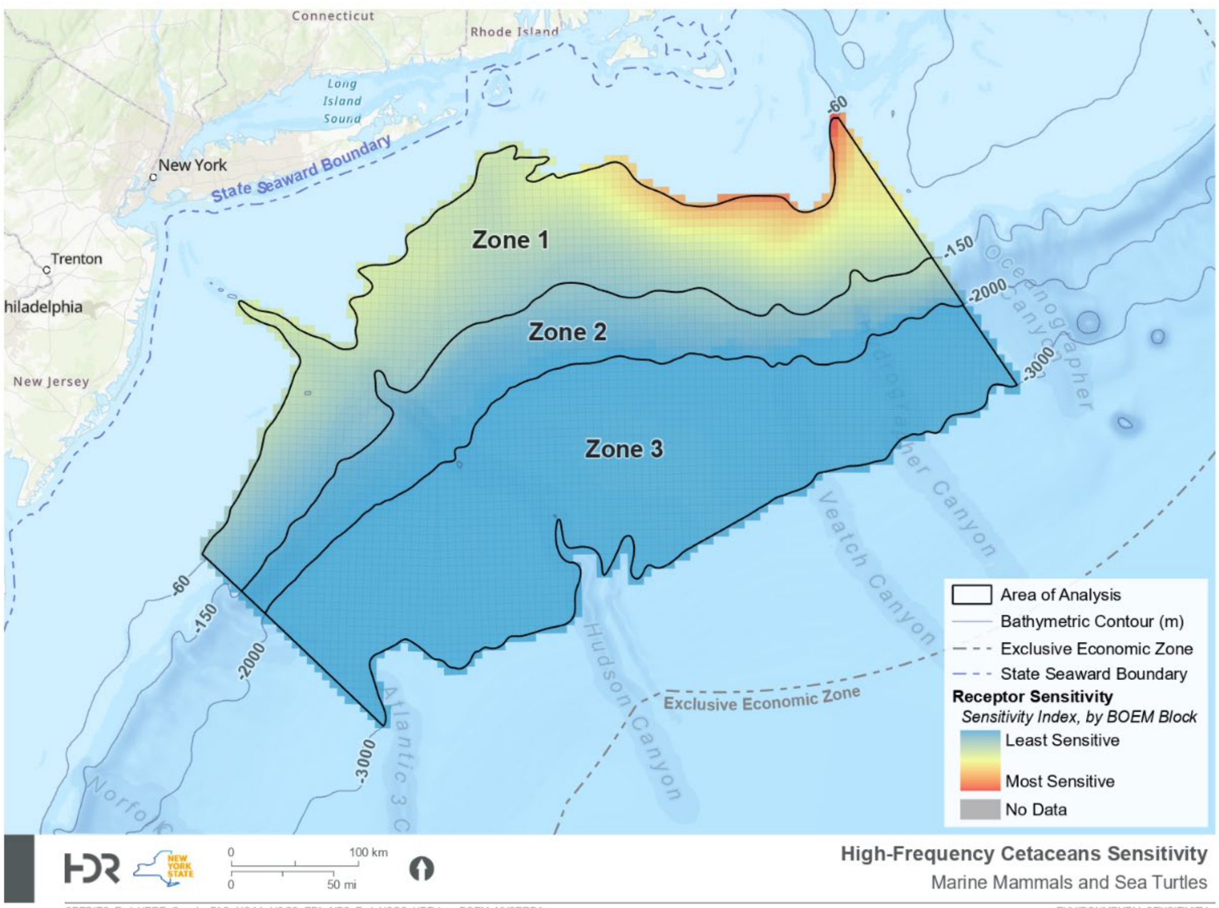


Figure 17 depicts the sensitivity of the mid-frequency cetacean receptor group. Areas of higher risk were identified predominantly in Zone 2, with comparatively less risk in Zones 1 and 3.

Figure 17. Mid-Frequency Cetaceans Sensitivity

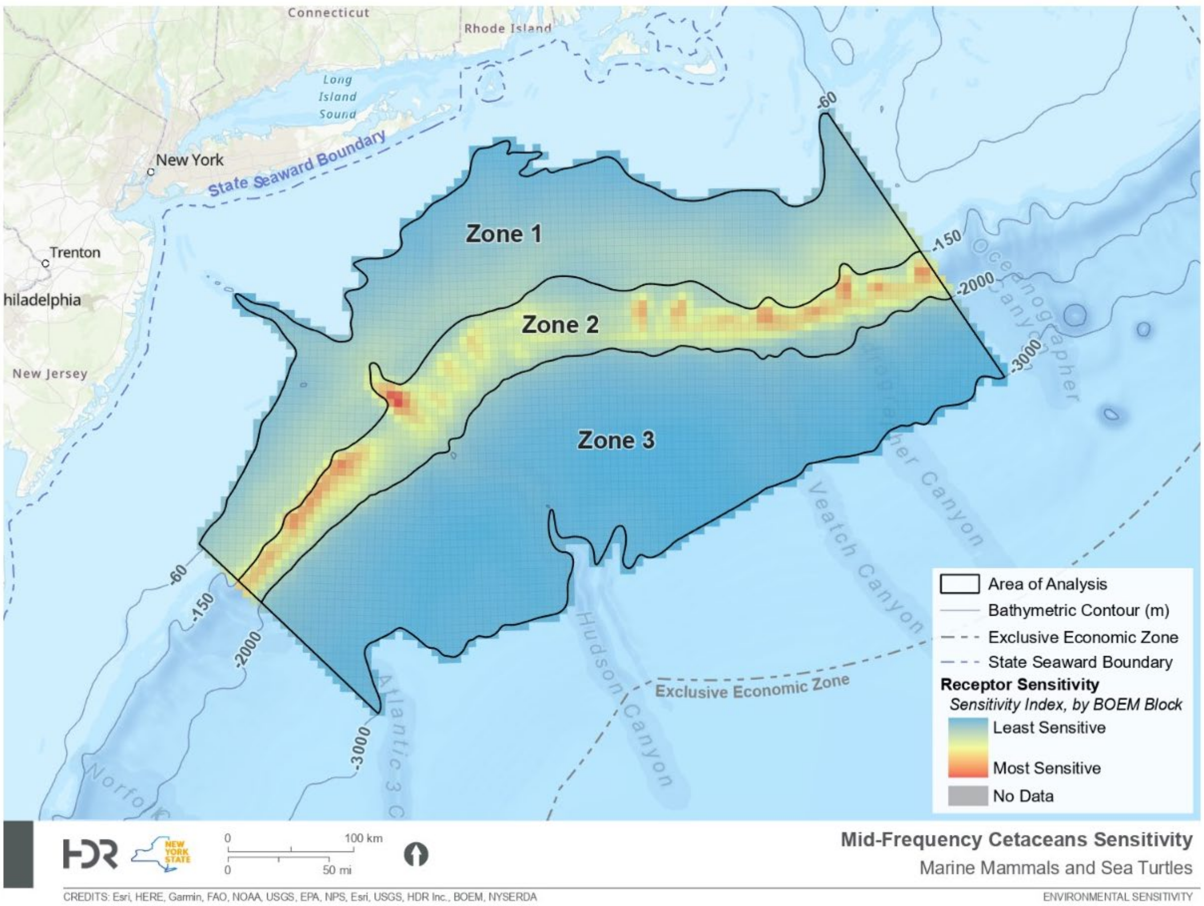


Figure 18 depicts the sensitivity of the low-frequency cetacean receptor group. Areas of higher risk were identified predominantly in the northeast corner, Hudson Canyon in Zone 1, and along the shelf break in Zone 2. Roughly half of Zone 2 had comparably high risk but decreased as it moved farther into Zone 3.

Figure 18. Low-Frequency Cetaceans Sensitivity

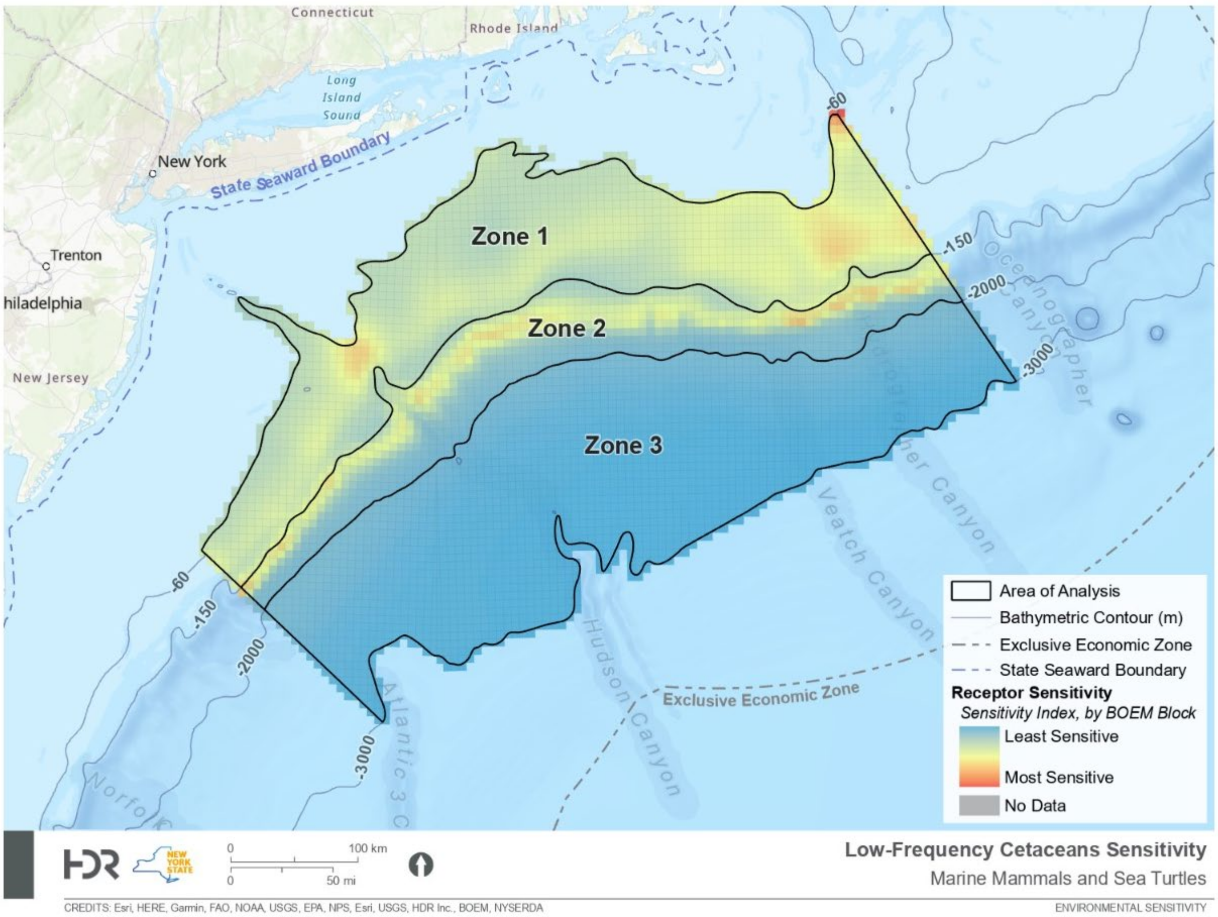


Figure 19 depicts the sensitivity of the seal receptor group. Areas of higher risk were identified predominantly along the northern edge of Zone 1, with comparatively less risk in Zones 2 and 3.

Figure 19. Seals Sensitivity

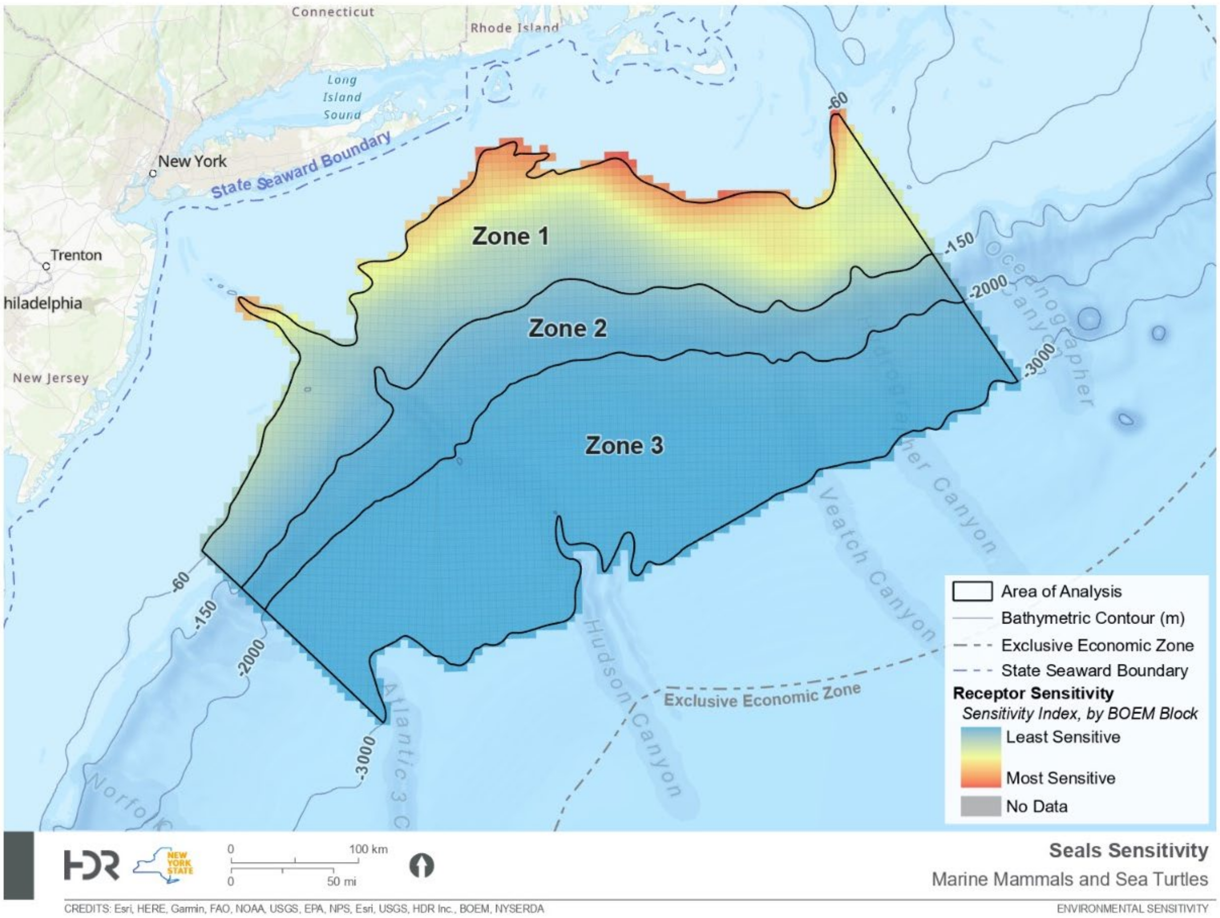


Figure 20 depicts the sensitivity of the NARW receptor group. Areas of higher risk were identified predominantly in the northeast corner of Zone 1. An area of moderate risk was identified in the center of Zone 1. Zone 2, and Zone 3 had comparably lower risks throughout.

Figure 20. North Atlantic Right Whale Sensitivity

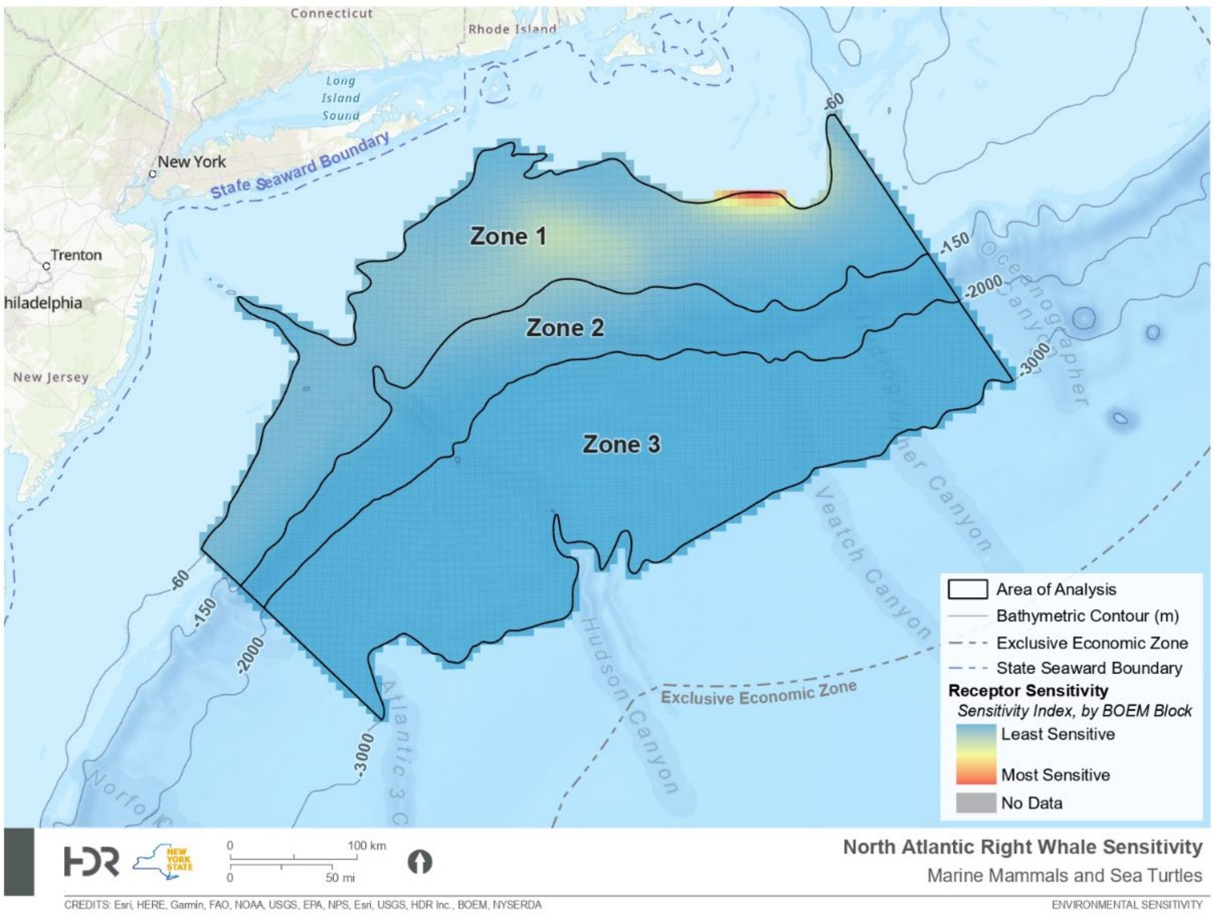


Figure 21 depicts the sensitivity of the Other Marine Mammals of Special Conservation Status receptor group. Areas of higher risk were identified predominantly in the northern portion of Zone 1, with decreasing risk in Zones 2 and 3.

Figure 21. Other Marine Mammals of Special Conservation Status Sensitivity

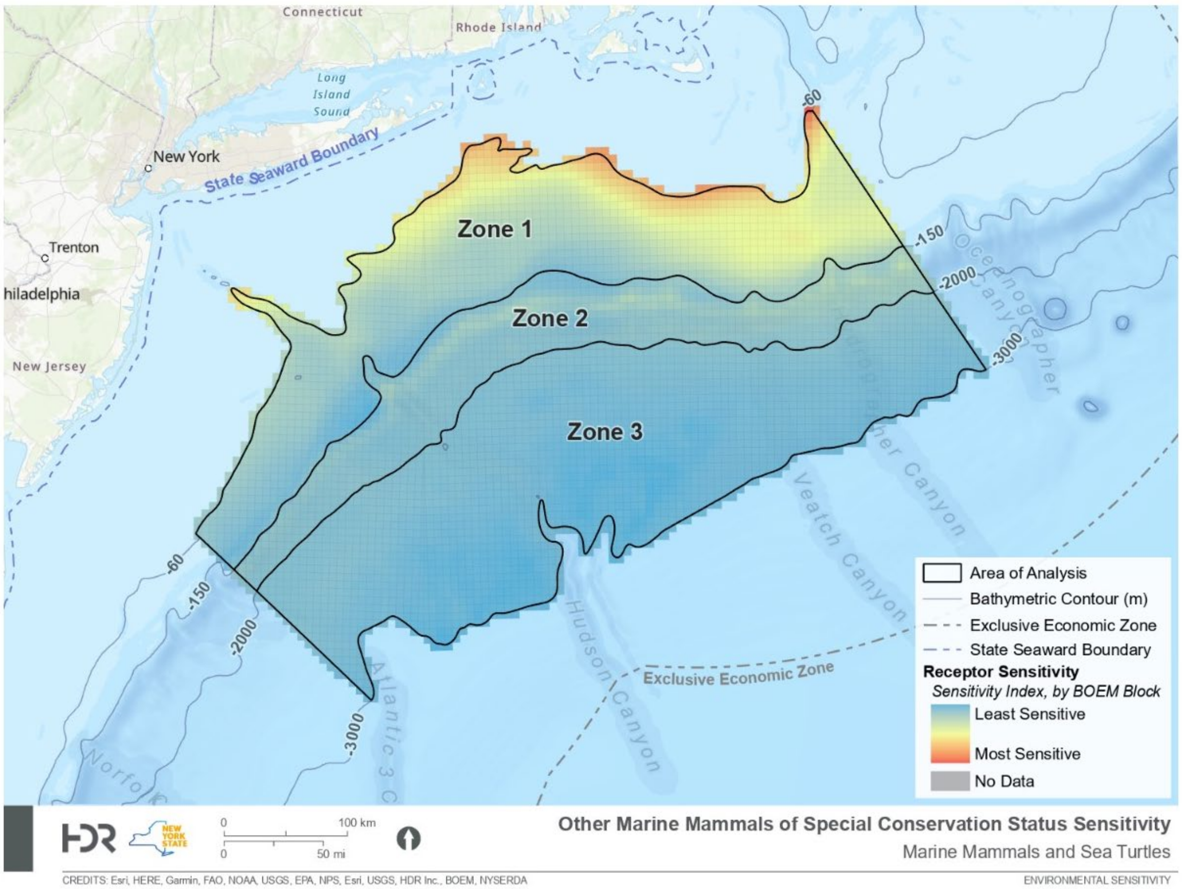


Figure 22 depicts the sensitivity of the deep-diving cetacean receptor group. Areas of higher risk were identified predominantly in Zone 2, along the shelf break, and within Hudson Canyon. Zone 3 and other portions of Zone 2 (corresponding to areas of deep water) were identified as having moderate risk. Zone 1 had the least risk relative to these two zones.

Figure 22. Deep-Diving Cetaceans Sensitivity

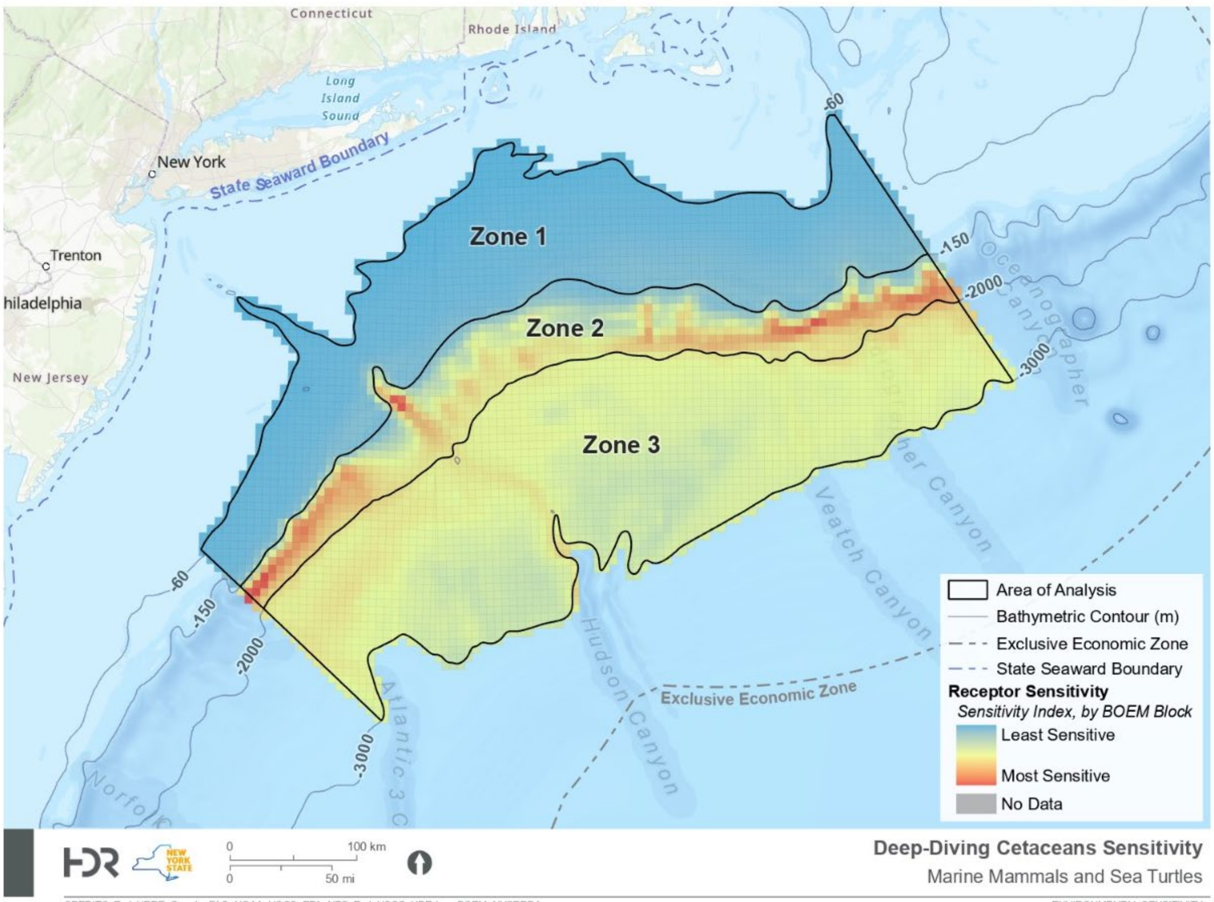


Figure 23 depicts the sensitivity of the shallow-diving cetacean receptor group. Areas of higher risk were identified in predominantly Zone 2 near the shelf break and within canyons. Zone 1 had a low to moderate risk, and Zone 3 had the lowest risk of the three zones.

Figure 23. Shallow-Diving Cetaceans Sensitivity

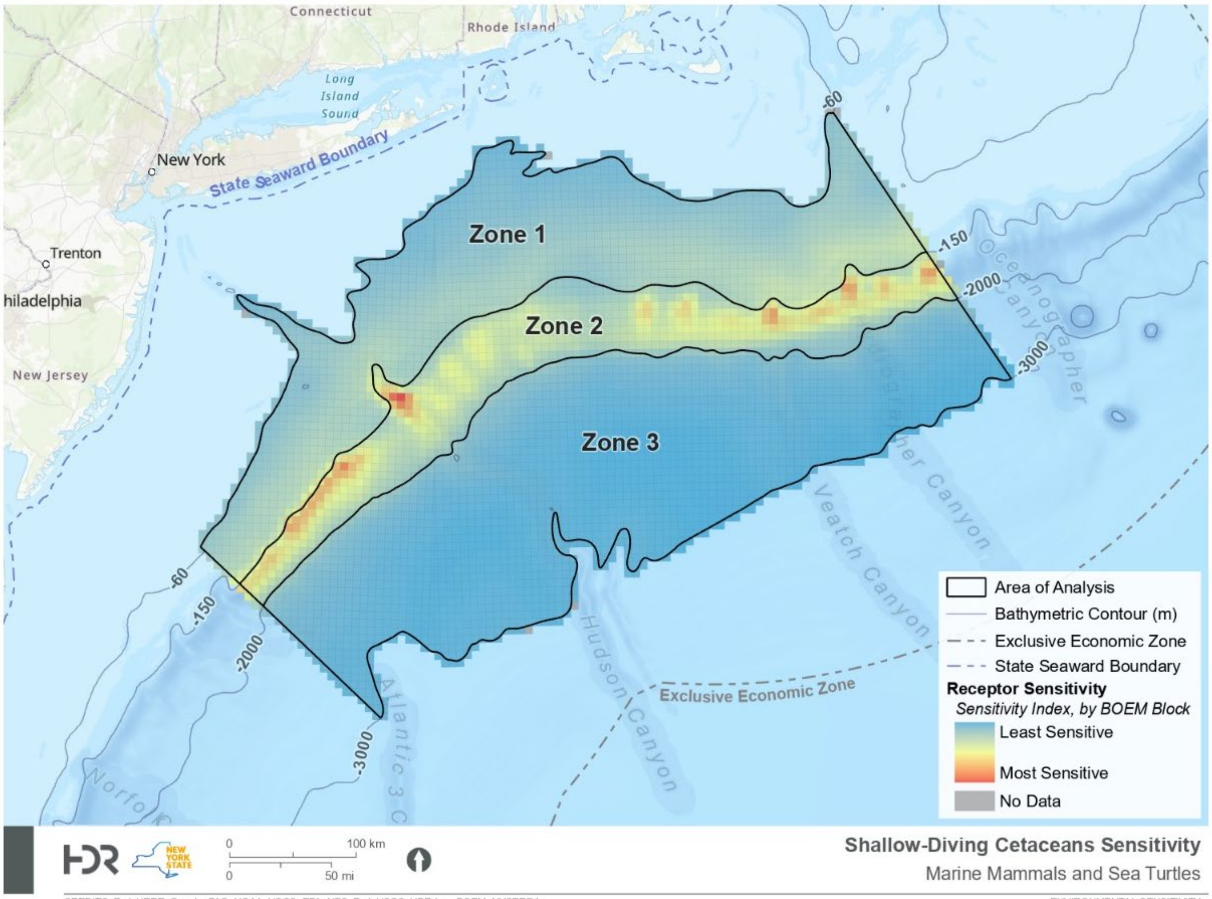
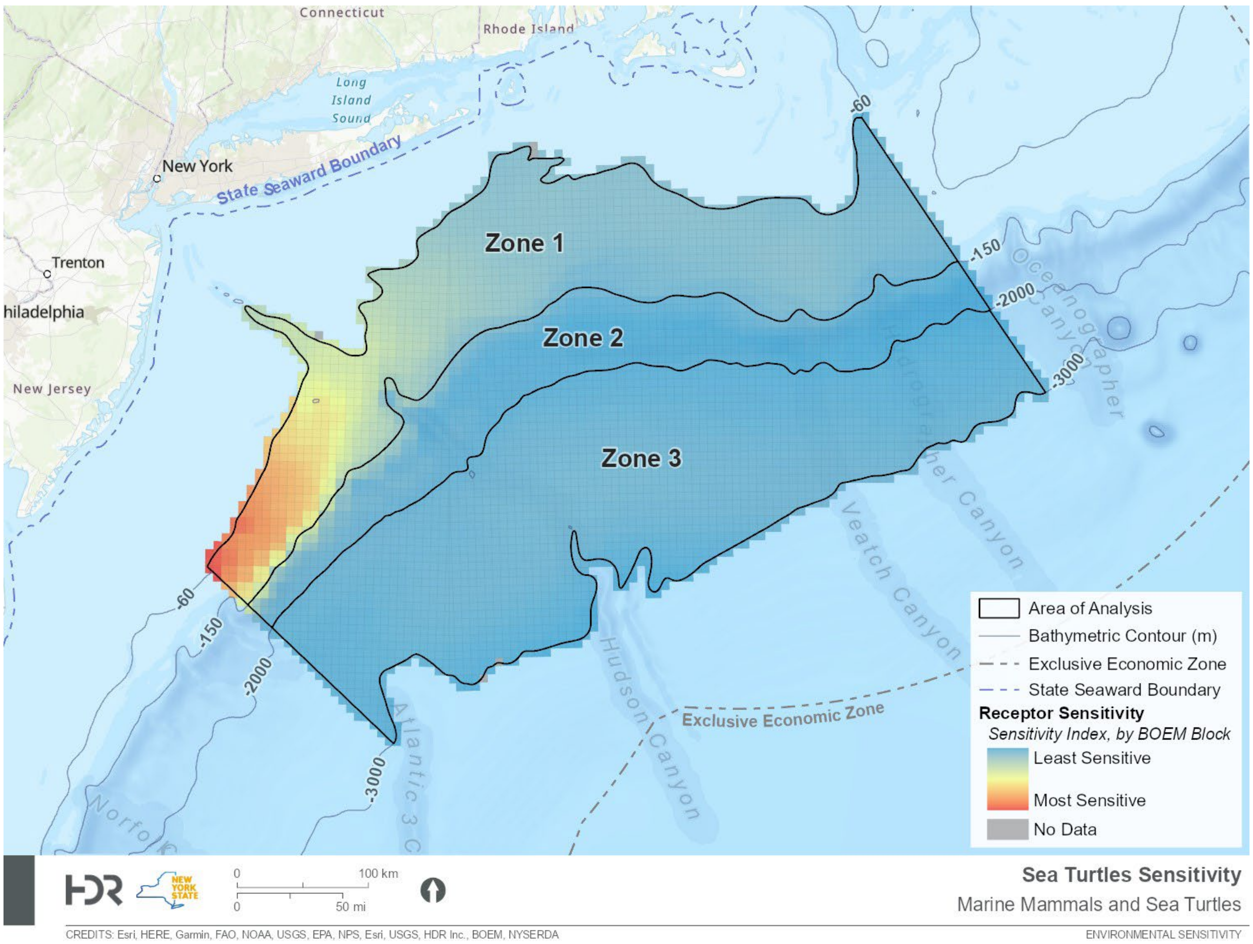


Figure 24 depicts the sensitivity of the sea turtle receptor group. Areas of higher risk were identified in the southwest portion of Zone 1, with comparatively less risk in Zones 2 and 3.

Figure 24. Sea Turtle Sensitivity



4.3.1.2 Overall Marine Mammal and Sea Turtle Sensitivity

Figure 25 depicts the overall composite sensitivity of the marine mammal and sea turtle resource group. Overall, Zones 1 and 2 had the greatest risk to this resource group, with Zone 3 having comparatively less risk. Areas of higher risk were in the northeast corner of Zone 1, along the shelf break, and within canyons in Zone 2.

The overall data coverage for this group is shown in Figure 26, which shows that most of the AoA has complete data coverage, with notably some receptor groups missing from Zone 3, as discussed above. Refer to section 3 for a detailed discussion regarding data gaps.

Figure 25. Overall Sensitivity of Marine Mammals and Sea Turtles Resource Group

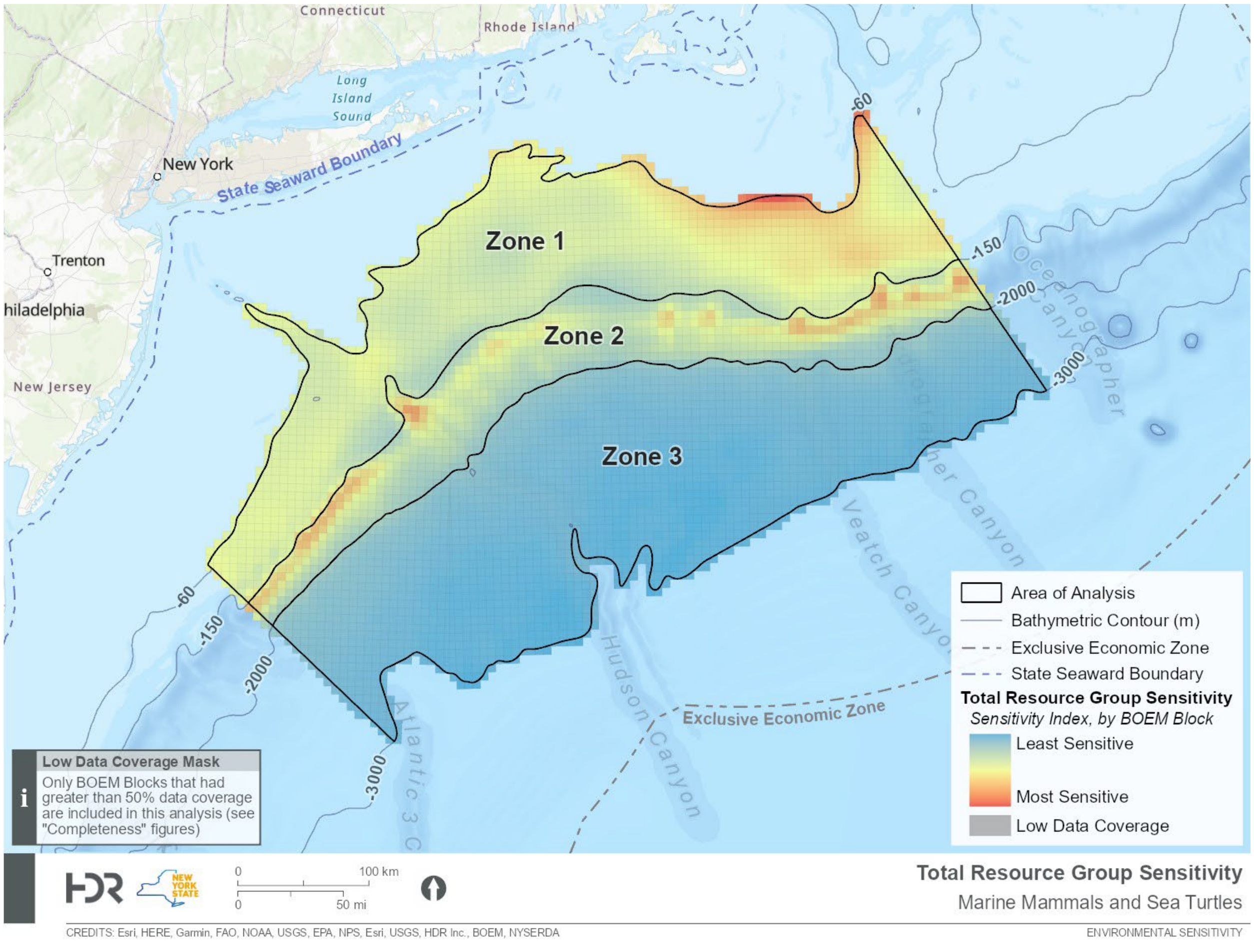
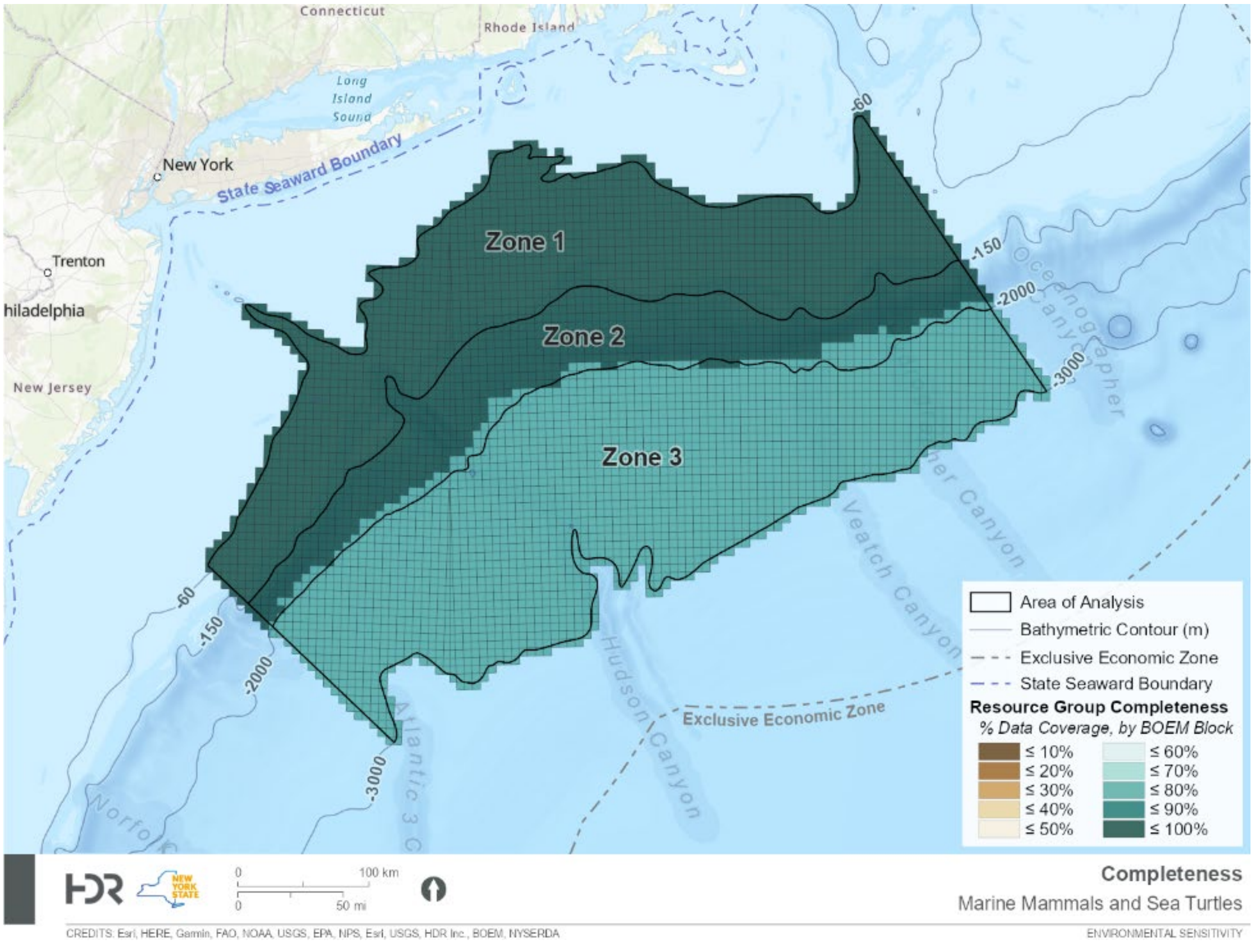


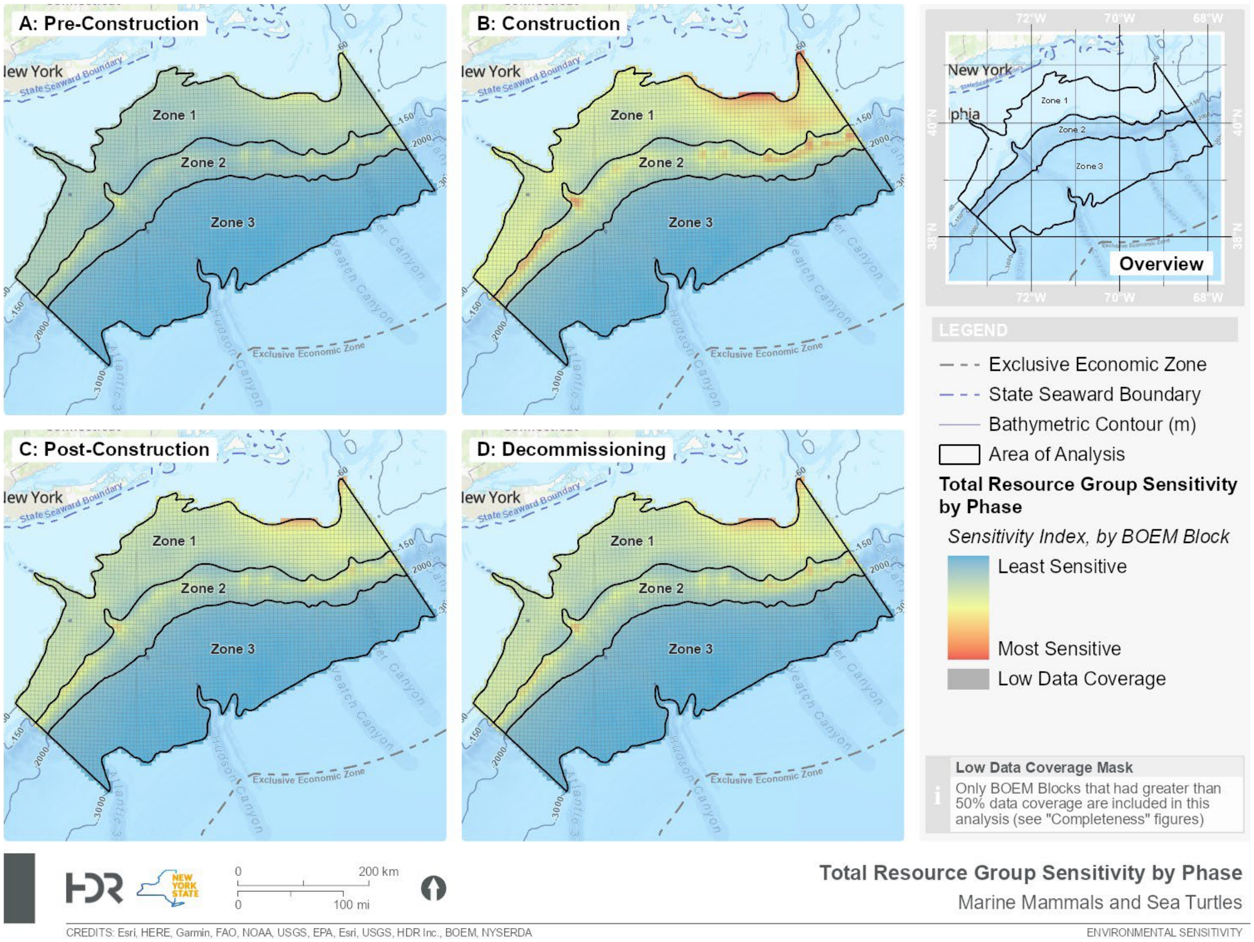
Figure 26. Percent Coverage of Marine Mammals and Sea Turtles Data Used in the Sensitivity Analysis



4.3.1.3 Sensitivity by Phase

The highest sensitivity of marine mammals and sea turtles to OSW in the AoA occurs during the construction phase (Figure 27). Risk during the post-construction and decommissioning phases was ranked slightly lower. The pre-construction phase of OSW is expected to pose a lower risk to marine mammals and sea turtles. New in-water structures, noise, and vessel traffic are the primary stressors expected to affect marine mammals and sea turtles negatively and were, therefore, the primary drivers of risk for these groups of species.

Figure 27. Marine Mammal and Sea Turtles Sensitivity by Phase



4.3.2 Birds and Bats

4.3.2.1 Sensitivity by Receptor

Bird CV (Figure 28), DV (Figure 29), and PV (Figure 30), were combined across all 47 species and seasons to produce an overall risk map of marine birds in the AoA (Figure 31). Bird collision vulnerability was moderate along most of Zones 1 and 2, with smaller areas identified as having a higher risk. Zone 3 was identified as having lower risk, although areas of this zone had data poor, so risk could not be assessed.

Figure 28. Bird Collision Vulnerability

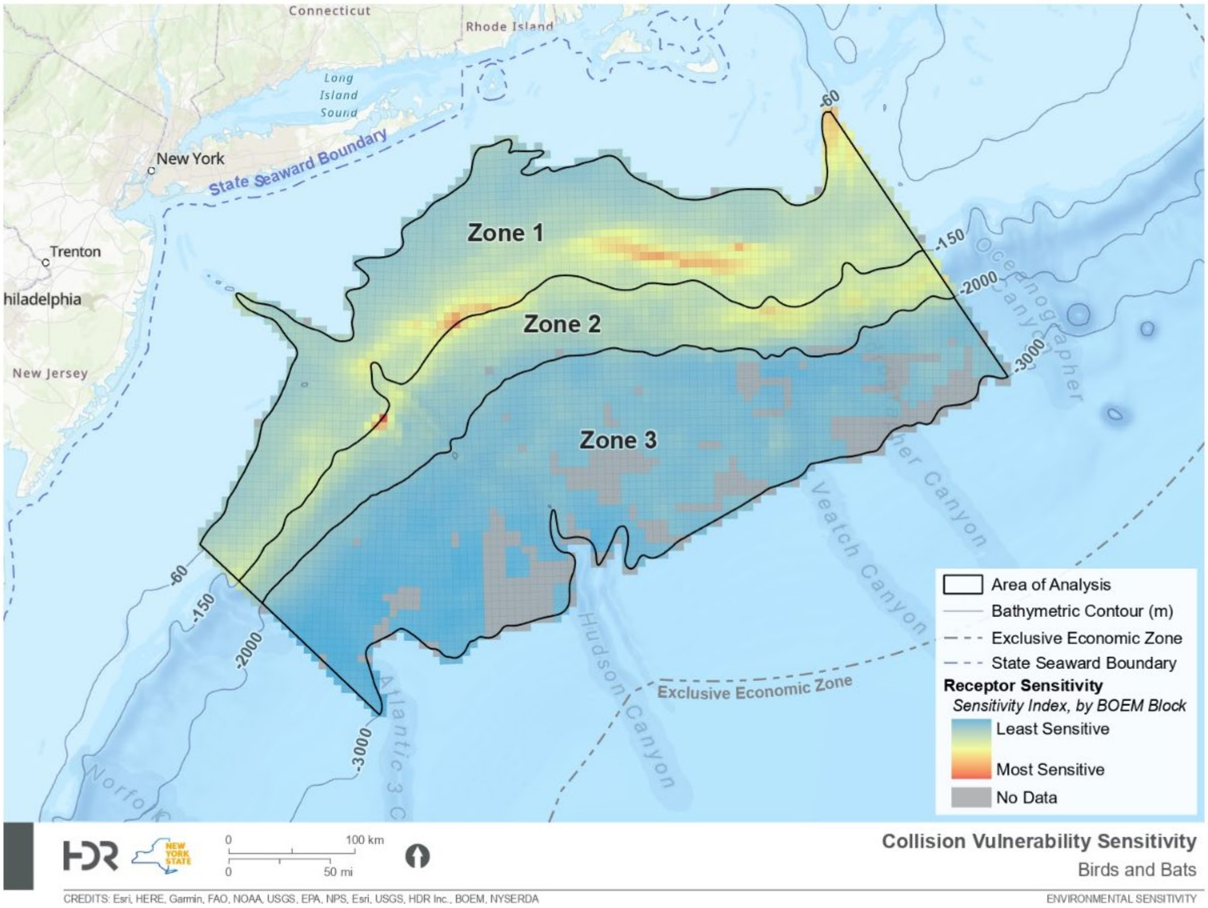


Figure 29 depicts bird displacement vulnerability, with similar patterns as displayed in the collision vulnerability. Zones 1 and 2 had moderate risk, with areas of higher risk present near the canyons and shelf break and in the northeast corner. Zone 3 displayed lower risk, with areas that were data poor where risk could not be assessed.

Figure 29. Bird Displacement Vulnerability

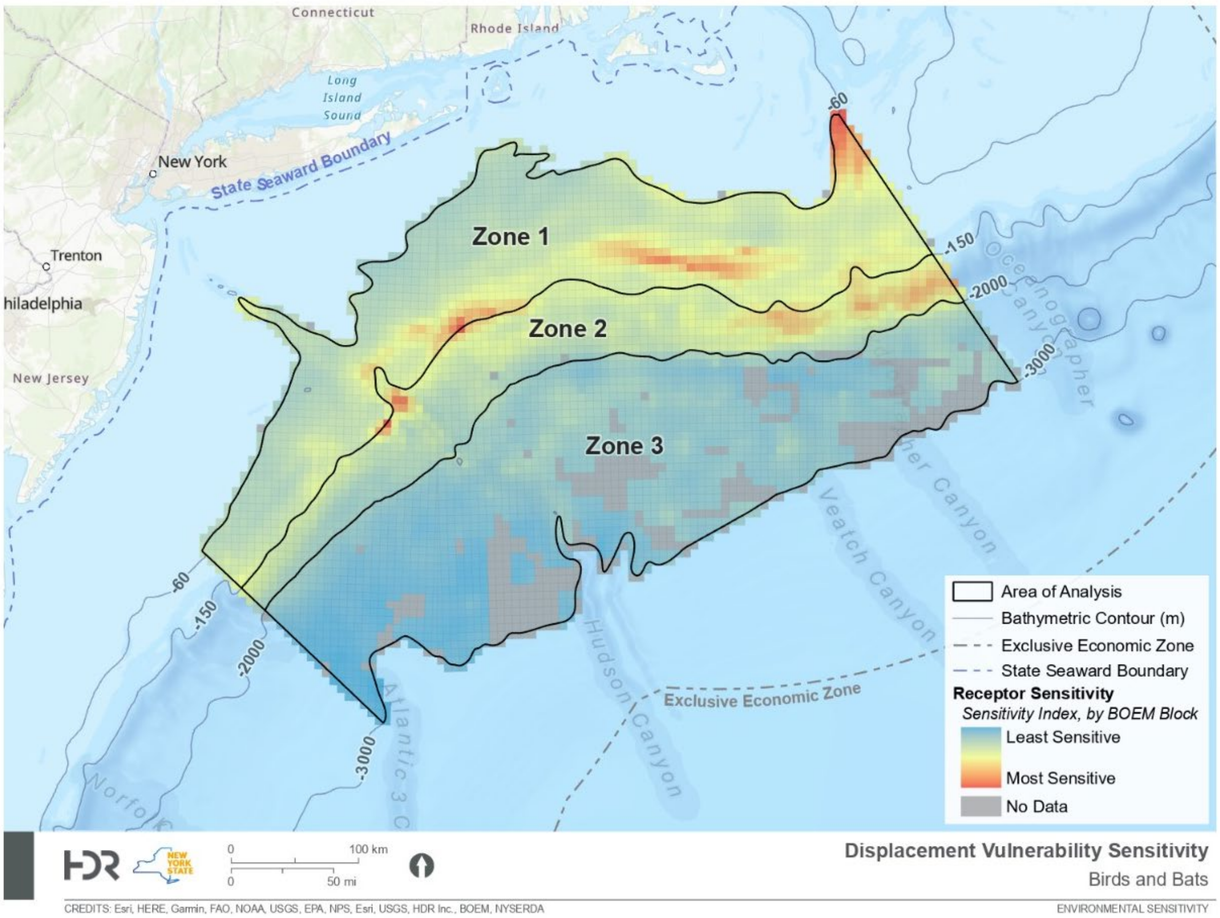
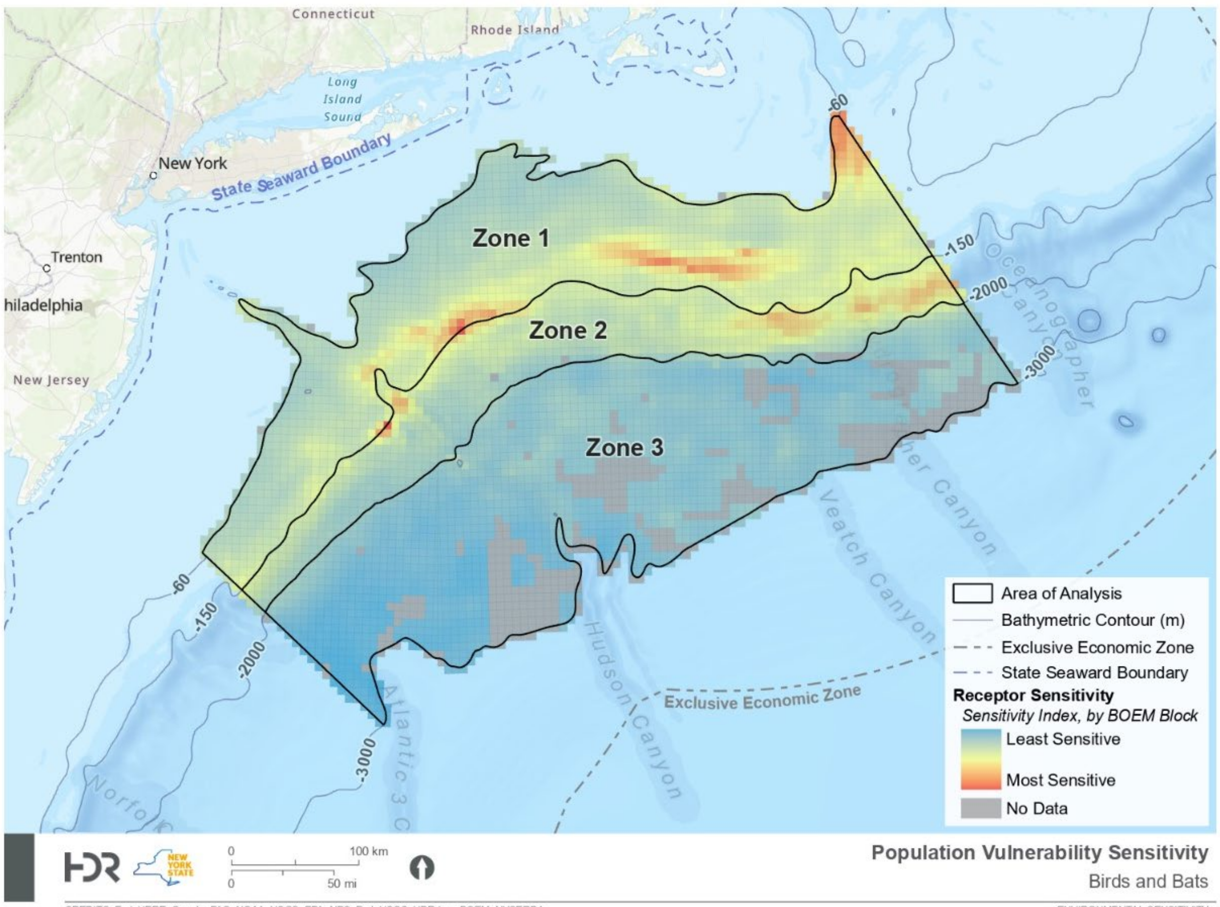


Figure 30 depicts bird population vulnerability, with areas of higher risk in the northeast corner of Zone 1, along the shelf break, and on the border of Zones 1 and 2. The remainder of Zones 1 and 2 were identified as having moderate risk. Zone 3 displayed lower risk, with areas that had data poor where risk could not be assessed.

Figure 30. Bird Population Vulnerability



4.3.2.2 Overall Bird Sensitivity

The highest overall risk to birds in the AoA was on the continental shelf and at the shelf break (in Zones 1 and 2, Figure 31); however, the greatest uncertainty occurred beyond, on the continental rise (Zone 3), due to a lack of data far offshore (Figure 32). This uncertainty also applied to bats throughout the AoA, due to a lack of data on bats far offshore. Offshore migrants and pelagic birds were the most vulnerable taxa exposed to OSW in the AoA, as well as some of the most data-poor taxa. Federally threatened shorebirds (red knot, piping plover) and endangered seabird species (roseate tern) were three of the most data-poor species that used that AoA during migration.

The overall data coverage for this group is shown in Figure 32, which shows that most of the AoA has complete data coverage with some missing data in Zone 3. Refer to section 3 for a detailed discussion regarding data gaps.

Figure 31. Overall Sensitivity Map for Birds

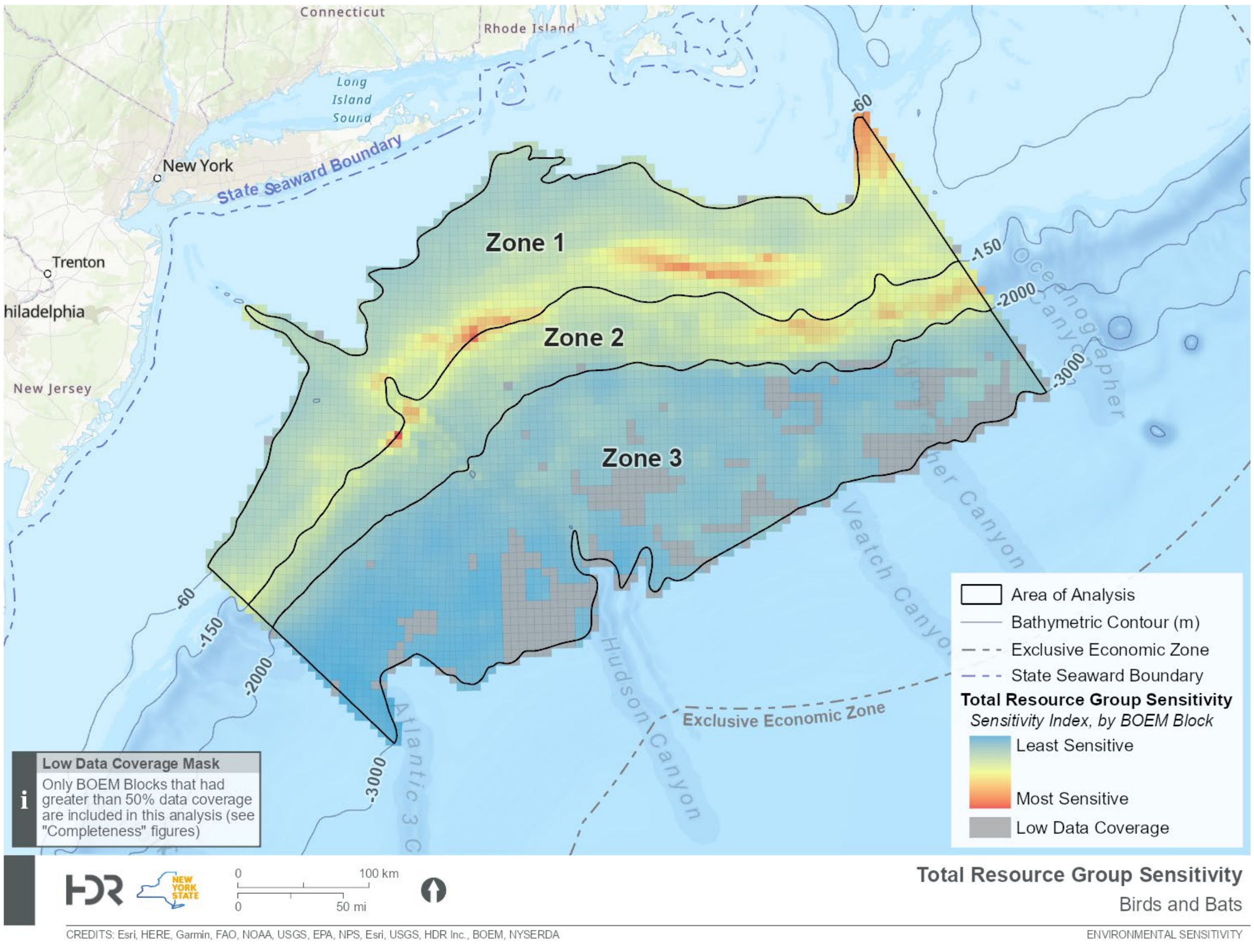
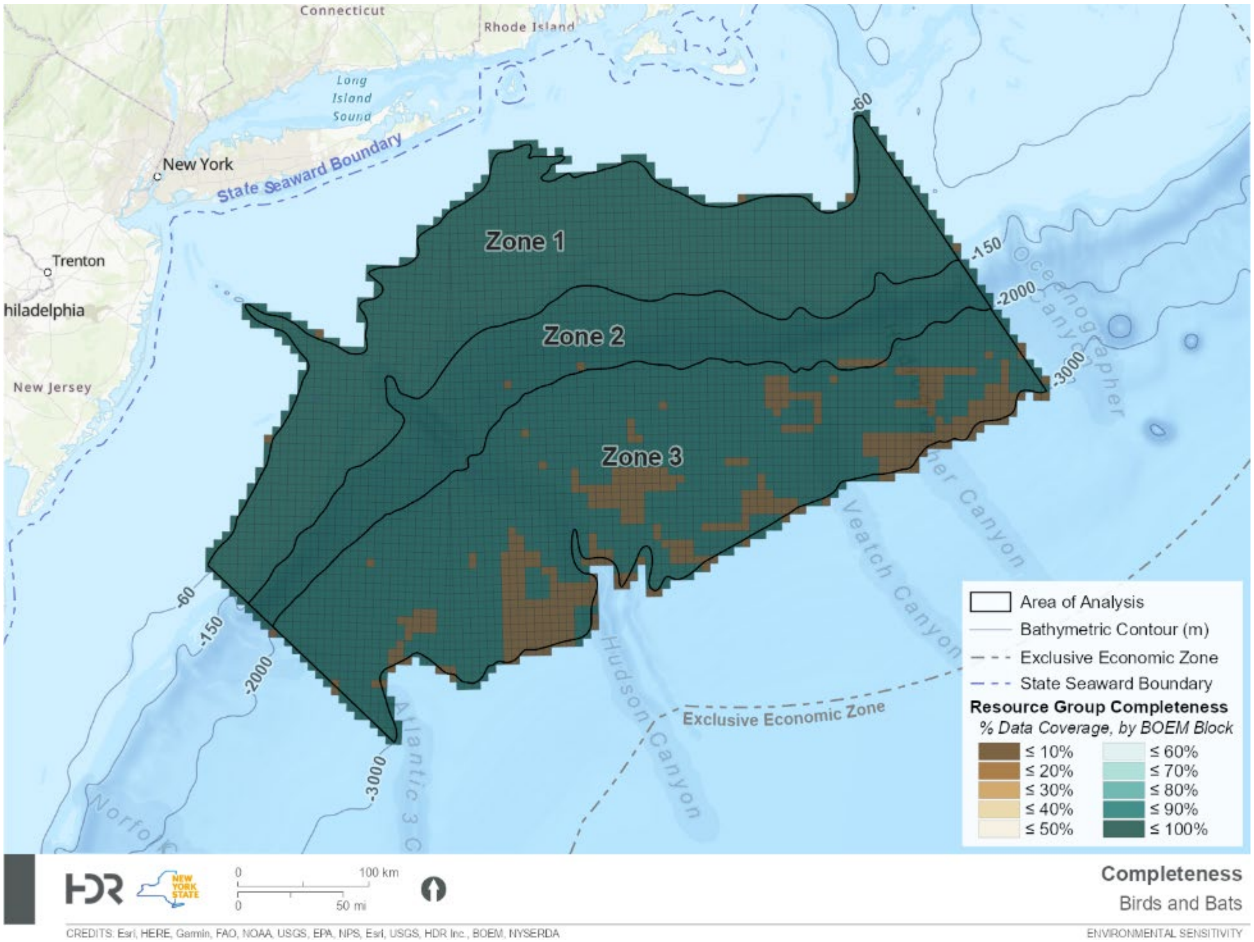


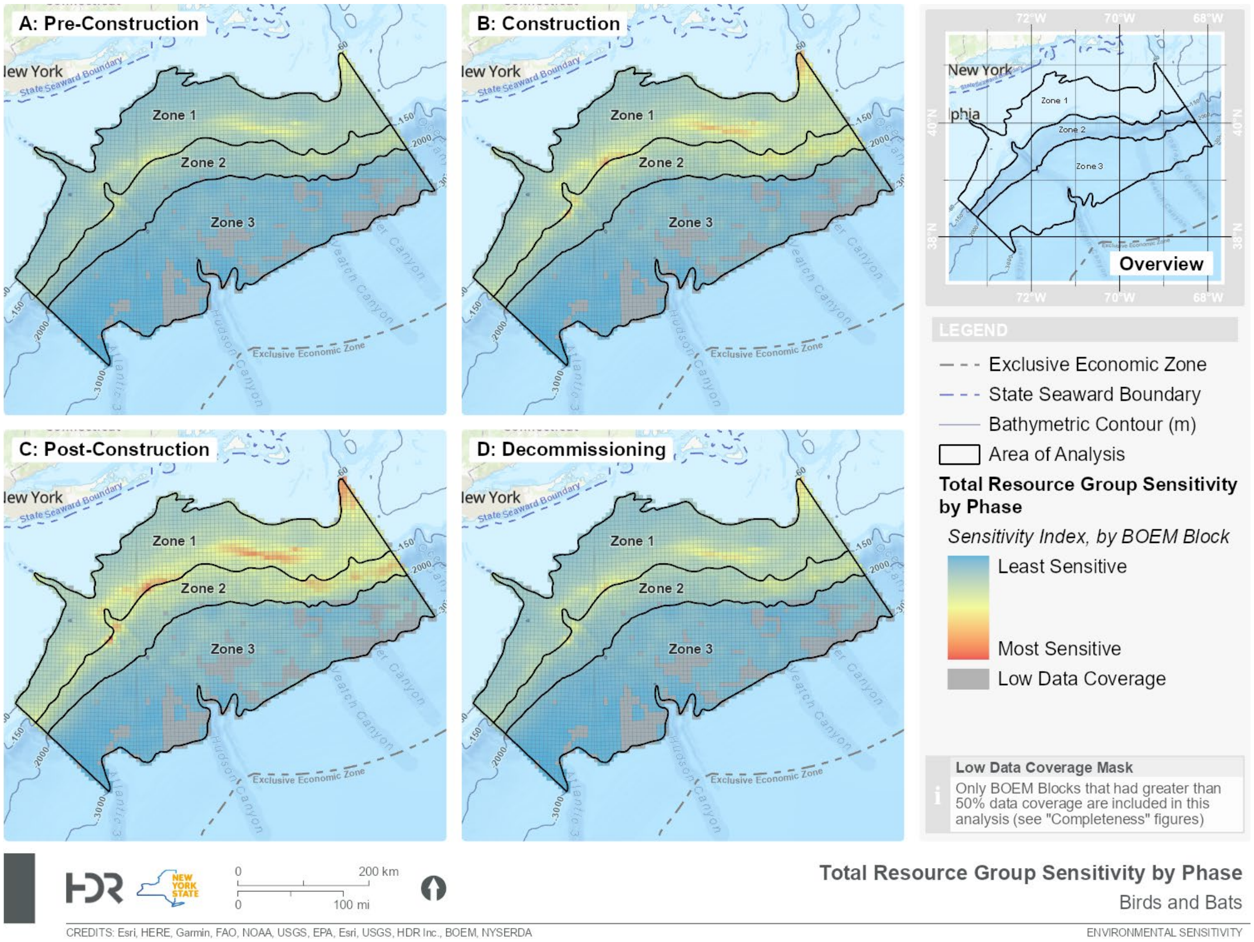
Figure 32. Percent Coverage of Birds and Bats Data Used in the Sensitivity Analysis



4.3.2.3 Sensitivity by Phase

New above-water structures remain the primary stressor expected to affect birds and bats negatively, via indirect habitat-induced displacement as well as direct collision risk Artificial lighting is a secondary stressor expected to contribute substantially to attraction and collision risk in birds. Vessel traffic is the third stressor anticipated to cause the temporary displacement of rafting birds from foraging areas, such as sea ducks. The highest sensitivity of birds to OSW in the AoA occurs during post-construction (operations phase), primarily due to collision and displacement vulnerability from new structures (Figure 33). The construction phase poses a secondary risk due to the construction of new structures and vessel traffic. The decommissioning and pre-construction phases are expected to pose a lower risk of bird collision and displacement sensitivity to OSW.

Figure 33. Sensitivity for Birds by Phase



4.3.3 Fish and Fisheries

4.3.3.1 Sensitivity by Receptor

Figure 34 shows the risk to fish habitat resources within the AoA. The highest risk to fish habitat is expected to occur along the continental shelf in Zone 1 and along the shelf break and continental slope in Zone 2. These data are largely driven by EFH, HAPCs, and the range of the ESA-listed species of Atlantic sturgeon. Risk is rated on a relative scale, and areas shown in blue or with no data should not be considered areas of no risk. Within Zone 2 and Zone 3, in particular, many HMS rely upon habitat seaward of the shelf break for seasonal migrations and foraging opportunities, which could be impacted by OSW in those zones.

Figure 34. Sensitivity Map for Habitat Layer

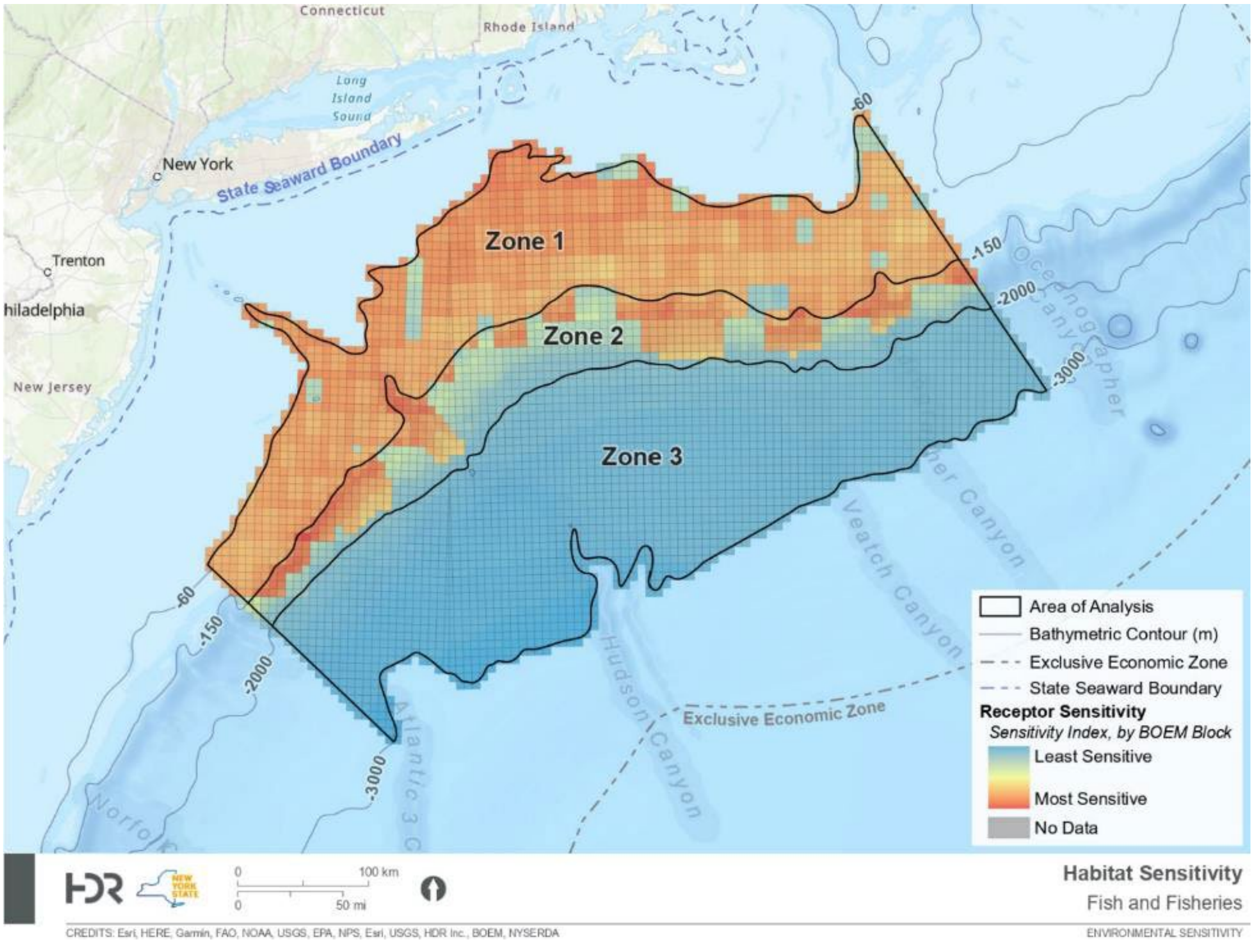


Figure 35 shows the risk to fish species within the AoA. The highest risk to fish species is expected to occur in the northeast part of Zone 1, along the continental shelf. Patchiness in risk occurs throughout most of Zone 1 and parts of Zone 2, where risk ranges from low to moderate according to the sensitivity analysis. The deeper portion of Zone 2 and all of Zone 3 are data poor, due to the limitations of the bottom trawl survey data; the risk there cannot be assessed. These zones should be evaluated further when considering future OSW siting, as many HMS utilize waters seaward of the shelf break (Zone 2 and Zone 3) for seasonal migrations and foraging.

Note that risk is rated on a relative scale, and areas shown in blue should not be considered areas of no risk. For example, the NEFSC Spring and Fall Bottom Trawl Survey data showed the highest deep-sea red crab biomass occurs along the shelf break at the Zone 1/Zone 2 boundary; similarly, tilefish also occur along the shelf break (refer to the accompanying Fish and Fisheries Data Aggregation Study). Although the sensitivity analysis depicts an overall low to moderate risk to fish species in this area, OSW along the shelf break will place tilefish and deep-sea red crab at higher risk because of their limited distributions. As an additional note, due to the seasonal nature of the bottom trawl survey, species such as the northern shortfin squid (*Illex illecebrosus*) may not be effectively sampled because they are not in the survey area during those times. Instead, they are farther offshore in Zone 3 and beyond and only migrate into Zones 1 and 2 during the summer months when the trawl survey doesn't occur (NOAA 2023d).

Figure 35. Sensitivity Map for Species Layer

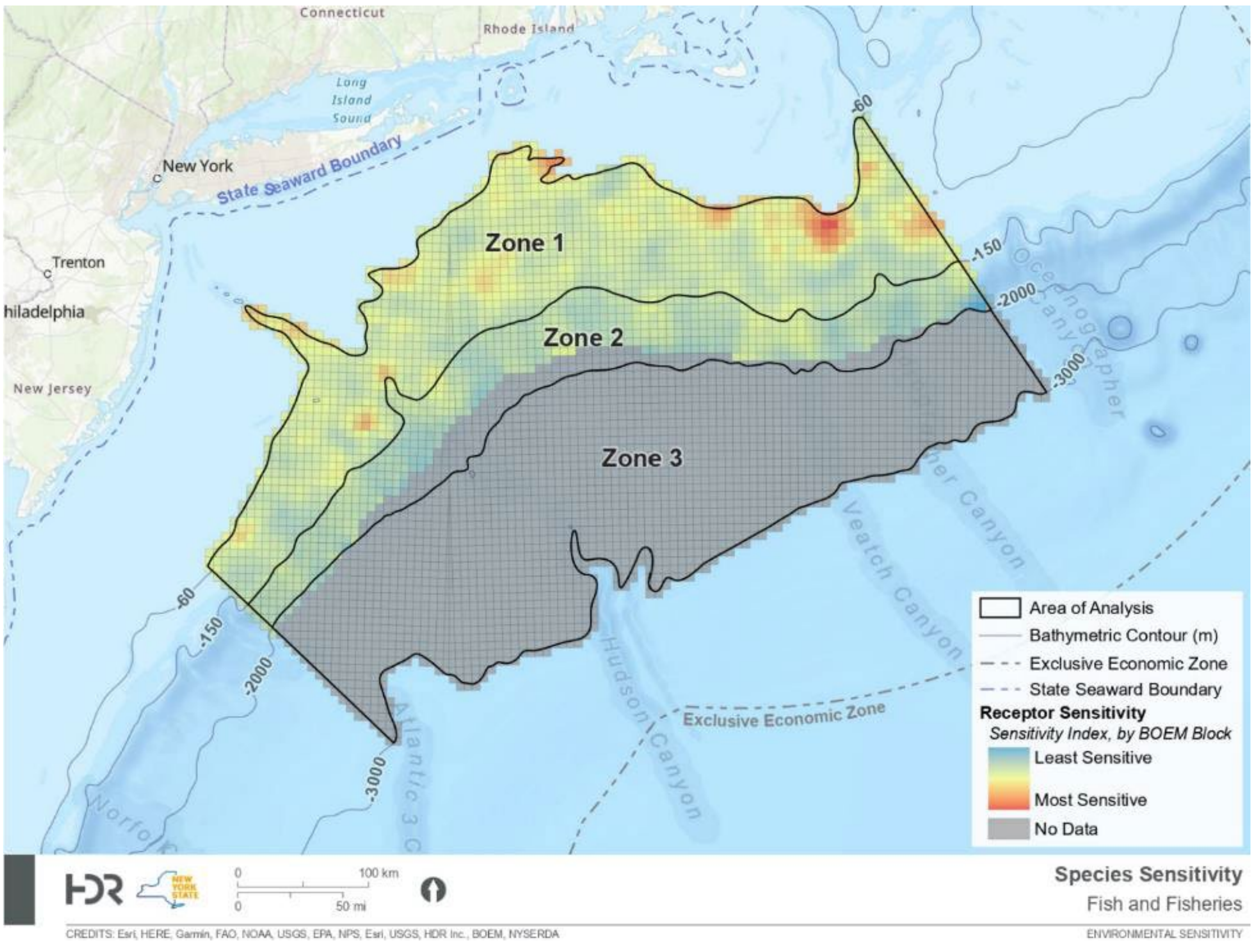
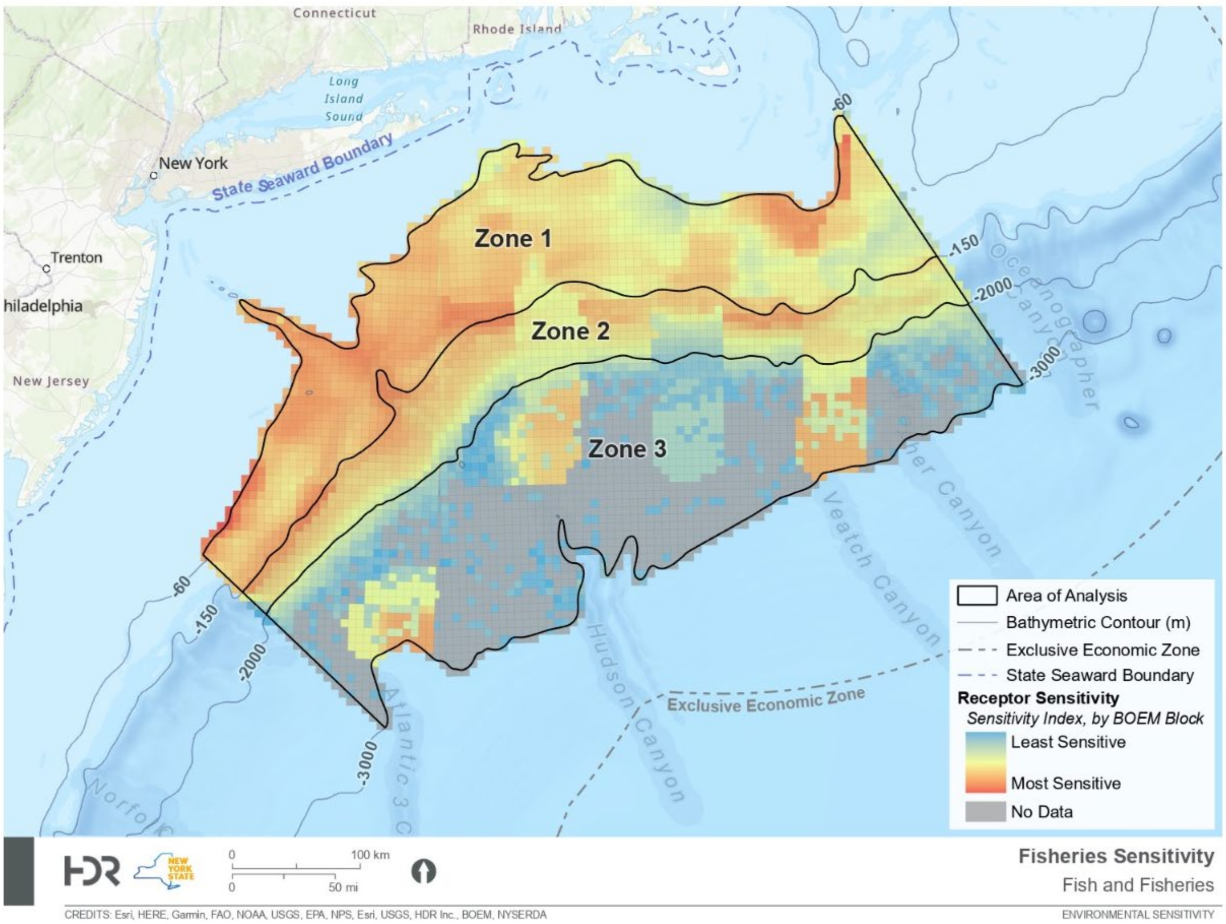


Figure 36 shows the risk to fisheries within the AoA. Areas of higher risk to fisheries were identified in the sensitivity analysis, primarily within Zones 1 and 2. Most of Zone 1 is expected to be moderate to high risk for OSW. Similarly, within Zone 2, much of the available data indicates moderate to high risk. Within Zone 3, data are limited; however, the results suggest areas of moderate risk in portions. The pattern of data coverage shown mostly in Zone 3 is a function of the source data used for this receptor. For confidentiality, the source data are point-based and generalized to 10-minute grid squares.

Note that risk is rated on a relative scale, and areas shown in blue should not be considered areas of no risk. For example, fishing vessel data have indicated that HMS are often targeted in Zone 2 of the AoA; therefore, OSW in Zone 2 is likely to impact the HMS fishery. When evaluating the available fisheries data within Zone 2 and Zone 3 of the AoA, additional data and further research are recommended to determine the potential suitability of these zones for future OSW.

Figure 36. Sensitivity Map for Fisheries Layer



4.3.3.2 Overall Fish and Fisheries Sensitivity

When each of the three individual receptor layers shown above is combined with the weights by receptor (Table 8), the overall risk to fish and fisheries from OSW is compiled and shown in Figure 37. Overall, the results indicate a comparatively moderate to high risk primarily in Zone 1 along the continental shelf, and extending into areas such as the Hudson Canyon, along the shelf break and other HAPCs in Zone 2.

Portions of Zone 3 show moderate risk, with others showing lower risk; however, most of Zone 3 is data poor, so risk is not able to be assessed in most of this zone. Although the sensitivity analysis shows variable risk along the shelf break (Zone 1/Zone 2 boundary), OSW projects in this area will place tilefish and deep-sea red crab at higher risk because of their limited distributions. Additionally, although risk was not weighted separately by zone, risk in Zones 1 and 2 is likely higher from changes to atmospheric and oceanographic dynamics, as the cold pool, a prominent seasonal stratification process that occurs on the continental shelf in Zone 1. Other processes in the Mid-Atlantic region, such as the formation of the Gulf Stream warm core rings (NOAA 2023a; Silver et al. 2023) and coastal upwelling and water column mixing that occur within the submarine canyons, may be disrupted in Zone 2.

Figure 37. Overall Risk Map for Fish and Fisheries Resources within the Area of Analysis

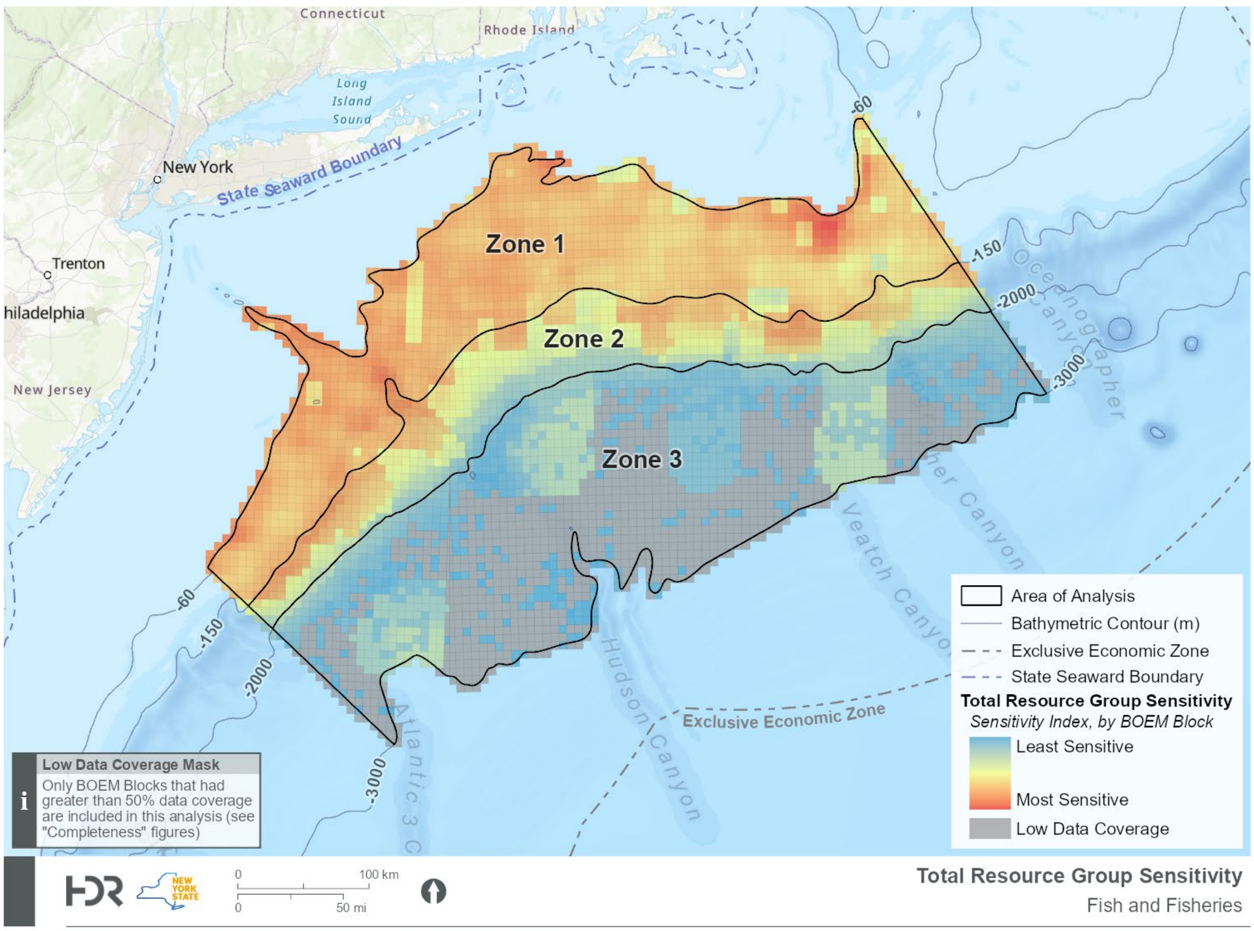
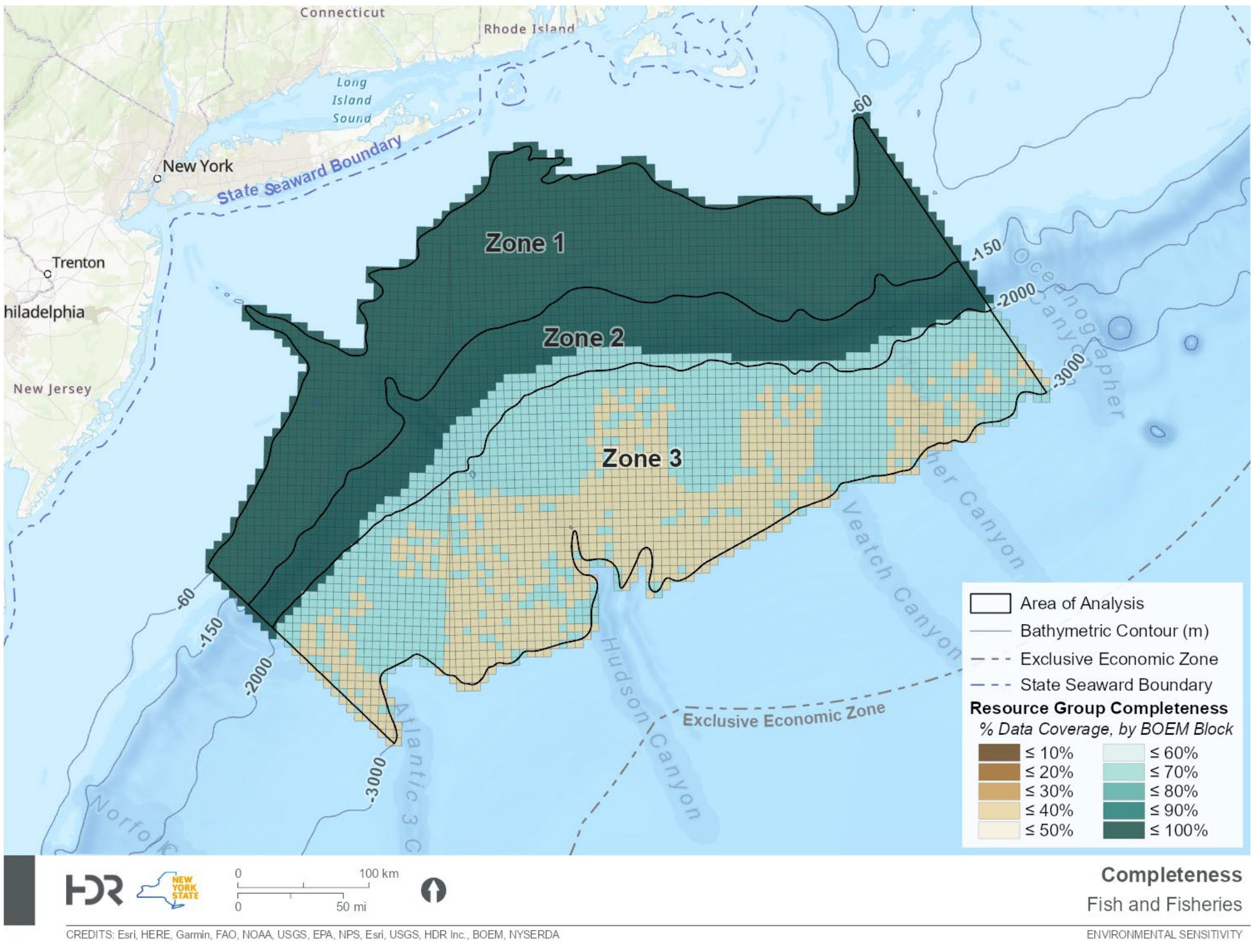


Figure 38 shows the percentage of coverage for the available data sets used in the sensitivity analysis. The results highlight that overall, the least amount of data was available within Zone 3, which was primarily limited to HMS EFH mapping, as well as some NOAA Fisheries Observer data and VMS data, which were sparse. Zone 2 also had some gaps in coverage. Additional data and further research are recommended to determine the potential suitability of these zones for future OSW projects.

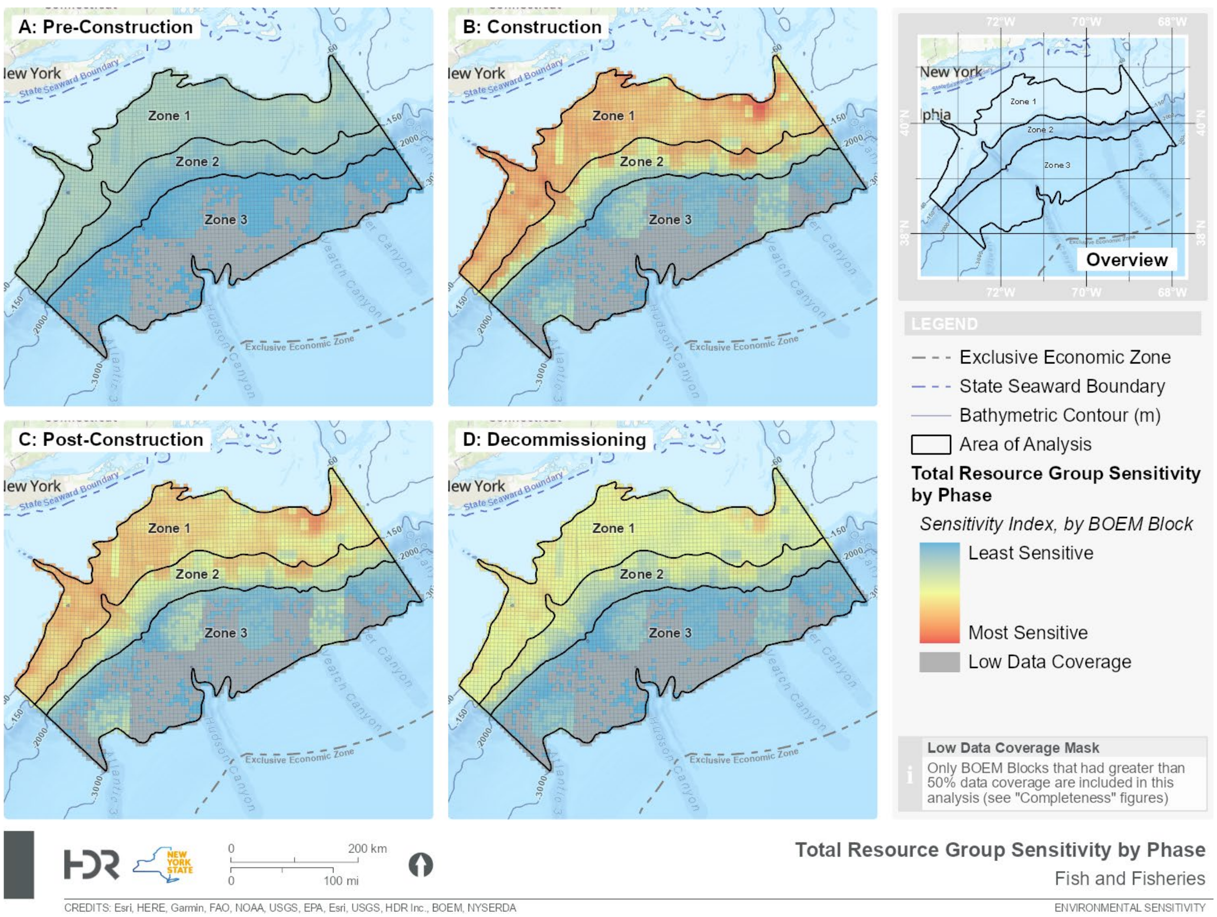
Figure 38. Percent Coverage of Fish and Fisheries Data Used in the Sensitivity Analysis



4.3.3.3 Sensitivity by Phase

Applying the weights by stressor for fish and fisheries, Figure 39 shows the comparative risk by project phase to fish and fisheries resources, with the highest risks expected to occur during construction and post-construction in Zones 1 and 2. Risk is rated on a relative scale, and areas shown in blue should not be considered as areas of no risk; similarly, large areas of Zone 3 are data poor, thus an assessment of risk there is not possible. The highest risks are expected to be associated with new structures and bottom disturbance, with atmospheric and oceanographic dynamics also identified as having moderate risk. Zone 3 is data poor; therefore, assessment of risk is not possible within large areas of this zone.

Figure 39. Relative Risk of Construction Phase to Fish and Fisheries from Offshore Wind



4.3.4 Benthic Habitat

4.3.4.1 Sensitivity by Receptor

As discussed in section 3, the benthic habitat group had the lowest percentage of data coverage of all groups. Vast areas of Zones 1 and 3 contained no data for most of the biological receptors; thus, the risk to those receptors in those areas is harder to predict. Areas without data do not represent an absence of risk.

The sensitivity analysis for coral density yielded areas of high to low risk in Zone 2 (Figure 40), areas of low risk in Zones 1 and 3, and large areas in Zones 1 and 3 lacking data. Sensitivity analysis for coral suitability resulted in areas of high and moderate risk in Zone 2, mostly near the head of Hudson Canyon; however, data for this receptor was only available for Zone 2 (Figure 41).

Figure 40. Sensitivity Based on Coral Density

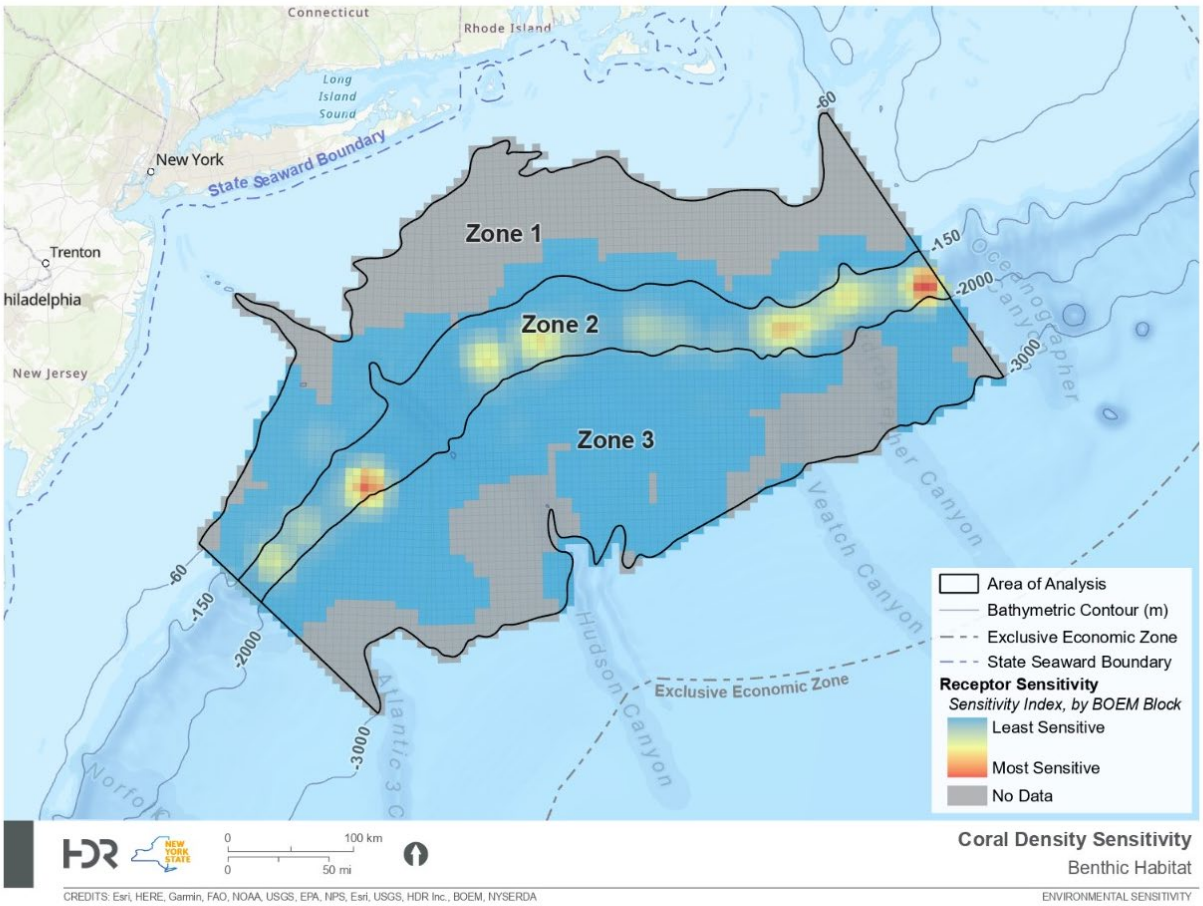
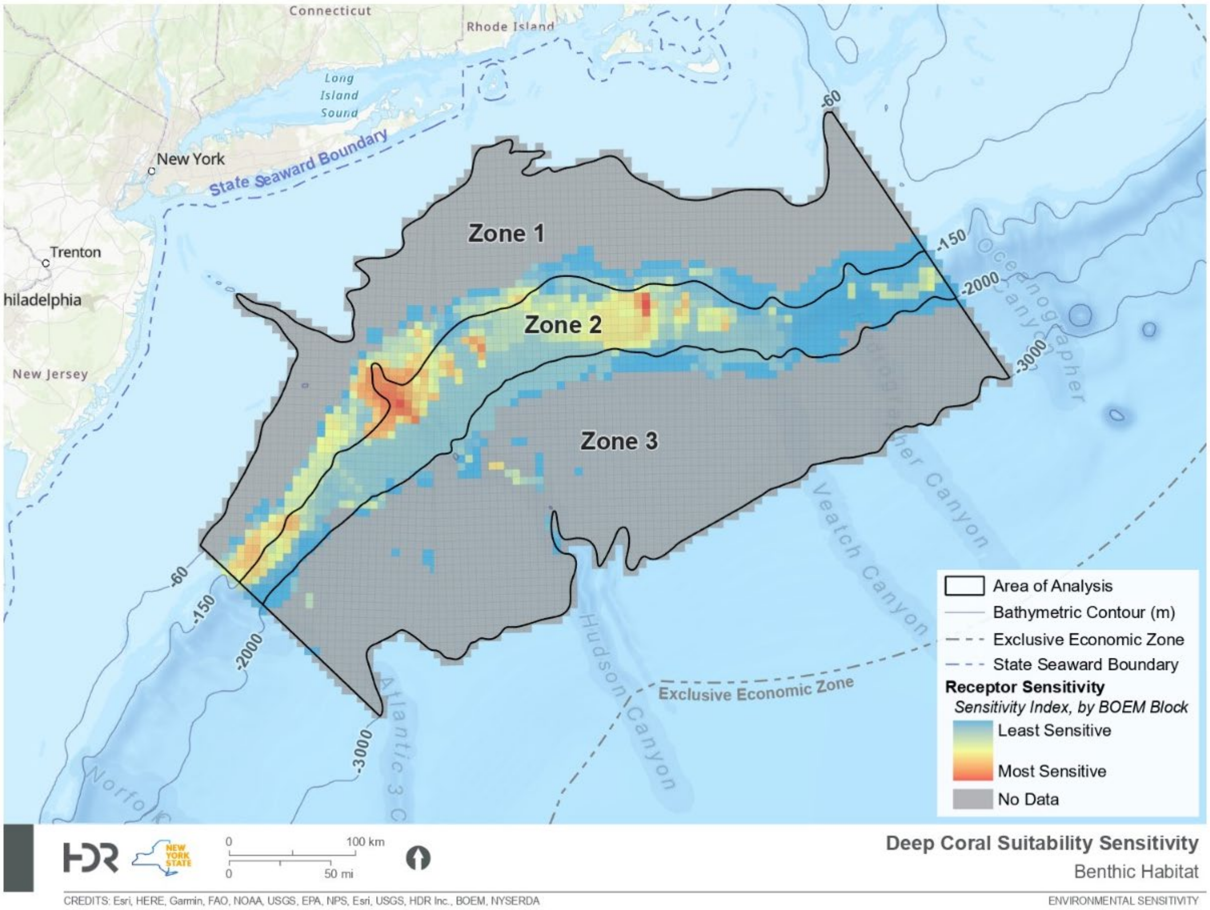


Figure 41. Sensitivity Based on Coral Habitat Suitability



The sensitivity analysis for sea pen density yielded small areas of highest sensitivity in Zone 2 (Figure 42), areas of low sensitivity in Zones 1 and 3, and large areas of Zones 1 and 3 lacking data. Sensitivity analysis for sea pen habitat suitability resulted in areas along the edge of Zones 1 and 2 with high and moderate sensitivity (Figure 43). Most of Zone 3 had no sea pen habitat suitability data, thus risk could not be assessed, but areas with data were generally rated as low or moderate in sensitivity.

Figure 42. Sensitivity Based on Sea Pen Density

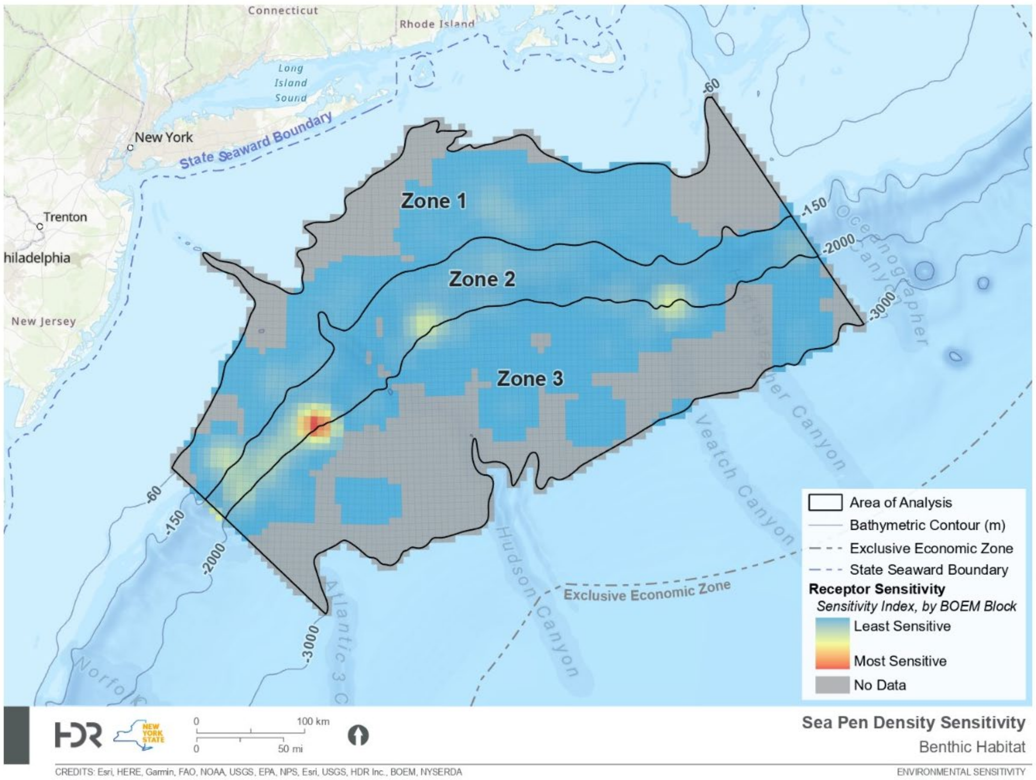
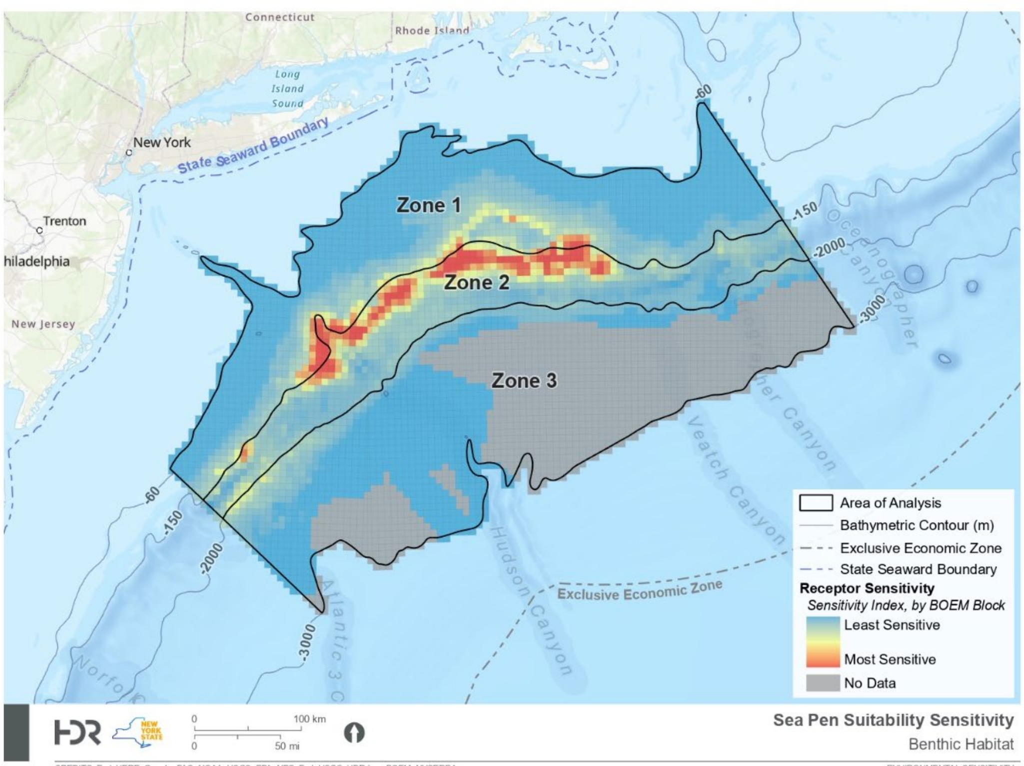
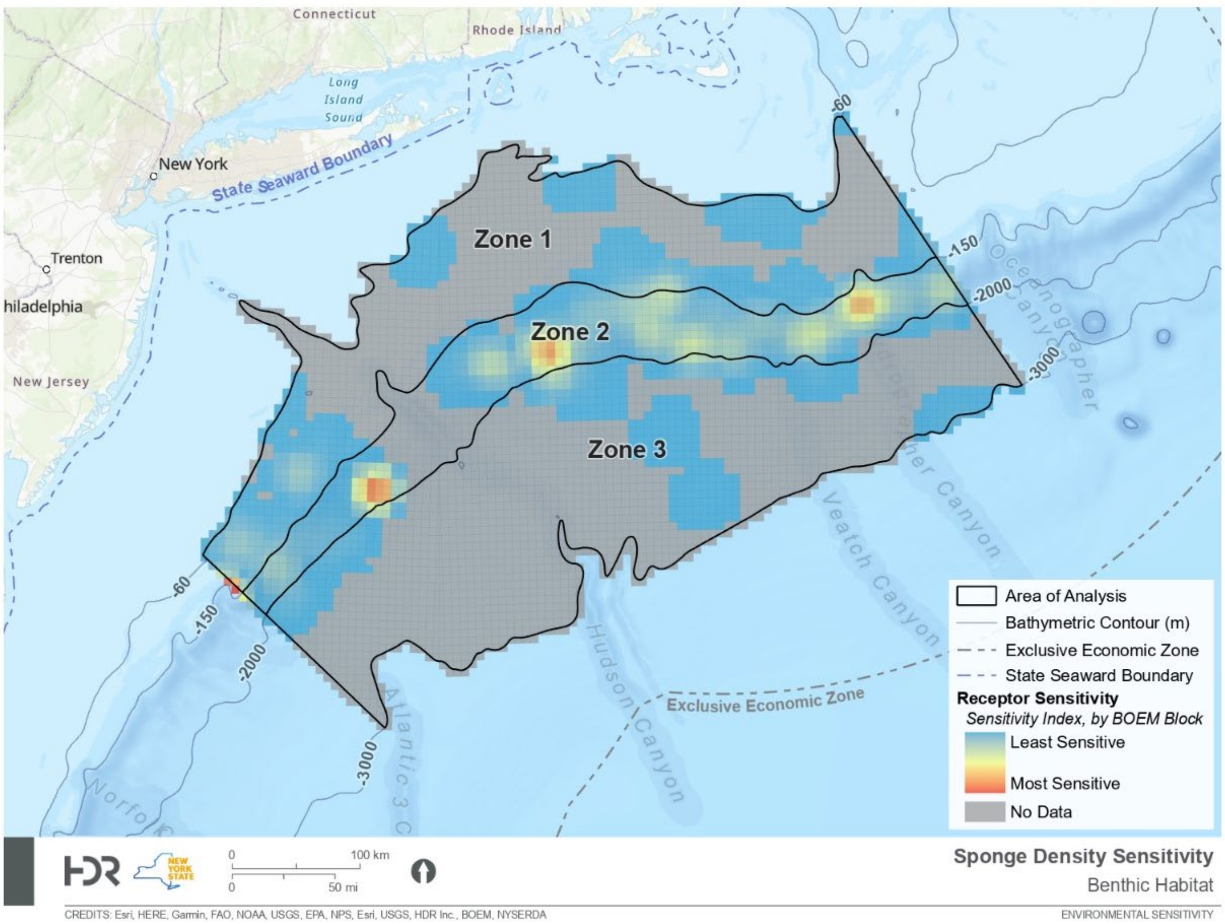


Figure 43. Sensitivity Based on Sea Pen Habitat Suitability



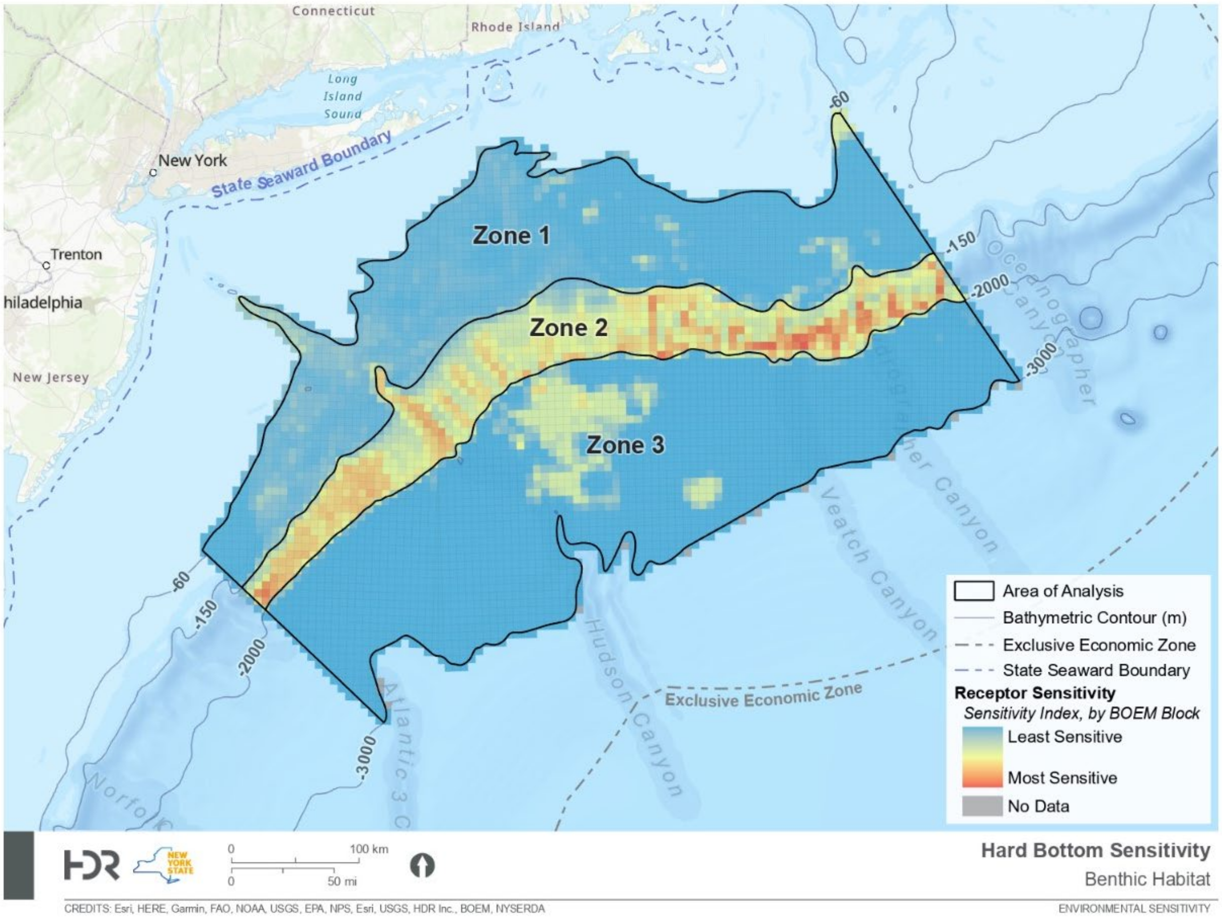
The sensitivity analysis for sponge density yielded small areas of highest sensitivity in Zone 2 (Figure 44), similar to the sensitivity map for coral density. However, large areas of Zones 1 and most of Zone 3 had no data coverage, and the area of Hudson Canyon lacked sponge density data; therefore, risk could not be assessed.

Figure 44. Sensitivity Based on Sponge Density



The sensitivity analysis for hard bottom substrates resulted in the entirety of Zone 2 being ranked moderately to highly sensitive (Figure 45). With the exception of an area in the center of Zone 3 being ranked as low to moderately sensitive, the remaining areas were data poor; therefore, risk could not be assessed. Similarly, vast areas of Zone 1 were data poor, with some areas identified as having a low to moderate sensitivity.

Figure 45. Sensitivity Based on Hard Bottom Substrates



4.3.4.2 Overall Benthic Habitat Sensitivity

Applying the weights by benthic habitat receptor (Table 8) shows that the overall risk to benthic habitat from OSW is moderate along most of Zone 2, with some areas characterized by higher risk and a few others characterized by lower risk (Figure 46). Areas of high risk tend to fall on or near canyon edges or breaks. Most other areas in Zones 1 and 3 were data poor, thus risk could not be assessed (Figure 47). Those areas containing data in Zone 1 were assessed as having low to moderate risk and areas in Zone 3 containing data were generally assessed as having lower risk. In addition to the receptors selected for this analysis, NOAA-designated Coral Protection Areas cover the entirety of Zone 3 and much of Zone 2. These designations may also inform the sensitivity of these zones, as the designation is a recognition of these areas as potential coral habitat.

Figure 46. Overall Risk to Benthic Habitat from OSW

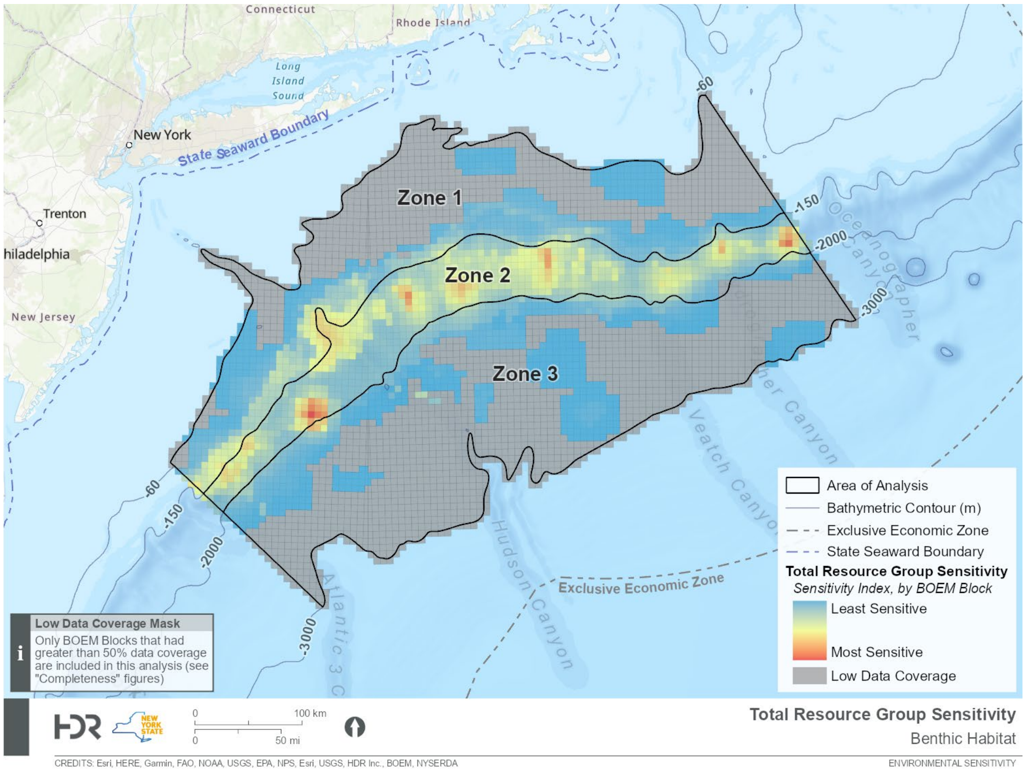
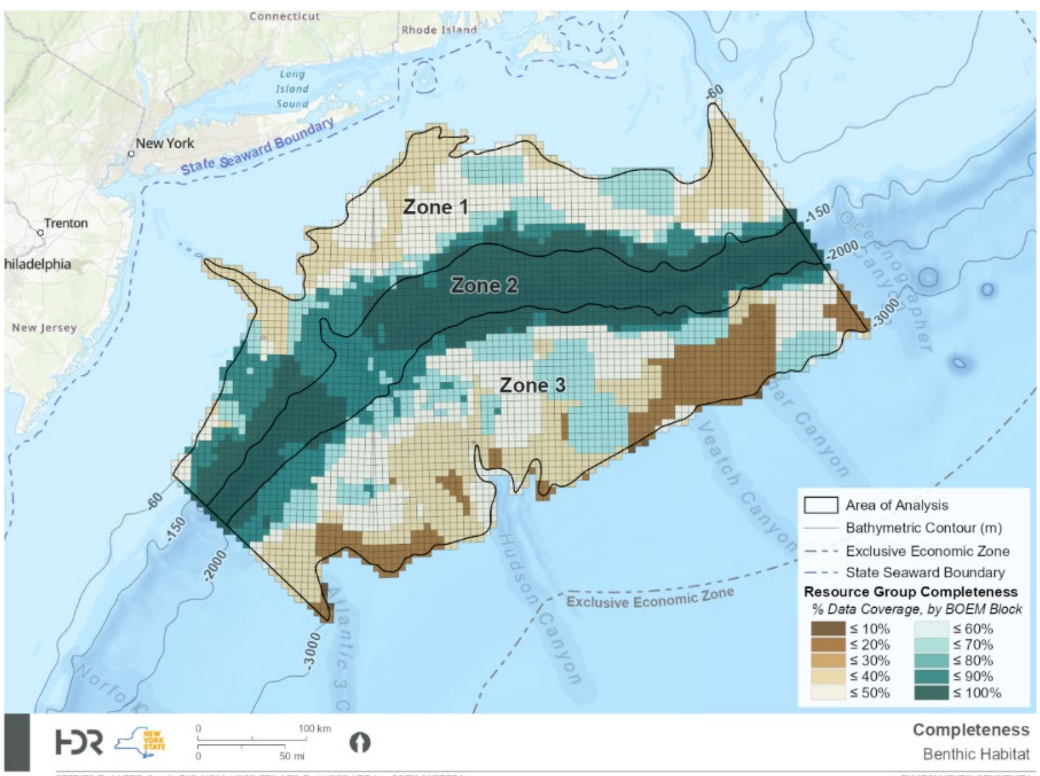


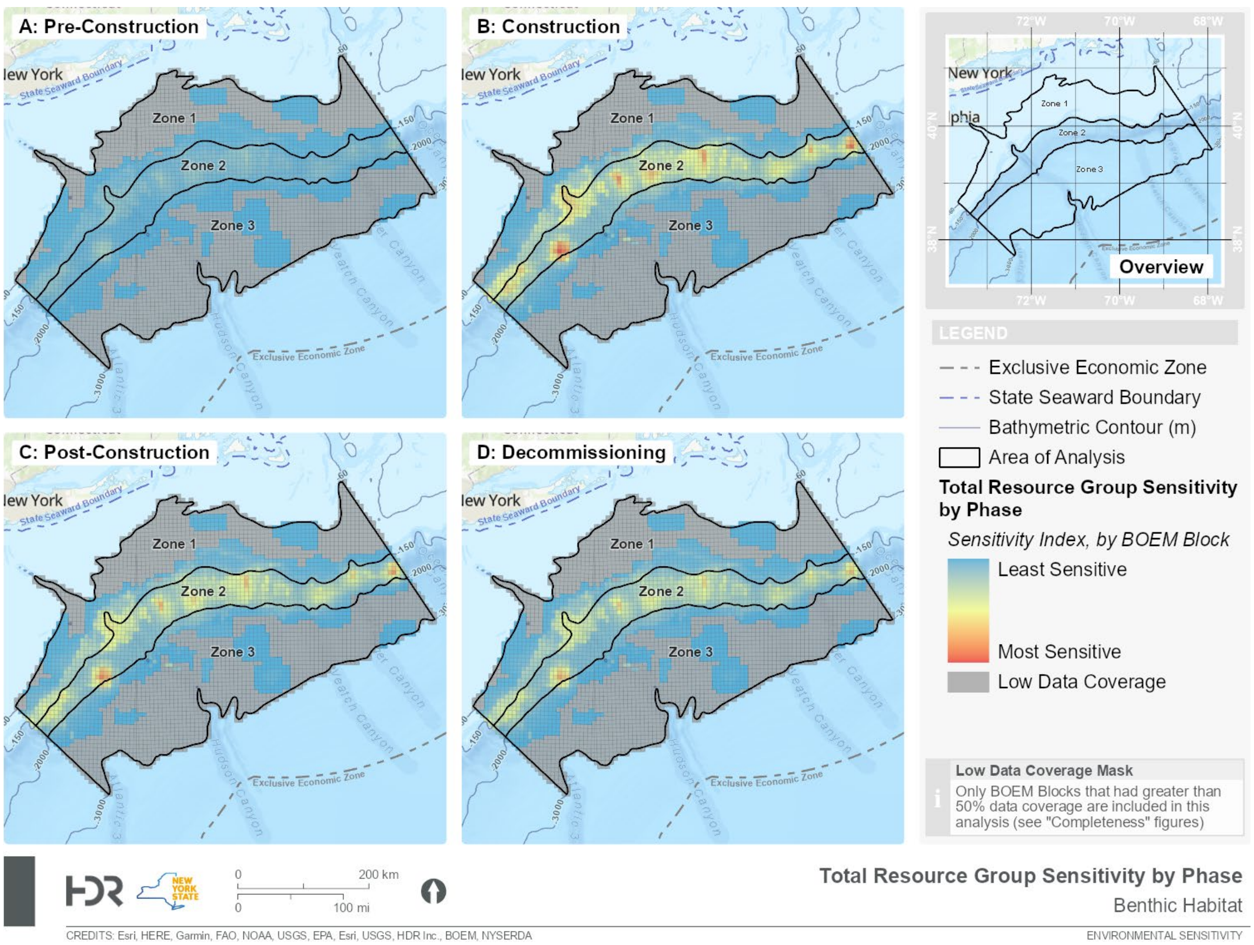
Figure 47. Percent Coverage of Benthic Data Used in Sensitivity Analysis



4.3.4.3 Sensitivity by Phase

Applying the weights by phase for benthic habitat (Table 8) shows that the risk to benthic habitat by phase of OSW is ranked highest during construction, slightly lower in the post-construction and decommissioning phases, and the lowest during the pre-construction phase (Figure 48). Bottom disturbance activities and new structures were ranked highest and were, therefore, the primary drivers of risk for this resource group.

Figure 48. Risk to Benthic Habitat from OSW by Construction Phase



5 Conclusions and Future Considerations

An MCDA approach combined with the AHP was used to conduct a weighted environmental sensitivity analysis in the AoA. This approach structures the complex problem of determining environmental sensitivity across multiple marine resource groups in a logical and organized manner, considers multiple criteria explicitly, and ultimately allows for better informed decisions. Following are additional benefits of this approach:

- MCDA can be used to evaluate multiple, often conflicting, criteria with respect to a defined goal or metric like environmental sensitivity. It is particularly well suited for this application given the available data sets and data gaps (e.g., spatial coverage and temporal coverage).
- The conceptual framework and hierarchical approach are modular in nature and, hence, adaptable to future conditions. As additional data sets become available or updated, or if new information is available on stressor impacts, these data can be integrated into the framework, and, therefore, results can be continuously updated as more information becomes available.
- The AHP process provides a rigorous, egalitarian, and quantifiable approach to SME elicitation for determining the relative weighting among the various data sets evaluated. The AHP method focuses the effort of the SME to consider supporting evidence and rationale for each comparison in addition to using their judgments about the elements' relative meaning and importance. Moreover, the method has additional functionality to ensure consistency among responses and provides an unbiased method to obtain rankings independently from each SME.

The high-level sensitivity mapping analysis identified regions of relatively higher or lower sensitivity within the three zones of the AoA. In general, Zones 1 and 2 had the highest overall sensitivity, and Zone 3 had the lowest, but this should be considered carefully as the data gaps were substantially greater in Zone 3 due to a lack of readily available data for many receptors. Certain AoA regions were identified as consistently more environmentally sensitive, including the shelf slope in Zone 2, Hudson Canyon, and other smaller canyons.

Marine mammal and sea turtle sensitivity predominated Zones 1 and 2, with a notable sensitive area in the northeast portion of the AoA due to the predicted abundance of NARWs in this region. Bird sensitivity was primarily concentrated along the border between Zones 1 and 2 on the eastern half of the AoA. There was limited bat data available at the time of this report; therefore, the potential risk to bats is uncertain. Fish and fisheries sensitivity is concentrated in Zone 1 nearshore waters and is generally homogenous within this zone, with the notable exception of the northeast corner of the AoA. Benthic habitat sensitivity is almost exclusively focused in Zone 2 along the continental shelf area, as this area is most likely to contain suitable habitat for benthic species.

Bottom disturbance was the most impactful stressor for fish and benthic habitat, and new structures were most impactful for birds and mammals. Additionally, artificial light was impactful for birds, and vessel traffic was impactful for marine mammals. In general, sensitivity was greater during the construction phase for marine mammals, sea turtles, fish and fisheries, and benthic habitat, and during post-construction for birds and bats.

A focus on the boundaries of these higher-risk areas to delineate them could further reduce risk to resources and identify areas of least suitability for the advancement of OSW. This analysis is one tool among several that could be used in the context of the mitigation hierarchy in later phases of development. The mitigation hierarchy is the process by which environmental assessments, or impact statements, document how to reduce the impacts of stressors on receptors. Thorough planning (i.e., avoidance through siting) and selection of appropriate installation methods throughout the project lifetime may mitigate some of the impacts that OSW imposes on environmental resources (NYSERDA 2017a).

6 References

Abdel-Basset, M., A. Gamal, R.K. Chakrabortty, and M. Ryan. 2021. A new hybrid multi-criteria decision-making approach for location selection of sustainable offshore wind energy stations: a case study. *Journal of Cleaner Production* 280(2):124462. https://doi.org/10.1016/j.jclepro.2020.124462

Abramic, A., A. García Mendoza, and R. Haroun. 2021. Introducing offshore wind energy in the sea space: Canary Islands case study developed under maritime spatial planning principles. *Renewable and Sustainable Energy Reviews* 145(2021):111119. https://doi.org/10.1016/j.rser.2021.111119

Arnett, E.B., W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A. Jain, G. Johnson, J. Kerns, R. Koford, C. Nicholson, T. O'Connell, M. Piorkowski, R. Tankersley, Jr.. 2008. Patterns of bat fatalities at wind energy facilities in North America. *Journal of Wildlife Management* 72(1):61–78. https://doi.org/10.2193/2007-221

Bailey, H., B. Senior, D. Simmons, J. Rusin, G. Picken, and P.M. Thompson. 2010. Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin* 60(6):888–897.

Balazik, M.T., K. Reine, A.J. Spells, C.A. Fredrickson, M.L. Fine, G.C. Garman, and S.P. Mcininch. 2012. The potential for vessel interactions with adult Atlantic sturgeon in the James River, Virginia. *North American Journal of Fisheries Management* 32(6):1062–1069.

Baston, D. 2023. Exactextractr: Fast Extraction from Raster Datasets Using Polygons. Manual. https://cran.r-project.org/web/packages/exactextractr/exactextractr.pdf

Bergstrom, L., F. Sundqvist, and U. Bergstrom. 2013. Effects of an offshore windfarm on temporal and spatial patterns in the demersal fish community. *Marine Ecology Progress Series* 485:199–210.

Bernasconi, M., C. Choirat, and R. Seri. 2009. *The Analytic Hierarchy Process and the Theory of Measurement*." University of Venice "Ca' Foscari. Department of Economics, Working Papers 56 (January). https://doi.org/10.2307/27784145

Blair, H.B., N.D. Merchant, A.S. Friedlaender, D.N. Wiley, and S.E. Parks. 2016. Evidence for ship noise impacts on humpback whale foraging behaviour. *Biology Letters* 12(8):20160005.

Brand, A. 2021. Explosives use in decommissioning—guide for assessment of risk (EDGAR): II determination of sound exposure levels for open water blasts and severance of conductors and piles from below the seabed. *Modelling* 2:534–554.

Bureau of Ocean Energy Management (BOEM). 2015. *Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic Outer Continental Shelf Offshore North Carolina*: Revised Environmental Assessment. OCS EIS/EA BOEM 2015-038.

———. 2016. *Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic Outer Continental Shelf Offshore New York: Revised Environmental Assessment*. OCS EIS/EA BOEM 2016-070. US Department of the Interior, Bureau of Ocean Energy Management, Herndon, VA. http://www.boem.gov/NY-Public-EA-June-2016/

Cassoff, R.M., K.M. Moore, W.A. McLellan, S.G. Barco, D.S. Rotstein, M.J. Moore. 2011. Lethal entanglement in baleen whales. *Diseases of Aquatic Organisms* 96:175–185.

Christiansen, N., U. Daewel, B. Djath, and C. Schrum. 2022. Emergence of large scale hydrodynamic structures due to atmospheric offshore wind farm wakes. *Frontiers in Marine Science* 9:818501.

Cooperman, A., P. Duffy, M. Hall, E. Lozon, M. Shields, and W. Musial. 2022. *Assessment of Offshore Wind Energy Leasing Areas for Humboldt and Morro Bay Wind Energy Areas, California*. NREL/TP-5000-82341. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy22osti/82341.pdf

Croll, D.A., A.A. Ellis, J. Adams, A.S.C.P. Cook, S. Garthe, M. Wing Goodale, C Scott Hall, et al. 2022. Framework for assessing and mitigating the impacts of offshore wind energy development on marine birds. *Biological Conservation* 276:109795. https://doi.org/10.1016/j.biocon.2022.109795

Curtice, C., J. Cleary, E. Scumchenia, and P.N. Halpin. 2019. *Marine-Life Data and Analysis Team (MDAT) Technical Report on the Methods and Development of Marine-Life Data to Support Regional Ocean Planning and Management*. Prepared on Behalf of the Marine-Life Data and Analysis Team (MDAT).

Daewel, U., N. Akhtar, N. Christiansen, and C. Schrum. 2022. Offshore wind farms are projected to impact primary production and bottom water deoxygenation in the North Sea. *Communications Earth & Environment* 3(292):1–8. Doi: 10.1038/s43247-022-00625-0

David, J.A. 2006. Likely sensitivity of bottlenose dolphins to pile-driving noise. *Water and Environment Journal* 20:48–54.

Deakin, Z., A. Cook, F. Daunt, A. McCluskie, N. Morley, E. Witcutt, L. Wright, and M. Bolton. 2022. *A Review to Inform the Assessment of the Risk of Collision and Displacement in Petrels and Shearwaters from Offshore Wind Developments in Scotland*. Report Produced for the Scottish Government. https://www.researchgate.net/publication/366139542

Delibes, M., P. Ferreras, and P. Gaona. 2001. Attractive sinks, or how individual behavioural decisions determine source–sink D\dynamics. *Ecology Letters* 4(5):401–403.

Díaz, H., and C. Guedes Soares. 2020. An integrated GIS approach for site selection of floating offshore wind farms in the Atlantic continental European coastline. *Renewable and Sustainable Energy Reviews* 134:110328. https://doi.org/10.1016/j.rser.2020.110328

Díaz, H., and C. Guedes Soares. 2022. “A novel multi-criteria decision-making model to evaluate floating wind farm locations. *Renewable Energy* 185:431–54. https://doi.org/10.1016/j.renene.2021.12.014

Duncan, E.M., Z.L.R. Botterell, A.C. Broderick, T.S. Galloway, P.K. Lindeque, A. Nuno, and B.J. Godley. 2017. A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. *Endangered Species Research* 34:431–448.

Erbe, C. 2009. Underwater noise from pile driving in Moreton Bay. *Australian Acoustical Society Queensland* 37(3):87–92.

ESRI. 2023. Understanding Overlay Analysis. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/understanding-overlay-analysis.htm

ESRI ArcGIS Pro. 2021. ESRI.

Farr, H., B. Ruttenberg, R.K. Walter, Y-H. Wang, and C. White. 2021. Potential environmental effects of deepwater floating offshore wind energy facilities. *Ocean and Coastal Management* 207:1–16.

Fox, A.D., and I.K. Petersen. 2019. Offshore wind farms and their effects on birds. Dansk Orn. Foren. *Tidsskr*. 113:86–101.

Fliessbach, K.L., K. Borkenhagen, N. Guse, N. Markones, P. Schwemmer, and S. Garthe. 2019. A ship traffic disturbance vulnerability index for northwest European seabirds as a tool for marine spatial planning. *Frontiers in Marine Science* 6:192–192.

Furness, R.W., H.M. Wade, and E.A. Masden. 2013. Assessing vulnerability of marine bird populations to offshore wind farms. *Journal of Environmental Management* 119:56–66. https://doi.org/10.1016/j.jenvman.2013.01.025

Garthe, S., and O. Hüppop. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. *Journal of Applied Ecology* 41(4):724–34. https://doi.org/10.1111/j.0021-8901.2004.00918.x

Geo-Marine Inc. 2010. *Ocean Wind Power Ecological Baseline Studies Final Report - Volume 1*: *Overview, Summary, and Application*. Report by Geo-Marine Inc.

Glasby, T.M., S.D. Connell, M.G. Holloway, and C.L. Hewitt. 2007. Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions? *Marine Biology* 151(3):887–895. Doi: 10.1007/s00227-006-0552-5

Goetsch, C., J. Gulka, K.D. Friedland, A.J. Winship, J. Clerc, A. Gilbert, H.F. Goyert, I.J. Stenhouse, K.A. Williams, J.R. Willmott, M.L. Rekdahl, H.C. Rosenbaum, and E.M. Adams. 2023. Surface and subsurface oceanographic features drive forage fish distributions and aggregations: implications for prey availability to top predators in the US Northeast shelf ecosystem. *Ecology and Evolution* 13(7):.

Goodale, M.W., and A. Milman. 2019. Assessing the cumulative exposure of wildlife to offshore wind energy development. *Journal of Environmental Management* 235(April):77–83. https://doi.org/10.1016/j.jenvman.2019.01.022

Goodale, M.W., and A. Milman. 2016. Cumulative adverse effects of offshore wind energy development on wildlife. *Journal of Environmental Planning and Management* 59(1):1–21. https://doi.org/10.1080/09640568.2014.973483

Goodale, M.W., and I.J. Stenhouse. 2016. A conceptual model to determine vulnerability of wildlife populations to offshore wind energy development. *Human-Wildlife Interactions* 10(1):53–61. https://doi.org/10.26077/1d31-m472

Guest, E.E., B.F. Stamps, N.D. Durish, A.M. Hale, C.D. Hein, B.P. Morton, S.P. Weaver, and S.R. Fritts. 2022. An updated review of hypotheses regarding bat attraction to wind turbines. *Animals* 12(3):343.

Hall-Spencer, J., V. Allain, and J.H. Fosså. 2002. Trawling damage to Northeast Atlantic ancient coral reefs. *Proceedings of The Royal Society of London Series B-Biological Sciences* 269 (1490):507–511.

Halpern, B.S., K.A. Selkoe, F. Micheli, and C.V. Kappel. 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. *Conservation Biology* 21(5):1301–1315. Doi: 10.1111/j.1523-1739.2007.00752.x

Haney, J.C. 1986. Seabird affinities for gulf stream frontal eddies: responses of mobile marine consumers to episodic upwelling. *Journal of Marine Research* 44 (2):361–84.

Hannay, D.E., and M. Zykov. 2022. *Underwater Acoustic Modeling of Detonations of Unexploded Ordnance (UXO) for Ørsted Wind Farm Construction, U.S. East Coast*. Document 02604, Version 4.4. Report by JASCO Applied Sciences for Ørsted.

Hayrapetyan, L.R. 2019. Random consistency indices for analytic hierarchy processes. *International Journal of Business, Marketing, and Decision Sciences* 12(1):31–43.

Hunt, G.L., and D.C. Schneider. 1987. Scale-Dependent Processes in the Physical and Biological Environment of Marine Birds. *Seabirds: Feeding Biology and Role in Marine Ecosystems*. Cambridge University Press, Cambridge, 7–41.

Jahan, A., and K.L. Edwards. 2013. Multi-Criteria Decision-Making for Materials Selection. In *Multi-Criteria Decision Analysis for Supporting the Selection of Engineering Materials in Product Design*, 31–41. Elsevier. https://doi.org/10.1016/B978-0-08-099386-7.00003-9

Jensen, A.S., and G.K. Silber. 2004. *Large Whale Ship Strike Database*. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-F/OPR:37.

Kelsey, E.C., J.J. Felis, M. Czapanskiy, D.M. Pereksta, and J. Adams. 2018. Collision and displacement vulnerability to offshore wind energy infrastructure among marine birds of the Pacific outer continental shelf. *Journal of Environmental Management* 227:229–247. https://doi.org/10.1016/j.jenvman.2018.08.051

Kinlan, B., M. Poti, A. Drohan, D. Packer, M. Nizinski, D. Dorfman, and C. Caldow. 2013. Digital Data: Predictive Models of Deep-Sea Coral Habitat Suitability in the U.S. Northeast Atlantic and Mid-Atlantic Regions. http://coastalscience.noaa.gov/projects/detail?key=35

Kinlan, B.P., M. Poti, A.F. Drohan, D.B. Packer, D.S. Dorfman, and M.S. Nizinski. 2020. Predictive modeling of suitable habitat for deep-sea corals offshore the Northeast United States. *Deep Sea Research Part I: Oceanographic Research Papers* 158(April):103229. https://doi.org/10.1016/j.dsr.2020.103229

Kite-Powell, H.K., A. Knowlton, and M. Brown. 2007. *Modeling the Effect of Vessel Speed on Right Whale Ship Strike Risk*. Project report for NOAA/NMFS Project NA04NMF47202394, April 2007.

Kraus, S.D., R.D. Kenney, and L. Thomas. 2019. *A Framework for Studying the Effects of Offshore Wind Development on Marine Mammals and Turtles*. Report prepared for the Massachusetts Clean Energy Center, Boston, MA 02110, and the Bureau of Ocean Energy Management. May 2019.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet, and M. Podesta. 2001. Collisions between Ships and Whales. *Marine Mammal Science* 17:35–75.

Landau, W.M. 2021. The targets R package: a dynamic make-like function-oriented pipeline toolkit for reproducibility and high-performance computing. *Journal of Open Source Software* 6(57):2959.

LeBlanc, A.R., D. Bourque, T. Landry, J. Davidson, and N.G. MacNair. 2007. *The Predation of Zooplankton by the Blue Mussel (Mytilus edulis) and the Clubbed Tunicate (Styela clava)*. Canadian Technical Report of Fisheries and Aquatic Sciences 2684. Department of Fisheries and Oceans, Gulf Fisheries Centre, Science Branch.

Lindeboom, H.J., H.J. Kouwenhoven, M.J. Bergman, S. Bouma, S. Brasseur, R. Daan, R.C. Fijn, D. de Haan, S. Dirksen, R. van Hal, R. Hille Ris Lambers, R. ter Hofstede, K.L. Krijgsveld, M. Leopold, and M. Scheidat, M. 2011. Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation, *Environmental Research Letters* 6:035101.

Madsen, P.T., M. Whalberg, J. Tougaard, K. Lucke, and P. Tyack. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Marine Ecology Progress Series 309:279–295.

Mahdy, M., and A.S. Bahaj. 2018. Multi criteria decision analysis for offshore wind energy potential in Egypt. *Renewable Energy* 118(2018):278–89. https://doi.org/10.1016/j.renene.2017.11.021

Marine Management Organisation. 2013. *Evaluation of the Current State of Knowledge on Potential Cumulative Effects from Offshore Wind Farms (OWF) to Inform Marine Planning and Marine Licensing*. A report produced for the Marine Management Organisation, pp 71. MMO Project No: 1009. https://doi.org/10.13140/RG.2.2.24812.77447

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. *Marine Seismic Surveys: Analysis and Propagation of Air-gun Signals; and Effects of Air-gun Exposure on Humpback Whales, Sea Turtles, Fishes and Squid*. Report Number R99-15. Prepared for Australian Petroleum Production Exploration Association by Centre for Maine Science and Technology, Western Australia.

Middleton, P., B. Barnhart, and J. Salerno. 2021. *Supporting National Environmental Policy Act Documentation for Offshore Wind Energy Development Related to Munitions and Explosives of Concern and Unexploded Ordinances*. Washington (DC): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2022-012.

Miller, R.G., Z.L. Hutchison, A.K. Macleod, M.T. Burrows, E.J. Cook, K.S. Last, and B. Wilson. 2013. Marine renewable energy development: assessing the Benthic Footprint at multiple scales. *Frontiers in Ecology and the Environment* 11(8):433–440.

Montevecchi, W.A. 2006. Influences of Artificial Light on Marine Birds. In *Ecological Consequences of Artificial Night Lighting*, C. Rich and T. Longcore (eds.), 94-113-94–113. Washington, D.C.: Island Press. https://doi.org/10.1111/bph.13539

Morrison, K.M., H.K. Meyer, E.M. Roberts, H.T. Rapp, A. Colaço, and C.K. Pham. 2020. The first cut is the deepest: trawl effects on a deep-sea sponge ground are pronounced four years on. *Frontiers in Marine Science* 7:605281. https://doi.org/10.3389/fmars.2020.605281

Murphy, G.P. 2018. Executive Order No. 08 - Promotes Offshore Wind Energy. New Jersey: The State of New Jersey.

———. 2019. Executive Order No. 92 - To Increase Offshore Wind Goal to 7,500 Megawatts by 2035. New Jersey: The State of New Jersey.

NAMERA. 2020. Sea Bed Forms and Soft Sediments Data Layers. The Nature Conservancy's Northwest Atlantic Ecoregional Assessment. https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/marine/namera/namera/Pages/default.aspx

Neves, B.D.M., E. Edinger, G.D. Layne, and V.E. Wareham. 2015. Decadal longevity and slow growth rates in the deep-water sea pen *Halipteris finmarchica* (Sars, 1851) (*Octocorallia: Pennatulacea*): implications for vulnerability and recovery from anthropogenic disturbance. *Hydrobiologia* 759(1):147–170. Doi: 10.1007/s10750-015-2229-x

New England Fishery Management Council in cooperation with the National Marine Fisheries Service (NMFS). 2017. *Canyon HAPCs*, Section 3.1.8 in Volume 2: EFH and HAPC Designation Alternatives and Environmental Impacts. Omnibus Essential Fish Habitat Amendment 2. New England Fishery Management Council in cooperation with the National Marine Fisheries Service.

New Jersey Board of Public Utilities and the Interagency Taskforce on Offshore Wind. 2020. New Jersey Offshore Wind Strategic Plan. Ramboll US Corporation.

New York State Energy Research and Development Authority (NYSERDA). 2015. *Advancing the Environmentally Responsible Development of Offshore Wind Energy in New York State: A Regulatory Review and Stakeholder Perceptions*. Final Report. NYSERDA Report 15-16. New York State Energy Research and Development Authority, Albany, NY. 228 pp.

NYSERDA (New York State Energy Research and Development Authority). 2017. New York State Offshore Wind Master Plan: NYSERDA Report 17–25. Prepared by: Ecology and Environment Engineering, P.C. New York, New York for New York State Energy Research and Development Authority.

———. 2017a. *New York State Offshore Wind Master Plan: Environmental Sensitivity Analysis*. NYSERDA Report 17-25I. https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/17-25i-Environmental-Sensitivity.pdf

———. 2017b. *New York State Offshore Wind Master Plan: Fish and Fisheries Study*. Final Report. New York State Energy Research and Development Authority. NYSERDA Report 17-25j.

———. 2017c. *New York State Offshore Wind Master Plan*. New York State Energy Research and Development Authority. NYSERDA.

New York State Energy Research and Development Authority (NYSERDA). 2025. "Offshore Wind Planning in the New York Bight: Benthic Habitat Study," NYSERDA Report Number 25-06. Prepared by Henningson, Durham & Richardson Architecture & Engineering, P.C., New York, NY. nyserda.ny.gov/publications

New York State Energy and Research Development Authority (NYSERDA). 2025. "Offshore Wind Planning in the New York Bight: Fish and Fisheries Data Aggregation Study," NYSERDA Report Number 25-07. Prepared by Henningson, Durham & Richardson Architecture & Engineering, P.C., New York, NY. nyserda.ny.gov/publications

New York State Energy Research and Development Authority (NYSERDA). 2025. "Offshore Wind Planning in the New York Bight: Birds and Bats Study," NYSERDA Report Number 25-08. Prepared by Biodiversity Research Institute, Portland, ME. nyserda.ny.gov/publications

New York State Energy and Research Development Authority (NYSERDA). 2025. "Offshore Wind Planning in the New York Bight: Marine Mammals and Sea Turtles Study," NYSERDA Report Number 25-09. Prepared by Henningson, Durham & Richardson Architecture & Engineering, P.C., New York, NY. nyserda.ny.gov/publications

NMFS (National Marine Fisheries Service, U.S. Fish) and Wildlife Service, and Secretariat of Environment and Natural Resources Mexico.) 2011. *Bi-National Recovery Plan for the Kemp's Ridley Sea Turtle (Lepidochelys kempii)*, Second Revision. National Marine Fisheries Service. Silver Spring, Maryland.

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2020. *Endangered Species Act status review of the leatherback turtle (Dermochelys coriacea)*. Report to the National Marine Fisheries Service Office of Protected Resources and U.S. Fish and Wildlife Service.

National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management. 2018. Frank R. Lautenberg Deep-Sea Coral Protection Areas Map & GIS.

National Oceanic and Atmospheric Administration (NOAA). 2023a. Enforcement: Vessel Monitoring. NOAA Fisheries. National Oceanic and Atmospheric Administration.

National Oceanic and Atmospheric Administration (NOAA). 2023b. Northeast Canyons and Seamounts Marine National Monument. National Oceanic and Atmospheric Administration.

National Oceanic and Atmospheric Administration (NOAA). 2023c. The Greater Atlantic Region ESA Section 7 Mapper. NOAA Fisheries National Oceanic and Atmospheric Administration.

National Oceanic and Atmospheric Administration (NOAA). 2023d. Bottom Trawl Surveys Data catalog. InPort. Northeast Fisheries Science Center (NEFSC). National Oceanic and Atmospheric Administration.

National Oceanic and Atmospheric Administration (NOAA). 2023e. Northeast Fisheries Observer Data. NOAA Fisheries. National Oceanic and Atmospheric Administration. Available upon request from NOAA.

NOAA (National Oceanic and Atmospheric Administration). 2023f. Layers of the Ocean. National Oceanic and Atmospheric Administration. Accessed 23 June 2023 from Layers of the Ocean | National Oceanic and Atmospheric Administration (noaa.gov) https://www.noaa.gov/jetstream/ocean/layers-of-ocean

National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries). 2023. 2017–2023 Minke Whale Unusual Mortality Event along the Atlantic Coast. Accessed July 2023. https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2023-minke-whale-unusual-mortality-event-along-atlantic-coast

Pebesma, E. 2018. Simple features for R: standardized support for spatial vector data. *The R Journal* 10(1):439–66.

Pebesma, E., and R. Bivand. 2023. *Spatial Data Science: With Applications in R*. 1st ed. Boca Raton: Chapman and Hall/CRC. https://doi.org/10.1201/9780429459016

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S. Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, M.B. Halvorsen, S. Lokkeborg, P.H. Rogers, B.L. Southall, D.G. Zeddies, and W.N. Tavolga. 2014. *Sound Exposure Guidelines for Fishes and Sea Turtles*: a Technical Report Prepared by ANSI-Accredited Standards Committee S3/SC1 and Registered with ANSI. SpringerBriefs in Oceanography, ASA Press.

R Core Team. 2021. R: A Language and Environment for Statistical Computing. http://www.r-project.org

Randall, A.L., J.A. Jossart, B.M. Jensen, B.H. Duplantis, and J.A. Morris, Jr. 2022a. *Development of the Central Atlantic Wind Energy Areas*. BOEM. https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/BOEM_NCCOS_JointReport_DraftWEAs_FINAL.pdf

Randall, A.L., J.A. Jossart, T. Matthews, M. Steen, I. Boube, S. Stradley, R. Del Rio, et al. 2022b. *Preliminary Wind Energy Areas (WEAs) in the Gulf of Mexico*. United States Department of the Interior BUREAU OF OCEAN ENERGY MANAGEMENT New Orleans Office.

Raoux, A., S. Tecchio, J-P. Pezy, G. Lassalle, S. Degraer, D. Wilhelmsson, M. Cachera, B. Ernande, C. Le Guen, H. M. Haraldsson, K. Grangeré, F. Le Loc'h, L, J-C. Dauvin, and N. Niquil. 2017. Benthic and fish aggregation inside an offshore wind farm: which effects on the trophic web functioning? *Ecological Indicators* 72:33–46.

Roach, M., A. Revill, and M.J. Johnson. 2022. Co-existence in practice: a collaborative study of the effects of the westermost rough offshore wind development on the size distribution and catch rates of a commercially important lobster (*Homarus gammarus*) population. *ICES Journal of Marine Science* 79:1175–1186.

Rodríguez, A., P. Dann, and A. Chiaradia. 2017. Reducing light-induced mortality of seabirds: high pressure sodium lights decrease the fatal attraction of shearwaters. *Journal for Nature Conservation* 39:68–72. https://doi.org/10.1016/j.jnc.2017.07.001

Rolland, R.M., W.A. McLellan, M.J. Moore, C.A. Harms, E.A. Burgess, and K.E. Hunt. 2017. Fecal glucocorticoids and anthropogenic injury and mortality in North Atlantic right whales *Eubalaena glacialis*. *Endangered Species Research* 34:417–429.

Ronconi, R.A., K.A. Allard, and P.D. Taylor. 2015. Bird interactions with offshore oil and gas platforms: review of impacts and monitoring Techniques. *Journal of Environmental Management* 147 (January):34–45. https://doi.org/10.1016/j.jenvman.2014.07.031

Saaty, R.W. 1987. The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling* 9(3–5):161–76. https://doi.org/10.1016/0270-0255(87)90473-8

Saaty, T.L. 1977. A scaling method for priorities in hierarchical structures. J*ournal of Mathematical Psychology* 15(3):234–81. https://doi.org/10.1016/0022-2496(77)90033-5

Saaty, T.L. 1980. *The Analytic Hierarchy Process*. McGraw-Hill, New York.

Saaty, T.L. 2004. Fundamentals of the analytic network process — dependence and feedback in decision-making with a single network. *Journal of Systems Science and Systems Engineering* 13(2):129–57. https://doi.org/10.1007/s11518-006-0158-y

Sammarco, P, A. Atchison, and G. Boland. 2004. Expansion of coral communities within the Northern Gulf of Mexico via offshore oil and gas platforms. *Marine Ecology Progress Series* 280:129–143. https://doi.org/10.3354/meps280129

Schick, R.S., S.D. Kraus, R.M. Rolland, A.R. Knowlton, P.K. Hamilton, and M. Pettis. 2013. Using hierarchical bayes to understand movement, health, and survival in the endangered North Atlantic right whale. *PLoS ONE* 8(6):e64166.

Schwemmer, P., B. Mendel, N. Sonntag, V. Dierschke, and S. Garthe. 2011. Effects of ship traffic on seabirds in offshore waters: implications for marine conservation and spatial planning. *Ecological Applications* 21(5):1851–60. https://doi.org/10.1890/10-0615.1

Shealer, D.A. 2002. Foraging behavior and food of seabirds. *Biology of Marine Birds* 14:137–77.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4):273–275.

Southall, B.L., D. Tollit, J. Amaral, C.W. Clark, and W.T. Ellison. 2023. Managing human activity and marine mammals: a biologically based, relativistic risk assessment framework. *Frontiers in Marine Science* 10 (February):1090132. https://doi.org/10.3389/fmars.2023.1090132

Sparks, L.M., and A. DiMatteo. 2023. Sea Turtle Distribution and Abundance on the East Coast of the United States. Technical Report prepared for Naval Undersea Warfare Center Division Newport. June 2023.

Stantec. 2016. *Long-Term Bat Monitoring on Islands, Offshore Structures, and Coastal Sites in the Gulf of Maine, Mid-Atlantic, and Great Lakes - Final Report*. Report by Stantec Consulting Services Inc. to U.S. Department of Energy. 171 pp.

Stepanuk, J., E. Adams, S. Dodgin, S., A. Gilbert., W. Goodale, W., and E. Jenkins, E. 2022. *Supporting Offshore Wind Siting in the Gulf of Maine – Marine Birds*. Portland, ME: Biodiversity Research Institute.

Synthesis of Environmental Effects Research (SEER). 2022. *Benthic Disturbance from Offshore Wind Foundations, Anchors, and Cables. U.S. Offshore Wind Synthesis of Environmental Effects Research*. Report by National Renewable Energy Laboratory and Pacific Northwest National Laboratory for the U.S. Department of Energy, Wind Energy Technologies Office.

ten Brink, T.S., and D. Dalton. 2018. Perceptions of commercial and recreational fishers on the potential ecological impacts of the Block Island Wind Farm (US). *Frontiers in Marine Science* 5:439.

Thorne, L.H., H.J. Foley, R.W. Baird, D.L. Webster, Z.T. Swaim, and A.J. Read. 2017. Movement and foraging behavior of short-finned pilot whales in the Mid-Atlantic Bight: importance of bathymetric features and implications for management. *Marine Ecology Progress Service* 584:245–257. https://doi.org/10.3354/meps12371

U.S. Department of the Interior, Minerals Management Service, Mapping and Boundary Branch (DOI MMS MBB). 1999. *Boundary Development on the Outer Continental Shelf*. MMS 99-0006. 99-0006.pdf (boem.gov).

von Benda-Beckmann, A.M., G. Aarts, H.Ö. Sertlek, K. Lucke, W.C. Verboom, R.A. Kastelein, D.R. Ketten, R. van Bemmelen, F.P.A. Lam, R.J. Kirkwood, M.A. Ainslie. 2015. Assessing the impact of underwater clearance of unexploded ordnance on harbour porpoises (*Phocoena phocoena*) in the Southern North Sea. *Aquatic Mammals* 41(4):503–523.

Van Berkel, J., H. Burchard, A. Christensen, L.O. Mortensen, O.S. Petersen, and F. Thomsen. 2020. The effects of offshore wind farms on hydrodynamics and implications for fishes. *Oceanography* 33(4):108–117.

Vinhoza, A., and R. Schaeffer. 2021. Brazil's offshore wind energy potential assessment based on a spatial multi-criteria decision analysis. *Renewable and Sustainable Energy Reviews* 146(August):111185. https://doi.org/10.1016/j.rser.2021.111185

Viola, S.M., H.M. Page, S.F. Zaleski, R.J. Miller, B. Doheny, J.E. Dugan, D.M. Schroeder, and S.C. Schroeter. 2018. Anthropogenic Disturbance Facilitates a Non-Native Species on Offshore Oil Platforms. *Journal of Applied Ecology* 55(4):1583–1593.

Watling, L., and E.A. Norse. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. *Conservation Biology* 12(6):1180–97. https://doi.org/10.1046/j.1523-1739.1998.0120061180.x

Wegner, A.S., E. Harvey, S. Wilson, C. Rawson, S.J. Newman, D. Clarke, B.J. Saunders, N. Browne, M.J. Travers, J.L. Mcilwain, P.L.A. Erftemeijer, J.P.A. Hobbs,, D. Mclean, M. Depczynski, and R.D. Evans. 2017. A Critical Analysis of the Direct Effects of Dredging on Fish, *Fish and Fisheries*, Wiley. 18: 967–985.

Williams, R., and P. O'Hara. 2010. Modelling ship strike risk to fin, humpback and killer whales in British Columbia, Canada. *Journal of Cetacean Research and Management* 11:1–8.

Willmott, J.R., G. Forcey, and A. Kent. 2013. *The Relative Vulnerability of Migratory Bird Species to Offshore Wind Energy Projects on the Atlantic Outer Continental Shelf: An Assessment Method and Database.* OCS Study BOEM 2013-207. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Herndon, VA. 275 pp.

Winship, A.J., B.P. Kinlan, T.P. White, J.B. Leirness, and J. Christensen. 2018. *Modeling At-Sea Density of Marine Birds to Support Atlantic Marine Renewable Energy Planning: Final Report*. OCS Study BOEM 2018-010. U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Sterling, VA. 67 pp.

Zahedi, F. 1986. The analytic hierarchy process: a survey of the method and its applications. *Interfaces* 16(4):96–108.

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on X, Facebook, YouTube, or Instagram.

New York State Energy Research and Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov