New York State Offshore Wind Master Plan

Environmental Sensitivity Analysis

NYSERDA Report 17-25i
November 2017

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New York State Offshore Wind Master Plan Environmental Sensitivity Analysis

Final Report

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Notice

No State or federal agency or entity has committed to any specific course of action with respect to the future development of offshore wind projects discussed in this study. This study does not commit any governmental agency or entity to any specific course of action, or otherwise pre-determine any outcome under State or Federal law. Any future offshore wind project will be required to meet all State and Federal permit or license approvals, including but not limited to under the Coastal Zone Management Act, prior to proceeding with development.

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

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Acronyms and Abbreviations

AoA	Area of Analysis
BGEPA	Bald and Golden Eagle Protection Act
BMP	Best Management Practice
BOEM	Bureau of Ocean Energy Management
DMA	dynamic management area
DOS	New York State Department of State
EA	environmental assessment
EFH	essential fish habitat
EMF	electric and magnetic fields
ESA	Endangered Species Act
GIS	geographic information system
HDD	horizontal directional drilling
HRG	high-resolution geophysical
MBTA	Migratory Bird Treaty Act
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MW	megawatt
NEFSC	Northeast Fisheries Science Center
NJDEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NYSERDA	New York State Energy Research and Development Authority
OCS	outer continental shelf
OCSLA	Outer Continental Shelf Lands Act
OREP	(BOEM) Office of Renewable Energy Programs
OSA	offshore study area
PTS	permanent threshold shift
right whale	North Atlantic right whale
SLA	Submerged Lands Acts
SPI	sediment profile imaging
Study	Environmental Sensitivity Analysis
U.S.C.	United States Code
WEA	Wind Energy Area

Executive Summary

This Environmental Sensitivity Analysis (Study) was conducted to identify areas of biological importance within the offshore Area of Analysis (AoA) using a risk assessment and sensitivity model. The model incorporated information on marine resources, or “receptors;” impacts on these resources, or “stressors;” and the level of risk associated with the stressors on a particular receptor during each phase of wind farm development. Results of the model were used to facilitate the identification of areas for consideration for offshore wind development and will inform future developers, potentially reducing the uncertainty and costs of their proposals.

For this Study, environmental sensitivity is defined as the relative potential susceptibility to alteration or influence from activities associated with offshore wind development. For example, since fish are potentially sensitive to localized turbidity, which may result from turbine installation, areas where fish and turbine installation may co-occur may be regions with elevated sensitivity relative to areas where they would not co-occur.

This Study 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 offshore wind development (i.e., pre-construction, construction, and post-construction) within the AoA. The AoA is 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. The marine resources were assessed as receptor groups (e.g., fish, benthic species, right whales, phocid seals, low-frequency cetaceans), which were expected to respond similarly to the identified stressors. Concurrent studies also appended to the New York State Offshore Wind Master Plan, and a study specific literature review informed the identification of receptors and stressors and the risk assessment.

A risk assessment was conducted, through which matrices were developed to differentiate relative risks. These risk matrices were constructed of defined criteria under which risk scores of 1 through 5 were assigned to the receptor groups for each potential stressor. This assessment process considered the probability of impact from an identified stressor and the vulnerability of the receptor group to the potential stressor. Based on the risk assessment described in the relative risk matrices, regulatory context,

permitting requirements, Bureau of Ocean Energy Management (BOEM) recommendations, seasonality, and other additional factors, sensitivity weight values of 1 through 5 were determined for receptor groups for each phase of offshore wind development.

These sensitivity weight values were incorporated into a sensitivity model, through which a series of seasonal and annual comparative maps were produced of the potential sensitivity of receptor groups during each of the offshore wind development phases. A series of overlay analysis methods were examined to determine the best-suited modeling technique. After preliminary evaluation, the weighted sum model (also known as the linear weighted method) was chosen for the modeling process. The model used comprehensive data sets that represented relative occurrence and temporal trends of the receptor groups within the AoA. This selection of input data was informed by concurrent studies.

The mapping outputs from the modeling exercise, along with other studies and tools, informed New York State's preliminary identification of wind energy areas in the AoA for BOEM's consideration. The output maps displayed seasonal sensitivity shifts for all receptor groups. Specifically, in all phases of offshore wind development, sensitivity was lower throughout the AoA during the fall and higher during the spring. Sensitivity was also consistently greater along the continental shelf slope and Hudson Canyon.

1 Introduction

This Environmental Sensitivity Analysis (Study) is one of a collection of studies prepared on behalf of New York State in support of the New York State Offshore Wind Master Plan. These studies provide information related to a variety of potential environmental, social, economic, regulatory, and infrastructure-related issues associated with planning for future offshore wind energy development off the coast of the State. In embarking on these studies, the State initially focused on a 16,740-square-mile (43,356-square-kilometer) area of the ocean extending from the south shore 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. This area was initially identified by the New York State Department of State (DOS) as part of its two-year Offshore Atlantic Ocean study (the "offshore study area [OSA]") (DOS 2013) (Figure 1). Each of the State's individual studies identifies an Area of Analysis (AoA), which is the geographic scope of analysis for that respective study. The AoA for this Study is described below in Section 1.2.

The State envisions that its collection of studies will form a knowledge base for the area off the coast of New York State that serves a number of purposes, including: (1) informing the preliminary identification of potential wind energy areas (WEAs) that were submitted to the Bureau of Ocean Energy Management (BOEM) on October 2, 2017 for consideration and further analysis; (2) providing current information about potential environmental and social sensitivities, economic and practical considerations, and regulatory requirements associated with any future offshore wind energy development; (3) identifying measures that could be considered or implemented with offshore wind projects to avoid or mitigate potential risks involving other uses and/or resources; and (4) informing the preparation of a Master Plan to articulate New York State's vision of future offshore wind development. The Master Plan identifies potential future WEAs for BOEM's consideration, discusses the State's goal of encouraging the development of 2,400 megawatts (MW) of wind energy off the New York State coast by 2030, and sets forth suggested guidelines and best management practices (BMPs) that the State will encourage to be incorporated into future offshore wind energy development.

Each of the studies was prepared in support of the larger effort and was shared for comment with federal and State agencies, indigenous nations, and relevant stakeholders, including nongovernmental organizations and commercial entities, as appropriate. The State addressed comments and incorporated feedback input into the studies. Feedback from these entities helped to strengthen the quality of the studies, and helped to ensure that these work products will be of assistance to developers of proposed offshore wind projects in the future. A summary of the comments and issues identified by these external parties is included in the *Outreach and Engagement Summary*, which is appended to the Master Plan.

The Energy Policy Act of 2005 amended Section 8 of the Outer Continental Shelf Lands Act (OCSLA) to give BOEM the authority to identify offshore wind development 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 farms. The State recognizes that all development in the OCS is subject to future review processes and decision-making by BOEM and other federal and State agencies. Neither this collection of studies nor the State's Master Plan 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 New York State coast, provide a resource for the various stakeholders, and encourage the achievement of the State's offshore wind energy goals.

1.1 Objectives

The objective of this Study is to develop a weighting sum model and map products that will allow for a comparative analysis of the potential sensitivities to construction and operation of offshore wind facilities for marine resources within the AoA. The Study considers activities that may occur during pre-construction, construction, and post-construction of offshore wind facilities. The AoA for this Study is 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 1). This Study is intended to serve as a planning level tool for identifying relative environmental sensitivity spatially in the AoA. In other words, does one region of the AoA have greater relative environmental sensitivity of marine resources to offshore wind development than another region? The resulting maps indicate areas of biological importance to facilitate the identification of areas for consideration for offshore wind development and inform developers, potentially reducing the uncertainty and costs of their proposals.

1.2 Scope of Study

Environmental sensitivity within the AoA is defined in this Study as the relative potential susceptibility to alteration or influence from activities associated with offshore wind development. For example, since fish are potentially sensitive to localized turbidity, which may result from turbine installation, areas where fish and turbine installation may co-occur may be regions with elevated sensitivity relative to areas where they would not co-occur. The environmental sensitivity model framework developed under this Study is based on a literature synthesis of potential impacts to marine resources from offshore wind development, findings from concurrent independent studies developed as part of the New York State offshore wind master planning process, and other referenced ranking and weighting studies (see Section 2.1). As part of the model framework, this Study examines seasonal differences in site use by migratory species and considers potential environmental risk to a variety of marine resources. It does not analyze any potential impacts of offshore wind development regarding human uses, costs, engineering concerns, or other factors.

The overall approach of this Study was to first conduct a risk assessment that identified risk and potential impacts for selected marine resources, followed by the development of a weighted sum model and the resulting sensitivity maps (model outputs). Risk is defined as the potential that marine resources may experience danger or harm when exposed to certain stressors associated with offshore wind activities (e.g., bottom surveys, pile driving).

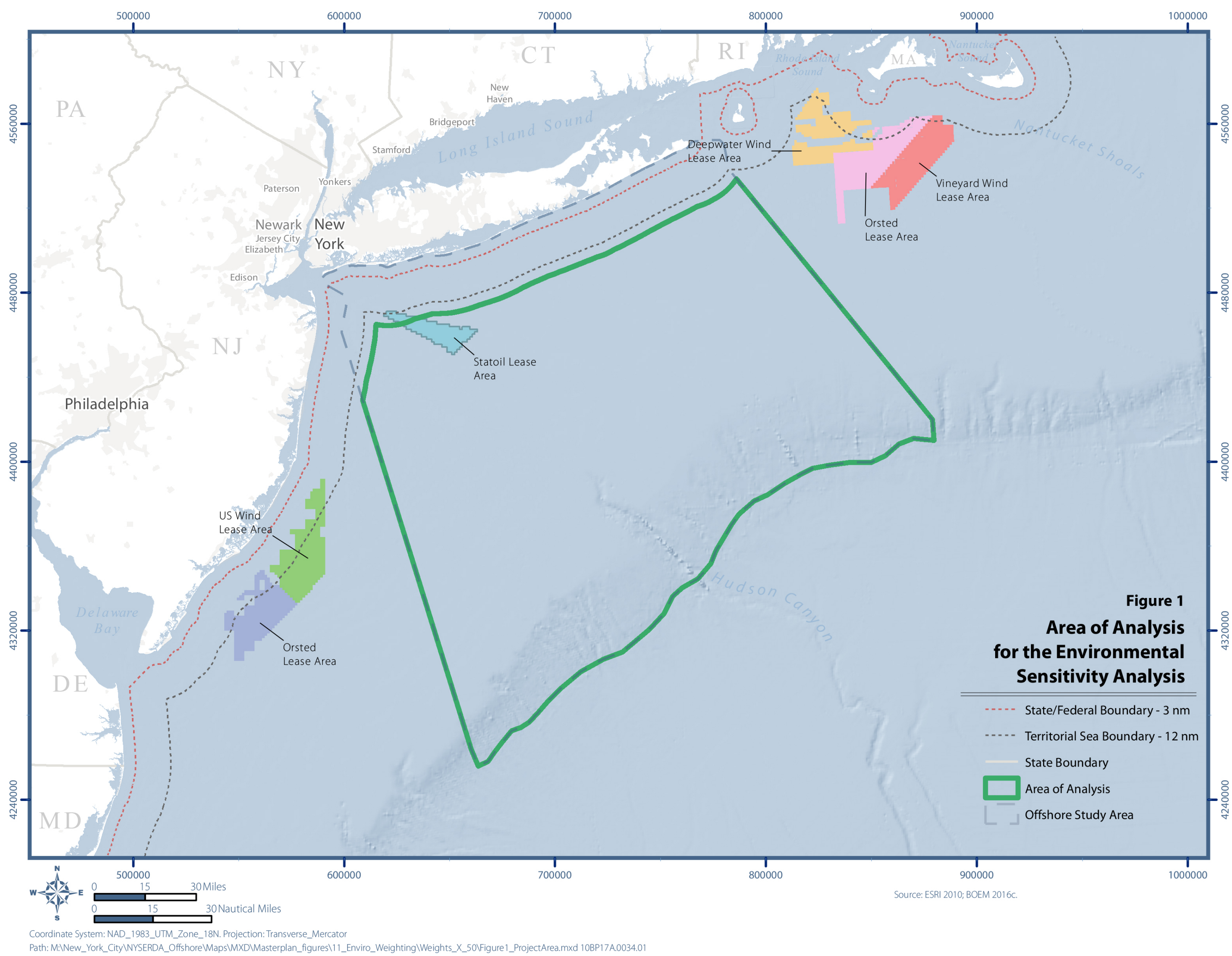
The risk assessment matrices, defined in Section 2.1, reflect differences among potential stressors regarding potential risks to key marine resources, referred to in this Study as receptors (see Section 2.2). Receptors are groups of species that are expected to respond similarly to a stressor. Species were grouped together based on similar permitting requirements, BOEM recommendations and requirements, or concerns such as protected species status. Sensitivity weight values of 1 through 5 were then determined for receptor groups for each phase of offshore wind development based on the risk assessment described in the relative risk matrix, regulatory context, permitting requirements, BOEM recommendations, seasonality, and other additional factors. These weighting values were then applied using a weighted sum model to produce maps of relative sensitivity throughout the AoA. The sensitivity mapping developed in this Study helped the State identify areas with the lowest potential biological sensitivity in the AoA. These areas, along with results from studies that address other offshore wind development factors, were submitted to BOEM for further consideration and analysis on 29 September 2017. The resulting sensitivity maps will serve to inform future offshore wind developers working in the AoA about areas of biological importance, potentially reducing the uncertainty and costs of specific proposals.

Concurrent species-specific studies have been conducted for many of the marine resources addressed in this Study; therefore, this Study summarizes the general environmental risks at a high level. The species and stressors identified in the concurrent studies informed this Study. However, several of the AoAs for the concurrent studies were expanded after the initial analyses. Due to differences in AoAs between this Study and some of the concurrent studies, there may be slight differences in the species considered in the final concurrent studies and this Study; these differences were taken into account in identifying the areas for BOEM's consideration. For additional details on the marine resources and associated potential risks, refer to the independent studies (see Section 2.1 for a full list of the independent studies).

Section 1 provides an introduction to the scope and objectives of the Study. Section 2 provides a general synthesis of the literature review regarding receptors and stressors and the resulting risk matrices for each of three phases of offshore wind development: pre-construction, construction, and post-construction. Section 3 outlines the modeling process, including a description of the input data layers and model selection and process. Section 4 presents maps of the model outputs and describes the results from the weighted sum model for environmental sensitivity. Finally, Section 5 describes general conclusions drawn from the model results.

Figure 1. Area of Analysis for the Environmental Sensitivity Analysis.

Source: ESRI 2010; BOEM 2016c



1.3 Agency and Stakeholder Engagement

Agency and stakeholder feedback was an important element of this environmental sensitivity analysis in identifying relative sensitivity to marine resources within the AoA. This Study was updated to reflect agency and stakeholder feedback; however, it does not necessarily reflect the commenters' opinions.

The State provided a first draft of this Study to 16 entities for review, including State and federal regulators, nongovernmental organizations, and other stakeholders on August 23, 2017 and afforded these agencies and stakeholders the opportunity to submit written comments on the draft's contents. Presentations were given on August 23 and 28, 2017 in which the Study author gave an overview of the document and fielded questions and concerns from participants. In total, the State received 152 comments from State and federal agencies, nongovernmental organizations, and other stakeholders.

The State considered all comments and, when appropriate, revised the Study in response to the comments. In some cases, comments required only a written response, whereas others resulted in edits to the text, figures, maps, or formatting of the Study. In general, most comments fell into one or more of the following categories:

- Provided additional sources of data or literature.
- Requested adjustments to the model to allow for comparisons of results between project phases (see detailed description below in Section 3).
- Requested clarification of the process including risk assessment and modeling.
- Requested that data limitations be more clearly identified and addressed.

Comment responses and/or edits to the Study often fell into one or more of the following updates or outcomes:

- Restructured order of document for more logical flow.
- Refined language concerning criteria and risk assessment including defining key terminology.
- Expanded methodology text and added visualization graphics.
- Added text concerning data restrictions.
- Incorporated additional sources of data or literature into the final Study.
- Adjusted modeling process to allow for between-phase comparisons of results.

2 Risk Assessment

Risk is defined as the potential that marine resources may experience danger or harm when exposed to certain stressors associated with offshore wind activities (e.g., bottom surveys, pile driving). Components of the risk assessment include defining levels of risk (Section 2.1), identification of the receptors to be evaluated (Section 2.2), and an identification of the stressors for particular groups of receptors (Section 2.3). Section 2.3 also summarizes how the risk levels were assigned to each of the stressors by receptor group in the resultant risk matrices.

Risk matrices differentiate levels of risk associated with the probability of an occurrence with the severity of the outcome or harm. Risk matrices address risk comprehensively and can facilitate decision-making. When developing risk matrices for this Study, both the probability of impact and the vulnerability of the receptor to a potential stressor were considered in order to address potential risk. The risk matrices in this Study do not account for mitigation, as mitigation methods will likely vary among developers and projects.

A density-based risk assessment system is an alternative approach to conducting a risk assessment that equates presence with risk. This approach was used in the New Jersey Ecological Baseline Studies Sensitivity Index to determine the distribution and use of ecological resources in waters off the coast of New Jersey (New Jersey Department of Environmental Protection [NJDEP] 2010). A density-based risk assessment system can overestimate or underestimate sensitivity in certain regions because it assigns greater sensitivity to areas with greater densities of individuals rather than taking into account the vulnerability to and likelihood of potential impact on a species. For example, a density-based approach might assign more weight to a region with a large flock of common birds, such as Laughing Gulls, than to an area with fewer—but endangered—North Atlantic right whales (right whales). In addition, previous density-based risk assessment systems have not addressed differences in risk associated with different phases of development.

2.1 Risk Assessment Criteria

Figure 2 presents the risk assessment criteria that were used in this Study. The risk assessment criteria are divided into five levels of potential risk (1–5), including high risk, increased risk, medium risk, low risk, and no risk (Figure 2). The five levels of potential risk are sufficient to differentiate distinct levels of risk without creating overly detailed granularity that might result in more subjective distinctions between more numerous levels of risk. They are also consistent with the scale used in a recent BOEM workshop (BOEM Office of Renewable Energy Programs [OREP] 2017b). Other studies have similarly prioritized marine resources based on the likelihood and significance of stressor interactions with receptors, the nature and scale of the effect, and the occurrence of population-level impacts (European Commission 2016; BOEM OREP 2016a).

Figure 2. Risk Assessment Criteria.

Vulnerability to Stressor

Likelihood of Impact

	Low Vulnerability	High Vulnerability
Low Likelihood	**No/Low Risk**	**Medium/Increased Risk**
High Likelihood	**Medium/Increased Risk**	**High Risk**

Scores describe sensitivity and will range between 1 (low risk) and 5 (high risk).

1 = no risk anticipated; either receptor not vulnerable to potential stressor or not co-located with region of potential impact; potential impacts may also be beneficial.

2 = low risk; receptor minimally vulnerable and/or may be co-located but is capable of avoiding potential stressor if encountered.

3 = medium risk; receptor either vulnerable or likely to encounter potential stressor; risk possible but would be temporary or confined to a small area; no long-term impacts anticipated.

4 = increased risk; receptor vulnerable and likely to encounter potential stressor; potential impact not temporary or confined to a small area; and/or long-term impacts possible but minimal (may impact individuals but not a population).

5 = high risk; co-occurring over large area with highly vulnerable receptor; long-term impacts could potentially be significant (may impact population).

For this Study, the likelihood of impact considers the likelihood that the potential stressor and receptor might co-occur spatially and temporally, as well as the vulnerability of the receptor to the stressor (Figure 2). A receptor may co-occur with a stressor but not be vulnerable to that stressor. For example, dolphins may be present in the region during grab-sampling studies but are not vulnerable to grab sampling. Receptors that are minimally vulnerable may theoretically experience an impact from a stressor, but that impact has either not been well studied or demonstrated. For example, the benthic species included in the Study (corals and sea grasses) are incapable of hearing pile-driving noise (separate from the issue of disturbance), but may detect the vibrations. Thus, they are identified as minimally vulnerable to pile-driving noise. For receptors identified as vulnerable to a stressor, an impact on the receptor has been studied and documented, as in the case of bottom-disturbing surveys and essential fish habitat (EFH), which may experience impacts from direct disturbance and increased turbidity. Highly vulnerable receptors are those that, due to biological and/or behavioral reasons, have a well-documented vulnerability to certain stressors even with minimal exposure. For example, high-frequency cetaceans, due to their hearing specialty, are particularly vulnerable to the high-frequency noise associated with high-resolution geophysical (HRG) surveys.

In addition, the risk criteria also consider the potential temporal and spatial extent of an impact, with greater potential risk assigned when an impact could occur over a greater area or during a longer time frame (Figure 2). A temporary impact is defined as a potential impact that would fade either after the relevant activity stops or within a few weeks. An example of a temporary impact is increased turbidity caused by bottom-disturbing surveys or construction activities. Long-term impacts are those that could persist for years after the activity stops and can include permanent or irreversible impacts. An example of a permanent impact is foundation scouring. A small area was defined as restricted to the immediate area around the stressor source, that is, the nearby vicinity. For example, the area that would be disturbed by grab sampling was considered small, as was the area potentially impacted by the resulting turbidity. A larger area is not restricted to the immediate area around the potential stressor source. For example, depending on the method, pile-driving noise can propagate for thousands of meters.

The criteria also address the degree to which an impact might affect an individual versus a population, with greater risk assigned to situations where some percentage of the population, rather than just a few individuals, might be at risk. Note that this is different for different species; injuring a few harbor porpoises will likely not affect the stock, but injuring a few right whales, especially reproductive females, could affect the population.

All of the risk assessments consider potential risks assuming potential siting of wind farms anywhere in the AoA, although it is recognized that avoidance of certain areas may greatly reduce potential risk. For a risk value of 1, no risk is anticipated. An example is the potential impact of the stressor HRG surveys on the receptor birds. For this analysis, as described in Section 2.3.1.1, noise produced from HRG surveys and its potential impacts on receptor groups was considered. Since the noise produced propagates underwater and birds may occasionally and briefly occupy the upper portion of the water column when exhibiting diving behavior, the two were considered to not co-occur spatially and so a risk value of 1 was assigned. A similar example is the potential impact of the stressor foundation scouring on low-frequency marine mammals, which are not vulnerable to this stressor.

A risk value of 2 results in a low potential risk. An example is the potential impact of the stressor new structure/vessel collision during construction on the receptor sea turtles. While sea turtles could potentially collide with structures or vessels, these animals are highly mobile and could avoid new structures. While boats may still collide with sea turtles, sea turtle occurrence in the AoA is low and so vessel collisions are unlikely. In addition, sea turtle displacement from habitat occupied by turbines is uncertain; therefore, the displacement of sea turtles into shipping lanes is also uncertain (see Section 2.3.2.3).

For a risk value of 3, medium potential risk is anticipated. An example is the potential impact of the stressor pile-driving noise on the receptor phocid seals. Pile driving produces noise that overlaps with the hearing range of phocid seals. However, pile driving would occur farther offshore, so noise would attenuate before reaching the nearshore region (within 20 nautical miles of shore), resulting in lower noise intensities in the nearshore region where seals are typically found. Therefore, impacts would likely consist of shorter-term behavioral changes.

For a risk value of 4, increased potential risk, an example is the potential impacts of the stressor HRG surveys on high-frequency cetaceans, which can include permanent threshold shifts (PTS) in hearing and disturbance. Therefore, permanent impacts on a few individuals are possible. However, the number of individuals impacted would likely be insufficient to affect the population.

For a risk value of 5, high potential risk, an example is the potential impacts of the stressor new structures in the water during post-construction on right whales. The score was based on the potential for permanent habitat displacement and, consequently, potential population-level impacts should such structures be placed within right whale habitat. In addition, right whales may be displaced into shipping lanes. A large vessel strike could result in injury or death to a right whale and, owing to the status of the species, impacts on a few individuals could affect the population.

This environmental sensitivity model is a simplified weighting analysis model tailored to focus on the most relevant environmental issues associated with the identification of areas to propose for further investigation as potential development areas. Other activities associated with offshore wind development, such as routine maintenance activities, are not considered in this analysis, but are addressed in the following independent studies:

- *Birds and Bats Study.*
- *Consideration of Potential Cumulative Effects.*

- *Fish and Fisheries Study.*
- *Marine Mammals and Sea Turtles Study.*
- *Cable Landfall Permitting Study.*
- *Sand and Gravel Resources Study.*

2.2 Identified Receptors

The selection of receptors identified for inclusion in the model framework was based on a review of literature, mapping analyses, concurrent independent studies, and regional agency Environmental Assessments (EAs) regarding offshore wind development (New York State Energy Research and Development Authority [NYSERDA] 2015; NJDEP 2010; Marine Management Organization 2013; BOEM OREP 2016a, 2016b). Receptors are groups of species that are expected to respond similarly to a stressor. Species were grouped together based on similar permitting requirements, BOEM recommendations and requirements, or concerns such as protected species status. Groups expected to occur within the AoA were then selected for the focus of the study. The identified receptors include low-frequency cetaceans, mid-frequency cetaceans, high-frequency cetaceans, right whales, phocid seals, sea turtles, birds, benthic species, EFH, and fish species.

Marine mammals were subdivided into separate receptor groups, taking into consideration the potential impacts from stressors described in Section 2.3. The subdivisions reflect best available science regarding marine mammal hearing groups and expert and agency guidance regarding how impacts on marine mammals should be analyzed. Review of current federal regulations informed the process of selecting species for consideration. All marine mammals are protected under the Marine Mammal Protection Act (MMPA) of 1972 from a "take" (to harass, hunt, capture, kill, or attempt at any such activity [16 United States Code (U.S.C.) 1362]). The marine mammal species that may occur in the AoA are listed in Table 1. The right whale was further separated from the other low-frequency specialists to allow for special consideration of this critically endangered species (National Oceanic and Atmospheric Administration [NOAA] 2016; Southall et al. 2007). Functionally, the potential risk to right whales and other large baleen whales from the included stressors is similar. However, distribution in the AoA differs slightly for right whales than for other large baleen whales. Thus, the right whale data layer will be weighted and input separately in the model, allowing areas where right whales are known to occur to reflect the relatively higher environmental sensitivity of these regions to offshore wind development due to the presence of these whales. The independent *Marine Mammals and Sea Turtles Study*, which is appended to the Master Plan, was used to inform the marine mammal species selection process.

For the risk assessment analysis, all sea turtle species that might occur in the AoA were considered (see Table 1). The independent *Marine Mammals and Sea Turtles Study* was used to inform the sea turtle species selection process. All sea turtles are listed under the Endangered Species Act (ESA) of 1973 and are therefore federally protected. Specifically to the species listed in Table 1, the loggerhead and green sea turtles are listed as threatened, and the leatherback and Kemp's ridley sea turtles are listed as endangered. While all of these species were included in the risk assessment, the subsequent sensitivity mapping exercise used a representative subset of the available data that was of sufficient quality for mapping, focused on loggerheads. The trends and relative occurrence in the AoA for loggerhead turtles were determined to be representative of general sea turtle occurrence in the AoA in the *Marine Mammals and Sea Turtles Study*.

For birds, the data included in this analysis are based on marine bird species that regularly occur within the AoA; these data adequately exhibit distribution and occurrence and address core areas in the AoA for birds as a whole. The Migratory Bird Treaty Act (MBTA) of 1918, 16 U.S.C. 703-718, prohibits the take, kill, or possession of a migratory bird and/or any part, nest, or egg of any such bird. Table 1 contains bird species within the AoA that are protected under the MBTA. For a more detailed review of use of the AoA by birds, including passerines, and the potential impacts on birds associated with wind energy development, refer to the *Birds and Bats Study*, which is appended to the Master Plan. Potential impacts on bats also were examined in the independent *Birds and Bats Study*. However, bats were excluded from the risk assessment and sensitivity analysis due to lack of data reflecting relative bat occurrence in different areas of the AoA that would inform relative sensitivity mapping.

Benthic species considered were limited to sessile organisms that are not included in the fish receptor group, occur in the AoA, and for which there is adequate available data regarding their spatial presence in the AoA. The analysis focuses on coral species and sea grass. Note that both corals and sea grasses were included in the risk assessment; however, after reviewing sea grass data prior to the sensitivity mapping exercise it was determined that no known sea grass occurred within the AoA. Therefore, sea grasses were not included in the mapping exercise. Also note that coral data indicated presence in the offshore space, with no occurrences nearshore or on the shelf, which drives a more spatially limited species occurrence pattern for the benthic species input data layer described in Section 3.

In the risk assessment and sensitivity analysis, impacts on EFH were considered separately from fish species due to the legal status of EFH and the differences in terms of response to stressors. EFH describes the waters and substrates necessary for certain fish activities. For a particular potential stressor, impacts on EFH can differ from impacts on the actual fish. For example, substrate is not vulnerable to pile-driving noise, while fish are capable of hearing such noise. Additionally, the 1996 Sustainable Fishery Act amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSA) require federal agencies to consult with NOAA Fisheries before they fund, permit, or undertake activities that may adversely affect EFH. Therefore, these receptors have been separated.

For the risk assessment, all fish species, including pelagic and demersal species that might occur in the AoA, were considered. The independent *Fish and Fisheries Study*, which is appended to the Master Plan, was used to inform the species selection process. While all species were included in the risk assessment, the sensitivity mapping exercise used a modeled data set based on the 1970–2014 Northeast Fisheries Science Center (NEFSC) fisheries-independent bottom-trawl surveys (Curtice et al. 2016; Fogarty and Perretti 2016). A recent study of fish and macro-invertebrates near designated WEAs on the northeast U.S. continental shelf (Walsh and Guida 2017) found that the bottom trawl utilized in the NEFSC survey may have weighted the results more toward larger demersal and pelagic, commercially important fish than toward smaller species or juveniles. For the scale and purposes of this model, these data were the most appropriate.

Table 1 summarizes the groups of species each receptor within those groups.

Table 1. Receptors and Species Considered in the Modeling Exercise

Low-Frequency Cetaceans	
Humpback Whale	*Megaptera novaeangliae*
Fin Whale	*Balaenoptera physalus physalus*
Sei Whale	*Balaenoptera borealis borealis*
Minke Whale	*Balaenoptera acutorostrata*
Blue Whale	*Balaenoptera musculus musculus*

Table notes are at the end of the table.

Table 1 continued

Mid-Frequency Cetaceans	
Sperm Whale	*Physeter macrocephalus*
Northern Bottlenose Whale	*Hyperoodon ampullatus*
Cuvier's Beaked Whale	*Ziphius cavirostris*
Mesoplodont Beaked Whales	*Mesoplodon* spp.
Killer Whale	*Orcinus orca*
Pygmy Killer Whale	*Feresa attenuata*
False Killer Whale	*Pseudorca crassidens*
Melon-Headed Whale	*Peponocephala electra*
Risso's Dolphin	*Grampus griesus*
Pilot Whales (Long- and Short-Finned)	*Globicephalus melas; G. macrorhynchus*
Atlantic White-Sided Dolphin	*Lagenorhynchus acutus*
White-Beaked Dolphin	*Lagenorhynchus albirostris*
Short-Beaked Common Dolphin	*Delphinus delphis*
Atlantic Spotted Dolphin	*Stenella frontalis*
Pantropical Spotted Dolphin	*Stenella attenuate*
Striped Dolphin	*Stenella coeruleoalba*
Fraser's Dolphin	*Lagenodelphis hosei*
Rough-Toothed Dolphin	*Steno bredanensis*
Clymene Dolphin	*Stenella clymene*
Spinner Dolphin	*Stenella longirostris longiristris*
Common Bottlenose Dolphin	*Tursiops truncatus truncatus*
High-Frequency Cetaceans	
Harbor Porpoise	*Phocoena phocoena*
Kogia spp. (Dwarf and Pygmy Sperm Whales)	*Kogia sima; K. breviceps*
North Atlantic Right Whale	
North Atlantic Right Whale	*Eubalaena glacialis*
Phocid Seals	
Harbor Seal	*Phoca vitulina concolor*
Gray Seal	*Halichoerus grypus grypus*
Harp Seal	*Pagophilus groenlandicus*
Hooded Seal	*Cystophora cristata*
Ringed Seal	*Pusa hipsida*
Sea Turtles	
Leatherback Sea Turtle	*Dermochelys coriacea*
Loggerhead Sea Turtle	*Caretta caretta*
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*
Green Turtle*	*Chelonia mydas*

Table notes are at the end of the table.

Table 1 continued

Birds (39 species spread among groups listed below)	
Waterfowl	*Anatidae* spp.
Loons	*Gaviidae* spp.
Pelagic Birds	*Procellaridae* spp., *Hydrobatidae* spp., *Sulidae* spp., *Stercorariidae* spp.
Cormorants	*Phalacrocoracidae* spp.
Shorebirds	*Scolopacidae* spp.
Alcids	*Alcide* spp.
Gulls and Terns	*Laridae* spp.
Benthic Species	
Corals	*Alcyonacea* spp., *Anthothecata* spp. *Antipatharai* spp., *Pennatulacea* spp., *Scleratinia* spp.
Sea Grasses	Common eelgrass (*Zostera marina*), Widgeongrass (*Ruppia maritima*)
Essential Fish Habitat	
Veneroida	Surfclam (*Spisula solidissima*), Ocean Quahog (*Artica islandica*)
Ostreoida	Atlantic Sea Scallop (*Placopecten magellanicus*)
Teuthida	Long-Finned Squid (*Doryteuthis pealeii)*, Short-Finned Squid (*Illex illecebrosus*)
Lamniformes*	White Shark (*Carcharodon carcharias*), Shortfin Mako Shark (*Isurus oxyrinchus*), Sand Tiger Shark (*Carcharias taurus*), Common Thresher Shark (*Alopias vulpinus*), Basking Shark (*Cetorhinus maximus*), Porbeagle Shark (*Lamna nasus*)
Carcharhiniformes*	Dusky Shark (*Carcharhinus obscurus*), Sandbar Shark (*Carcharhinus plumbeus*), Tiger Shark (*Galeocerdo cuvieri*), Blue Shark (*Prionace glauca*), Scalloped Hammerhead Shark (*Sphyrna lewini*), Smooth Dogfish (*Mustelus canis*)
Echinorhiniformes	Spiny Dogfish (*Squalus acanthias*)
Rajiformes	Little Skate *(Raja erinacea),* Rosette Skate *(Leucoraja garmani),* Winter Skate *(Leucoraja ocellata),* Clearnose Skate (*Raja eglanteria*)
Clupeiformes	Atlantic Sea Herring (*Clupea harengus*)
Salmoniformes*	Atlantic Salmon (*Salmo salar*)
Gladiformes	Red Hake (*Urophycis chuss*), Atlantic Cod (*Gadus morhua*), Haddock (*Melanogrammus aeglefinus*), Whiting* (*Merluccius bilinearis*), Offshore Hake* (*Merluccius albidus*), Pollock (*Pollachius virens*)
Lophiformes	Monkfish (Lophius americanus)

Table notes are at the end of the table.

Table 1 continued

Essential Fish Habitat continued	
Perciformes	Black Sea Bass (*Centropristis striata*), Bluefish (*Pomatomus saltatrix*), Cobia* (*Rachycentron canadum*), Scup (*Stenotomus chrysops*), Ocean Pout (*Macrozoarces americanus*), Atlantic Mackerel (*Scomber scombrus*), King Mackerel* (*Scomberomorus cavalla*), Spanish Mackerel* (*Scomberomorus maculatus*), Albacore* (*Thunnus alalunga*), Yellowfin Tuna* (*Thunnus albacares*), Bluefin Tuna* (*Thunnus thynnus*), Skipjack Tuna* (*Katsuwonus pelamis*), Atlantic Butterfish (*Peprilus triacanthus*), Swordfish* (*Xiphias gladius*)
Pleuronectiformes	Windowpane Flounder (*Scophthalmus aquosus*), Summer Flounder (*Paralichthys dentatus*), Witch Flounder (*Glyptocephalus cynoglossus*), American Plaice (*Hippoglossoides platessoides*) Yellowtail Flounder (*Limanda ferruginea*), Winter Flounder (*Pseudopleuronectes americanus*)
Fish Species	
American Lobster	*Homarus americanus*
American Shad	*Alosa sapidissima*
Atlantic Butterfish	*Peprilus triacanthus*
Atlantic Mackerel	*Scomber scombrus*
Atlantic Sea Herring	*Clupea harengus*
Atlantic Sea Scallop	*Placopecten magellanicus*
Atlantic Sturgeon	*Acipenser oxyrinchus oxyrinchus*
Atlantic Torpedo	*Torpedo nobiliana*
Barndoor Skate	*Dipturus laevis*
Bay Anchovy	*Anchoa mitchilli*
Black Sea Bass	*Centropristis striata*
Blackbelly Rosefish	*Helicolenus dactylopterus*
Bluefish	*Pomatomus saltatrix*
Clearnose Skate	*Raja eglanteria*
Cusk	*Brosme brosme*
Dusky Smooth-Hound (Smooth Dogfish)	*Mustelus canis*
Fourspot Flounder	*Hippoglossina oblonga*
Giant Manta*	*Manta birostris*
Gulf Stream Flounder	*Citharichthys arctifrons*
Haddock	*Melanogrammus aeglefinus*
Horseshoe Crab	*Limulus polphemus*
Jonah Crab	*Cancer borealis*

Table notes are at the end of the table.

Table 1 continued

Fish Species continued	
Long-finned Squid	*Doryteuthis pealeii*
Monkfish	*Lophius americanus*
Northern Kingfish	*Menticirrhus saxatilis*
Northern Puffer	*Sphoeroides maculatus*
Northern Sand Lance	*Ammodytes dubius*
Northern Sea Robin	*Prionotus carolinus*
Northern Short-Finned Squid	*Illex illecebrosus*
Ocean Pout	*Macrozoarces americanus*
Ocean Quahog*	*Artica islandica*
Ocean Whitetip Shark*	*Carcharhinus logimanus*
Red Hake	*Urophycis chuss*
Red-Eye Round Herring	*Etrumeus sadina*
Rosette Skate	*Leucoraja garmani*
Roughtail Stingray	*Bathytoshia centroura*
Scup	*Stenotomus chrysops*
Sea Raven	*Hemitripterus americanus*
Silver Hake	*Merluccius bilinearis*
Spiny Dogfish	*Squalus acanthias*
Spot	*Leiostomus xanthurus*
Spotted Codling (Spotted Hake)	*Urophycis regia*
Squeteague (Weakfish)	*Cynoscion regalis*
Striped Bass	*Morone saxatilis*
Striped Sea Robin	*Prionotus evolans*
Summer Flounder	*Paralichthys dentatus*
Surfclam*	*Spisula solidissima*
Tautog (Blackfish)	*Tautoga onitis*
Tilefish	*Lopholatilus chamaeleonticeps*
White Hake	*Urophycis tenuis*
Windowpane Flounder	*Scophthalmus aquosus*
Winter Flounder	*Pseudopleuronectes americanus*
Winter Skate	*Leucoraja ocellata*
Witch Flounder	*Glyptocephalus cynoglossus*
Yellowtail Flounder	*Limanda ferruginea*

* = species that were not included in the sensitivity model.

2.3 Identified Potential Stressors

Section 2.3 summarizes the potential stressors identified to occur during offshore wind development, and assigns a risk level to each receptor group based on the risk criteria identified in Section 2.1. A literature review was conducted to identify studies that consider the potential general impacts of offshore wind development on marine receptors. These included both studies that target specific receptor groups, such as marine mammals and birds, and larger synthesis reports that address multiple species groups. Particular consideration was given to studies that address the risk to various receptor groups and assess the qualitative or quantitative ranking of the groups. In addition to the relevant literature, stakeholder feedback and information received at various meetings and workshops were considered (see Section 1.3).

In order to address differences in risk factors at various phases of offshore wind development, potential stressors were grouped into three categories: pre-construction, construction, and post-construction. Other studies have addressed risk by development phase as well using similar categories (European Commission 2016; Marine Management Organization 2013).

2.3.1 Potential Pre-construction Stressors

Pre-construction covers the period before construction begins, when surveys are conducted to identify potential sites for development. These surveys typically include those designed to help site wind farms, such as benthic and geophysical surveys, and those designed to identify potentially sensitive species. Many of the more general wildlife surveys do not generate impacts that are relevant at this stage of identifying potential WEAs for consideration, and so were excluded from this analysis. Instead, for the pre-construction phase, the framework focuses on surveys that might generate potentially harmful noise or disturb the sea bottom.

2.3.1.1 Noise-Generating Surveys

HRG surveys, which would be required to assess potential wind areas, might generate potentially harmful underwater noise. Two types of technology are typically employed to identify depth and seafloor features: side-scan sonar and multi-beam sonar. These technologies rely on sound waves to create an image of the seafloor and determine depth and are typically deployed from survey vessels. Some vessels may also use single-beam echo sounders as an alternative technology.

HRG surveys produce noise capable of disturbing marine mammals and instigating changes in behavior (BOEM OREP 2016a, 2017a). Side-scan sonar uses frequencies greater than 200 kilohertz, which should be inaudible to all marine mammals, sea turtles, and fish. However, multi-beam sonars have the potential to cause PTS and disturbance of high-frequency cetaceans (BOEM OREP 2016a). In addition, cumulative noise exposure can cause injury and PTS in the hearing of other cetaceans and phocid seals, though due to the limited overlap in hearing this is less probable and context specific. High-frequency cetaceans are at higher risk of injury and PTS due to significant overlaps in the hearing frequency of these cetaceans and the frequencies produced by HRG technologies (Crocker and Fratantonio 2016; BOEM OREP 2017a). However, PTS would only occur over a small spatial extent (BOEM OREP 2017a). It should also be noted that seals are more likely to occur in nearshore areas, while the surveys would be conducted farther offshore. The noise generated from these surveys could also affect fish and sea turtles, though these impacts are less well understood (BOEM OREP 2013). Due to the limited overlap in the hearing range of these species and the sound typically produced by HRG surveys in conjunction with the high mobility of these species, only limited behavioral impacts to a small number of individuals are likely to occur (BOEM OREP 2013, 2016a; NYSERDA 2015).

Acoustic sub-bottom profiling is sometimes performed in advance of seabed construction and can involve high-energy, low-frequency sound, which may be audible to marine mammals and fish (Crocker and Fratantonio 2016). However, the intensity of this source is often low enough to avoid acoustic harassment. In addition, it is anticipated that other systems, such as multi-beam sonar, may be used rather than sub-bottom profilers.

2.3.1.2 Bottom-Disturbing Surveys

A second series of surveys is required to determine the bathymetric contours, sediment types, suitability for proposed turbine foundations, and subsea cable routes. Two types of technology are typically employed to characterize surficial sediments: vibracoring and sediment profile imaging (SPI). Other available though less common methods include piston coring, box coring, and rotary core boring. These surveys often involve sediment coring, which has the potential to increase turbidity locally and may displace benthic infauna. Local organisms may be impacted by resuspended sediment-bound contaminants and contaminants introduced with drilling mud (Hiscock et al. 2002; NJDEP 2010). These impacts tend to be temporary and localized, with benthic communities recovering to densities and biodiversity similar to undisturbed areas (Daan et al. 2009; Hiscock et al. 2002).

2.3.1.3 Pre-construction Risk Matrix

Table 2 summarizes the levels of potential risk associated with pre-construction activities. Risk values were assigned using the system described in Section 2.1 based on the information concerning the potential impacts and vulnerabilities that are described in Section 2.3.1. Again, potential risk is evaluated in this matrix assuming potential future siting of wind farms anywhere in the AoA, whereas avoidance of certain areas may greatly reduce potential risk.

Table 2. Pre-construction Risk Matrix

Receptor	Stressors	
	Noise-generating Surveys	Bottom-disturbing Surveys
Low-Frequency Cetaceans	3	1
Mid-Frequency Cetaceans	3	1
High-Frequency Cetaceans	4	1
Phocid Seals	2	1
North Atlantic Right Whales	3	1
Sea Turtles	3	1
Birds	1	1
Benthic Species	1	3
Essential Fish Habitat	1	3
Fish Species	2	2

2.3.2 Potential Construction Stressors

Construction covers the period of offshore wind development when installation of offshore turbines, cables, and other supporting activities occur. Construction activities are grouped as follows: construction noise (not including pile driving), pile-driving noise, collision risk, and bottom disturbance. Pile driving was analyzed as a separate construction activity because potential impacts associated with pile driving are a particular concern for endangered cetacean species, including the critically endangered right whale. This approach is consistent with recent workshops and analyses that have focused on pile driving as an isolated activity in order to better understand potential impacts on endangered cetaceans (BOEM OREP 2017a; Marine Management Organization 2013).

2.3.2.1 Construction Noise (non-pile-driving)

Noise associated with various aspects of construction, such as vessel noise, dredging, horizontal directional drilling (HDD) operation, trenching, and backfilling may disturb marine organisms, including marine mammals, sea turtles, and fish (Marine Management Organization 2013; BOEM OREP 2016a). Much of the noise produced would likely be temporary and localized. Therefore, construction may result in temporary displacement of mobile marine species as they navigate away from noisy, localized areas of construction (Small et al. 2017; European Commission 2016). For larger vessels, the noise may propagate farther and overlap more with the hearing range of low-frequency cetaceans, potentially causing them to avoid the area of construction (BOEM OREP 2017b; Hildrebrand 2009; Southall et al. 2007).

Potential noise and disturbance impacts were considered for birds; however, construction-related noises are localized and of short-term duration. The potential impacts associated with construction activities would be minor relative to the potential collision and displacement impacts that are the primary focus of offshore wind energy development impacts on birds in Europe and the U.S. Therefore, potential collision and displacement impacts, particularly during operations, receive the highest consideration for birds (see Sections 2.3.2.3 and 2.3.3.3).

2.3.2.2 Pile-Driving Noise

Pile driving is a common method for installing turbine monopoles and associated support piles. The noise generated by pile driving could overlap with the hearing ranges of marine mammals, sea turtles, and fish and could potentially result in behavioral disturbance, stress, PTS, and injury in many species (BOEM OREP 2017d; NOAA 2016). Due to the high intensity of the noise produced and the distances over which the noise could propagate, this activity has been identified as a priority concern, especially for marine mammals and fish (BOEM OREP 2017b; European Commission 2016; Marine Management Organization 2013). Sea turtles may be vulnerable if in close proximity (Marine Management Organization 2013). Avoidance responses to pile driving by harbor porpoises and seals have been documented in Europe (Dähne et al. 2013; Edren et al. 2010). The marine mammal species in coastal New York could be at high risk due to the greater number of endangered large whales present, including the critically endangered right whale, with low-frequency and high-frequency cetaceans having the largest areas of potential impact due to their hearing ranges (BOEM OREP 2017d; NOAA 2016; Southall et al. 2007).

Potential noise and disturbance impacts were considered for birds; however, construction-related noises are localized and of short-term duration. The potential impacts associated with pile-driving activities would be minor relative to the potential collision and displacement impacts that are the primary focus of offshore wind energy development impacts on birds in Europe and the U.S. Therefore, potential collision and displacement impacts, particularly during operations, receive the highest consideration for birds (see Section 2.3.2.3).

2.3.2.3 Collision Risk (vessel or structure)

The presence of new structures and construction equipment in the water might result in overlap between construction areas and important habitat for feeding, breeding, and migrating marine animals. The overlap may displace marine mammals and sea turtles from their typical habitat and into nearby shipping lanes (Marine Management Organization 2013; BOEM OREP 2016a). For large whales, especially the right whale, this displacement may pose a high risk of collision with large shipping vessels and result in collisions and mortalities (Roberts et al. 2016; BOEM OREP 2017c; Culloch et al. 2016). Fin whales also have a biologically important feeding area on the eastern edge of the AoA, and displacement from this area could result in a greater number of collisions (Roberts et al. 2016). The collision risk for sea turtles also might increase; however, sea turtle use within the AoA occurs mostly along the continental shelf break, slope, and Hudson Canyon. The potential for turtle displacement in relation to future AoA turbines is uncertain (Marine Management Organization 2013; DOS 2013; NYSERDA 2015).

It is likely that birds may be drawn to any future construction site to utilize the half-completed structures as roosts or perches (English et al. 2017; Palmquist and Gard 2017). Dierschke et al. (2016) suggests that birds are likely to use the unfinished turbines as surfaces to outpost on, expanding their foraging range. Additionally, Ronconi et al. (2014) reports that migrating seabirds are attracted to lights and flares from offshore structures. Their presence in this space and height of flightpath could make them vulnerable to colliding with construction vessels, equipment, and wind turbines.

2.3.2.4 Bottom Disturbance

Bottom disturbance occurs during construction activities such as turbine and cable installation. Subsea cables are required to transmit the electricity generated by a wind farm to the power grid on the mainland. Depending on the type of installation chosen, turbine installation includes pile driving and other bottom-disturbing activities. Installation of subsea cables involves trenching, placing the cable in the trench, and backfilling over the cable. The impacts of installation are typically of short-term duration and include increased turbidity and sediment plumes, resuspension of sediment-bound contaminants, and the disturbance of benthic habitats in and close to the foundation footprint and nearshore habitats where the cable comes onshore (Hiscock et al. 2002; NJDEP 2010). These may, in turn, result in impacts on sessile organisms (e.g., ocean quahogs, surfclams, and seas scallops) and early life stages that are sessile (e.g., squid eggs), of limited mobility (e.g., juvenile fish), or dependent upon specific bottom habitat types of limited extent (e.g., black sea bass). Disturbed areas may also experience changes in macrofaunal communities, which may, in turn, lead to impacts through the food web (Hiscock et al. 2002; NJDEP 2010). However, benthic fauna generally adapt to minor, temporary increases in suspended sediments by physiological mechanisms such as expelling filtered sediments or reducing filtration rates (Clarke and Wilbur 2000). Based on existing studies, impacts on benthic communities tend to be temporary and localized, with benthic communities recovering to densities and biodiversity similar to undisturbed areas (Daan et al. 2009; Hiscock et al. 2002). The time to recovery is variable; depending on the habitat type and other physical and biological factors, recovery may occur within a few months or take as long as a decade (Minerals Management Service [MMS] 2009).

In the event that the substrate is rocky and a cable cannot be buried in certain areas, cable may need to be installed on top of the seafloor with an additional protective layer around it. This would result in the introduction of an unnatural, hard substrate, which may modify biotic interactions (Hiscock et al. 2002; Heery et al. 2017).

2.3.2.5 Potential Construction Risk Matrix

Table 3 summarizes the levels of potential risk associated with construction activities. Risk values were assigned using the system described in Section 2.1 based on the information concerning potential impacts and vulnerabilities that are described in Section 2.3.2. Again, potential risk is evaluated in this matrix assuming potential siting of wind farms anywhere in the AoA, whereas avoidance of certain areas may greatly reduce potential risk.

Table 3. Potential Construction Risk Matrix

Receptor	Stressors			
	Construction Noise	Pile-driving Noise	Collision Risk (vessel or structure collision)	Bottom Disturbance
Low-Frequency Cetaceans	4	5	4	1
Mid-Frequency Cetaceans	3	5	2	1
High-Frequency Cetaceans	3	5	2	1
Phocid Seals	1	3	1	1
North Atlantic Right Whales	4	5	4	1
Sea Turtles	3	3	2	1
Birds	3	3	3	1
Benthic Species	1	1	1	3
Essential Fish Habitat	1	1	1	3
Fish Species	3	4	1	3

2.3.3 Potential Post-Construction Stressors

Post-construction includes the period after turbine and cable installation, during which time a wind farm would be operational. It also includes the decommissioning of a wind farm. Activities were grouped as follows: foundation scouring, new structures (in water), new structures (in air), electric and magnetic fields (EMF), and decommissioning.

2.3.3.1 Foundation Scouring

Offshore wind turbines may be installed on steel monopiles, attached to gravity-based foundations, or on tripod/jacket foundations. Steel monopile foundations are single piles that are either hammered, drilled or vibrated into the seafloor. Gravity-based foundations are concrete or steel structures with a broad, flat base that sit on the seabed. Tripod foundations are comprised of tubular frames with three to four legged steel jackets, which are each secured to the seabed by steel piles, and are most suitable for deeper waters. While gravity foundations have been used in the shallower coastal European waters, their large mass and construction needs make them less suitable for use in the deeper waters of the OCS. As the gravity foundation is not ideal for the AoA and the monopile foundation is currently the most common foundation type used for offshore wind energy (U.S. Department of Energy and U.S. Department of the Interior 2016), the following discussion is based on the assumption that monopile foundations are the more suitable option for the AoA (Hiscock et al. 2002; MMS 2007).

Installation of the turbine monopile foundations may increase localized turbulence and disrupt the flow of water, potentially leading to erosion around the base of the turbines (McCann 2010). This process, referred to as “scour,” may ultimately cause a hole in the seafloor to form at the base of a wind turbine (McCann 2010; Marine Management Organization 2013). The altered local water flow across the sediment may result in localized scour behind the turbine, and deposition in front of the turbine (Hiscock et al. 2002). If multiple turbine monopiles are placed in close proximity to each other, they could affect water flow on a large scale, through and around the developed area (Hiscock et al. 2002; NJDEP 2010; Heery et al. 2017). The style and complexity of turbine monopile foundation design may also effect the velocity of water and sediment scouring on a local scale (MMS 2009; McCann 2010). The diffraction and interference of the wave energy through and around a wind farm could affect wave energy, resulting in potential localized reductions in current energy and wave height, and changes to local sediment dynamics (Hiscock et al. 2002; MMS 2007; NJDEP 2010; Marine Management Organization 2013). This disturbance of the local hydrography may also affect grain sizes in the vicinity of turbine monopiles, as smaller grain sizes are more easily resuspended and transported during disturbance, potentially impacting the benthic community (McCann 2010; Heery et al. 2017).

A method used to protect the foundation of turbine monopiles and minimize the effects of scour is the installation of scour protection devices such as rock mattresses, boulders, grout bags, and grass mattresses around the foundation of turbines to minimize erosion (MMS 2007; Hammar et al. 2008; McCann 2010). In addition to protecting the local area, scour protection may also provide habitat to benthic invertebrates and prey fish due to the increase in heterogeneity of the seafloor (Hiscock et al. 2002; Hammar et al. 2008; McCann 2010; NJDEP 2010; Bergström et al. 2014). The development of scour holes near turbine monopile foundations also may provide habitat to decapod crustaceans and some fish species (McCann 2010).

2.3.3.2 New Structures (in water)

As with the construction phase, the presence of any new structures in the water might result in an overlap between future wind farms and important habitat for feeding, breeding, and migrating marine animals. Potential impacts and risks to receptors are similar to those described in Section 2.3.2.3. With any new, permanent structures, benthic species could be at risk of habitat loss, but the area affected would be minimal, and while changes to colonizing epifauna have been documented, there has been no evidence of changes to infauna (European Commission 2016).

New structures may also serve as new habitat for fish and invertebrate species, which could be beneficial (European Commission 2016; Marine Management Organization 2013; Palmquist and Gard 2017). The new presence of a hard structure in the water in an area of low hardground habitat may provide substrate to invertebrates. In turn, fish species would be drawn to the increased density of prey items on the structures, causing a “reef effect.” While this may be beneficial to epifauna, new colonization could attract bird species into the area making them vulnerable to collisions with turbines. This “attractive nuisance” could lead to greater bird mortality (Palmquist and Gard 2017).

2.3.3.3 New Structures (in air)

The siting requirements of wind farms (exposed areas, average wind speeds) can lead to an overlap between wind farms and habitats for breeding, wintering, and migrating birds and bats. This potential overlap could place birds and bats at increased risk for colliding with wind farm components such as rotors, towers, nacelles, and meteorological masts.

While offshore wind turbines have the potential to result in collision-related bat and bird mortalities, research suggests more than 99 percent of birds avoid striking offshore turbines, either by circumventing wind farms or dodging turbine blades (Desholm and Kahlert 2005; Cook et al. 2014). Additionally, collision risks are dependent on a number of factors, including flight height, flight paths, weather, and time of day (European Commission 2016). For example, birds flying at night are at an increased risk of collision (Desholm and Kahlert 2005).

Some birds may avoid entering wind farms, which could displace them from preferred foraging areas, resulting in habitat loss (Drewitt and Langston 2006; Cook et al. 2014; European Commission 2016). Birds may alter travel routes and take more circuitous routes that may deplete energy reserves and potentially affect fitness (Desholm and Kahlert 2005; Drewitt and Langston 2006; Cook et al. 2014; European Commission 2016).

2.3.3.4 Electric and Magnetic Fields

Electricity generated at offshore windfarms is transmitted to the shore for integration into the power grid via subsea cables. Moving electricity through such subsea cables may generate EMF.

A number of examined marine taxa, including marine mammals, sea turtles, and elasmobranchs, have magnetic or electric senses. Recent studies also show the presence of electric sense in decapod crustaceans (Gill et al. 2009; Normandeau et al. 2011). Based on available information, life functions, including orientation, homing, and navigation, may theoretically be affected in species sensitive to artificially generated EMFs. These life functions are used by marine taxa for migrating or moving, foraging for prey, avoiding predators, and social or reproductive behaviors (Gill et al. 2009; NJDEP 2010; Normandeau et al. 2011). However, recent studies examining the impacts of existing marine transmission cables on migratory fish behavior and communities found no apparent impacts on successful migration (Kavet et al. 2016) and no biologically significant differences between fish and invertebrate communities along energized cables and those in natural habitats (Love et al. 2016).

Available information suggests that elasmobranchs and sea turtles are most likely to be affected by generated EMFs; however, the magnitude of the effects is likely dependent on EMF levels and which life stages are exposed to EMFs (Gill et al. 2009). Additionally, EMF levels are known to vary, depending upon depth of burial, with the strongest magnetic field directly over the cables and decreasing rapidly with vertical and horizontal distance from the cable (Love et al. 2016). Increasing burial depth reduces the intensity of the magnetic field and the induced magnetic field that reaches the water and organisms by increasing the distance between the cable and the aquatic environment (Normandeau et al. 2011). Depth of burial is highly dependent on sediment characteristics; however, typical power cables for offshore wind farms are buried to a depth of 1 to 3 meters beneath the surface to protect against scour, mobile sediments, trawl fishing, anchoring, or other activities (English et al. 2017).

The habitat preferences of species of other pelagic fish with known electro- or magenetosense do not tend to overlap with the location of the strongest generated EMFs (Normandeau et al. 2011). Little information is available on electro- or magnetosense in non-elasmobranch demersal fish. Some species of decapod crustaceans may theoretically be moderately impacted by any generated EMFs due to their habitat and relatively low mobility, while marine mammals are less likely to be impacted due to their high mobility (Normandeau et al. 2011).

It was determined that, due to a lack of certainty regarding impacts on marine resources, the risk from potential impacts from EMF could not be adequately ranked and would not be considered in the identification of potential WEAs. Therefore, EMF is not considered further in this Study.

2.3.3.5 Decommissioning

Once an offshore wind farm is no longer operating, the owner/operator may remove part or all seafloor obstructions associated with the wind farm. Potential impacts of the decommissioning of an offshore wind farm would likely be similar to the potential impacts of constructing an offshore wind farm, as the same vessels and generalized activities would be required to dismantle the wind farm (Marine Management Organization 2013; NJDEP 2010; Gill 2005). Additional potential impacts on benthic species may occur due to the removal of submerged and potentially colonized structures. The introduction of hard-bottom structures has been found to increase colonization of benthic organisms, fish species, and biodiversity, and the removal of such structures would be equivalent to removing habitat (NJDEP 2010). Disturbed sediments would potentially affect benthic species and their habitat through increased turbidity, resuspension of sediment-bound contaminants, and smothering of species and habitat (NJDEP 2010; Gill 2005). Other potential effects on the coastal environment include increased noise and vibration, as well as decreased habitat heterogeneity (Gill 2005). The potential ecological response for sedentary species includes a reduced diversity, but there is also a potential increase in opportunist abundance such as invasive species. Mobile species may be temporarily displaced or face long-term displacement. These displacements could be due to changes in nutrient availability; prey diversity and abundance; production and biomass; as well as community size, structure, and connectivity (Gill 2005).

The possible decommissioning process and potential impacts could vary, with options ranging from complete removal of turbines, to partial removal, and even no removal. Since each of these options has different impacts, it is hard to predict the level of risk associated with this phase of development at this time. It was determined that, due to uncertainty, the particular impacts from decommissioning would not be considered in the identification of potential areas for consideration. Decommissioning is not considered further in this Study, although the inclusion of construction impacts serves as a reasonable proxy.

2.3.3.6 Post-construction Risk Matrix

Table 4 summarizes the levels of potential risk associated with post-construction activities. Risk values were assigned using the system described in Section 2.1 based on the information concerning potential impacts and vulnerabilities described in Section 2.3.3. Again, potential risk is evaluated in this matrix assuming potential siting of wind farms anywhere in the AoA, whereas avoidance of certain areas may greatly reduce potential risk.

Table 4. Post-construction Risk Matrix

Receptor	Foundation Scouring	New Structures (in water)	New Structures (in air)
Low-Frequency Cetaceans	1	5	1
Mid-Frequency Cetaceans	1	3	1
High-Frequency Cetaceans	1	3	1
Phocid Seals	1	1	1
North Atlantic Right Whales	1	5	1
Sea Turtles	1	2	1
Birds	1	1	5
Benthic Species	3	1	1
Essential Fish Habitat	3	1	1
Fish Species	2	1	1

2.4 Sensitivity Weighting Framework

Sensitivity weight values of 1 through 5 were then determined for receptor groups for each phase of offshore wind development based on the risk assessment described in the relative risk matrix, regulatory context (including species status), permitting requirements, BOEM recommendations, seasonality, and other additional factors. The sensitivity weight values are provided in Table 5, followed by a discussion for each receptor group on how these weight values were determined.

Table 5. Sensitivity Weight Values

Receptor	Pre-construction Weight	Construction Weight	Post-construction Weight
Low-Frequency Cetaceans	4	5	5
Mid-Frequency Cetaceans	4	5	4
High-Frequency Cetaceans	5	5	4
Phocid Seals	2	3	1
Right Whales	4	5	5
Sea Turtles	3	3	3
Birds	1	4	4
Benthic Species	2	2	1
Essential Fish Habitat	2	2	2
Fish Species	3	4	1

2.4.1 Low-Frequency Cetaceans

Many low-frequency cetaceans are protected under the ESA. All marine mammals are also protected under the MMPA, which requires additional permitting and potential development costs. Therefore, mitigation required by regulatory agencies for marine mammals, especially for noise, can be costly, and permits take time to acquire. In addition, BOEM guidelines call for minimizing disruption and disturbance of marine life from sound emissions, including marine mammals. BOEM has applied extensive HRG survey requirements during the pre-construction phase that pertain to right whales, some of which also apply to other large whales (BOEM OREP 2017a). For pile-driving activities during construction, required mitigation would likely be more rigorous than for HRG surveys and potentially require consideration of the cumulative impacts of developing multiple nearby offshore wind farms. Consequently, low-frequency cetaceans were given high weights for all categories, especially during construction and post-construction.

2.4.2 Mid-Frequency Cetaceans

As with low-frequency cetaceans, all mid-frequency cetaceans are protected under the MMPA and their presence in a development area would likely require mitigation during HRG surveys, with even more extensive mitigation requirements and permitting likely necessary during the construction phase, in particular during pile driving. However, only one mid-frequency cetacean in the AoA, the sperm whale, is protected under the ESA. This ESA-listed species generally occurs in deeper waters farther offshore than the AoA. The sensitivity to displacement and vessel collision during wind farm operation would likely be lower, since most mid-frequency cetaceans tend to be smaller; however, collision and injury is possible. In addition, as described in the risk assessment, these species are susceptible to impacts from pile driving during construction and their presence in a development area would require permitting or mitigation under the MMPA. Consequently, mid-frequency cetaceans were given high weights for construction and relatively high weights for pre- and post-construction.

2.4.3 High-Frequency Cetaceans

As with low-frequency cetaceans, all high-frequency cetaceans are protected under the MMPA and their presence in a development area would likely require mitigation during HRG surveys, with even more extensive mitigation requirements and permitting likely necessary during the construction phase, in particular during pile driving. No high-frequency cetaceans in the AoA are ESA-listed (the harbor porpoise is state-listed in New Jersey). However, due to their hearing range, these species are predicted to be highly sensitive to HRG surveys and pile-driving noise. The sensitivity to displacement and vessel collision during wind farm operation would likely be lower, since high-frequency cetaceans tend to be smaller; however, collision and injury is possible. Consequently, mid-frequency cetaceans were given high weights for pre-construction and construction and a relatively high weight for post-construction.

2.4.4 Phocid Seals

Phocid seals are protected under the MMPA; however, no phocid seals in the AoA are protected under the ESA. Seals typically occur in more nearshore waters close to onshore haul-out sites. Therefore, there would be a significant spatial gap between potential WEAs and the areas frequented by seals. While some pile-driving noise might propagate a great distance, it would be somewhat attenuated by the time it reached nearshore waters. As with all marine mammals, mitigation can be costly and permits take time to acquire; however, it is unlikely seals would be as great a concern as other marine mammals due to the spatial gap between the animals and the stressors. The risk of seals colliding with vessels during wind farm operation would be lower than for cetaceans, since seals are smaller and mostly occur in nearshore waters miles away from future wind farms where there is no overlap between turbines and shipping lanes. Consequently, seals were given low sensitivity weights for pre-construction and post-construction and a moderate weight for construction.

2.4.5 North Atlantic Right Whale

The right whale is critically endangered; therefore, impacts on a few individuals can result in population-level effects. In addition to being protected under the ESA, right whales are also protected under the MMPA. BOEM has imposed extensive HRG survey requirements regarding the North Atlantic right whale for Atlantic renewable energy activities. These include prohibiting surveys or pile diving at night, requiring protected species observers, implementing general vessel-strike avoidance measures, and adhering to seasonal speed restrictions for vessels 65 feet or greater in length (BOEM OREP 2017d). Other requirements include a seasonal prohibition on sub-bottom profiling within right whale critical habitat, exclusion zones for sub-bottom profiling, and a requirement that all sub-bottom profiling stops within 24 hours of dynamic management area (DMA) establishment (BOEM OREP 2017a) (note other requirements may be applicable after the establishment of a DMA). The sensitivity to collision during operation would also need to be carefully considered. Consequently, right whales were given high weights for all categories, especially during construction and post-construction.

2.4.6 Sea Turtles

All sea turtles occurring in the AoA are protected under the ESA. BOEM has required projects to minimize disruption and disturbance to marine life, including sea turtles, from noise-generating activities. Due to differences in hearing sensitivity, the risk of impacts from noise generating activities are lower for sea turtles than for cetacean species. However, pre-construction surveys and construction activities could result in the temporary displacement of sea turtles. Mitigation measures, such as monitoring by protected species observers during HRG surveys and pile driving, would likely be necessary. The sensitivity to displacement and collision during wind farm operation would likely be lower for sea turtles than for larger species such as low-frequency cetaceans. Consequently, sea turtles were given moderate weights for all categories.

2.4.7 Birds

Nearly all bird species occurring in the AoA are protected under the MBTA, and some bird species in the AoA are also listed under the ESA. Bald eagles (*Haliaeetus leucocephalus*) and, to a lesser extent, golden eagles (*Aquila chrysaetos*), are protected under the Bald and Golden Eagle Protection Act (BGEPA), but mainly occur along the coasts and nearshore outside of the AoA and only in limited numbers. Mitigation measures and engineering solutions may be required to reduce impacts on birds and comply with the BGEPA. Research suggests that most birds avoid offshore wind farms; however, if a large migrating flock were to collide with the turbines, there could be a population-level impact. The sensitivity to collision would increase during inclement weather or at night. Birds were therefore given a relatively high weight for post-construction. Birds were also given a relatively high weight for construction, even though the sensitivity to collision with the turbines and construction equipment is low for similar reasons to those for construction. Since the majority of potential impacts for pre-construction could occur in water, birds were given a low weight for pre-construction.

2.4.8 Benthic Species

BOEM has indicated that a project should avoid locating facilities near sensitive seafloor habitats, including deep-sea coral reefs and sea grass habitat. Coral habitat in the AoA is primarily located along the shelf edge. Sea grass habitat is primarily located nearshore, with the nearest known sea grass communities sheltered by the barrier islands along New Jersey and Long Island (sea grasses were ultimately excluded from the mapping analysis due to lack of presence in the AoA). Potential impacts on corals during pre-construction bottom surveys would be minimal, as described in the risk assessment. No corals in the AoA are listed under the ESA or otherwise protected and so they would not require an extensive consultation processes. Consequently, corals were given low weights for all categories.

2.4.9 Essential Fish Habitat

EFH is designated and protected under the MSA, and implicates consultation requirements. BOEM has required that projects minimize impacts on fisheries and avoid locating facilities near sensitive seafloor habitats. EFH occurs throughout the AoA, though the number of overlapping species-specific habitats varies spatially. EFH might only be minimally disturbed by pre-construction bottom surveys but could be disturbed by construction activities if they overlap spatially. However, these impacts, as described in Section 2.3.2, would likely be short-term and/or spatially constrained. Consequently, EFH was given low weights for all categories.

2.4.10 Fish

Fish play an important role in both the marine ecosystem and the economy. Atlantic sturgeon (*Acipenser oxyrinchus*) are listed as endangered under the ESA; however, these fish occur primarily in nearshore, shallow coastal waters and estuaries. Several state-listed fish species and species of concern also occur in the AoA. BOEM has required that projects minimize impacts on fisheries. Current BOEM guidelines also include minimizing disruption and disturbance to marine life from sound emissions, including fish. As described in Section 2.3, fish might experience impacts from certain offshore wind development activities such as pile-driving noise (2.3.2.2) and the presence of new structures (2.3.3.2). Mitigation may be necessary during HRG surveys, bottom-disturbing activities, and pile-driving activities. In addition, some permits will be required under the MSA. Consequently, fish were given a moderate weight for pre-construction, a relative high weight for construction, and a low weight for post-construction.

3 Sensitivity Model Methodology

Section 3 outlines the modeling methodology, including a description of the input data layers and model selection and process.

3.1 General Methodology

In order to compare relative sensitivity throughout the AoA, a sensitivity model was developed using the sensitivity weighting values developed in Section 2 and the input data noted in Table 7. A comparison of areas of the AoA was prepared by conducting a weighted sum overlay analysis in which a group of geospatial modeling methodologies was used to characterize an area and identify potentially suitable areas to consider for wind energy development, based on biological sensitivity. This is an effective technique for applying a common scale of values to disparate inputs (e.g., density vs. core abundance) to allow for a comparative analysis. The goal of the analysis was to produce maps of relative sensitivity in the AoA, which accounted for seasonality and phase of construction.

There are various approaches to performing an overlay analysis, and each approach implements some permutation of the following steps:

1. Define the model.
2. Break the model into sub-models.
3. Determine representative input data layers.
4. Reclassify or transform the data within a layer to allow multiple input layers with different ranges of values or units to be combined effectively.
5. Weight the input layers.
6. Add or combine the layers.

3.2 Evaluation of Overlay Analysis Methods

Each overlay analysis method has its strengths, and it is important to evaluate the different premises and assumptions in relation to the model goals in order to choose the most appropriate approach. Sensitivity analyses can be performed using vector data (data represented as points, lines, or polygons) or raster data (data represented as grid cells, or pixels, each with a specific value). Since each cell in a raster can have a specific value, raster data are best used for representing data with non-integer, or non-whole number, values. In GIS, non-integer data are called floating-point data. An example is a density grid, where a cell value may equal an average value of 1.6 animals per grid cell. Given the size of the AoA and that the majority of the input data layers are available in a floating-point (non-integer) raster format, overlay analyses that favored raster data were evaluated. The following summary presents the findings of the potential model type evaluation.

1. **Weighted Overlay**.
   The weighted overlay model normalizes the input data on a defined relative scale (i.e., 1 to 10) to remove units, weights the input rasters, and adds them together. Weights assigned to the input rasters must equal 100 percent. The layers are multiplied by the appropriate multiplier, and for each cell, the resulting values are added together and rescaled back to the defined integer scale (i.e., 1 to 10). The weighted overlay model, in this case, assumes that more sensitive factors would result in the higher values in the output raster. The resultant raster surface presents cell values as integers, thereby removing the granularity (i.e., resolution or level of detail) of some of the original floating-point raster data within the AoA (ESRI 2017). In other words, non-integer (non-whole number) data is rounded to integer (whole-number data). For example, the density of 1.6 animals/cell from above might be represented as a 2.
2. **Weighted Sum (also known as the Linear Weighted Model).**
   The weighted sum analysis method follows the same general steps of the weighted overlay analysis described above. Similar to the weighted overlay approach, the values for the input layers need to be reclassified along a common ratio scale (i.e., 1 to 10). Weights assigned to the input rasters can be any value and do not need to add to a specific sum (e.g., 100 percent)—unless results need to be compared within or across sub-models (see Section 3.3.2). When combining the input rasters, the weighted sum output values are a direct result of first multiplying each input data value by the weight and then adding those multiplied layers, and any additional rescaling that is required to allow for analysis across multiple sub-models without compromising the original input attribute resolution (i.e., keeps decimal values). The weighted sum model results, in this case, assume that more sensitive factors would result in the higher values in the output raster, with resultant cell values presented as a floating-point raster data within the AoA (ESRI 2017).
3. **Ordinal Combination Method.**
   This overlay analysis approach does not apply weights but takes into consideration sensitivity during the reclassification of input data layers. For example, the values for input rasters are classified into three classes, with 1 representing values that pose the least environmental sensitivity, 2 representing values that are medium sensitivity, and 3 representing values classified as high sensitivity areas. Reclassified layers are then combined together, adding cell values, to create a final raster with cell values equal to the total potential sensitivity of all input layers at a specific location. This method creates a raster with integer values, which means the granularity of the original input layer values are lost (MacDonald 2006).
4. **Rules of Combination.**
   This overlay analysis method is expressed in terms of verbal logic (i.e., descriptive words such as high, medium, or low) rather than in terms of numbers or arithmetic. In this method, values from each input layer are grouped into high, moderate, or low sensitivity classes—not reclassified across a defined scale (Hopkins 1977). Then, rather than simply adding ranks together, rules are defined for combining different rankings for each factor to determine final levels of sensitivity for each cell (MacDonald 2006). The resultant raster values are not numeric but fall into one of the aforementioned sensitivity classes (i.e., high, medium, or low) and do not honor the original resolution or format of the input rasters; however, the values result in coarse-scaled characterization of sensitivity trends within the AoA.

5. **Binary (or Boolean) Suitability.**
   This overlay analysis method is the simplest of all suitability modeling approaches. Each input layer is reclassified into suitable or unsuitable groups—or in this case, high or low sensitivity classes. Layers are combined together using the rule that if any input value is classed as high, it trumps any low input values that are present in the same location. For example, when combining marine mammal and fish data sets, if the marine mammal dataset contained a cell classed as high in the same location as the fish dataset had a cell classed as low, the resulting combined output would class that location as high. The end result is a raster of high and low sensitivity areas. The result is very coarse and masks the spatial trends, which could then inform a detailed sensitivity analysis, found in each input data layer.
6. **Fuzzy Overlay.**
   Fuzzy overlay loosely follows the general overlay analysis steps discussed above but differs in the meaning of the reclassified values and the results from combining the multiple criteria. This method is based on set theory and fuzzy logic—which provides techniques to address inaccuracies in attribute and geometry of spatial data—recognizing that some spatial phenomena do not have crisp boundaries, thereby defining possibilities, not probabilities. Like the weighted overlay and weighted sum models (methods 1 and 2, respectively), fuzzy overlay analysis reclassifies data values to a common scale of 0 through 1. Weighting the criteria is not applicable in this method; instead, layers are combined and GIS tools are used to explore the interaction of the possibility of the phenomenon at any given location if the resultant raster belongs to multiple sets (or degrees) of suitability or sensitivity. This method produces values that are not easily discernable as high or low environmental sensitivity areas, which makes it difficult to characterize the AoA in easily understood terms. In addition, this model contains assumptions about input data layer inaccuracies that are not reflected across all the layers identified for this project (ESRI 2017).

Each overlay analysis method was evaluated in conjunction with overall project goals, input data layers and sources, weights, and reproducibility. Given the importance of comparing seasonal results across development phases, the weighted sum model was chosen because it honors the format of the original input data layer values, and results can be rescaled to fit a common scale to allow for effective comparison without losing original granularity (i.e., floating-point). It is also one of the most commonly used suitability modeling methods.

3.3 Weighted Sum Model Workflow

The model was designed and implemented using ESRI ArcGIS Desktop 10.5 software, including Spatial and 3D Analyst extension tools. In addition, Python 2.7.8 and Microsoft Excel were used to manage portions of the workflow. The following technical steps were performed as part of a comprehensive sensitivity analysis across the AoA.

3.3.1 Defined the Model and Study Area

In order to perform the analysis, the study area or analysis environment was defined as the AoA. Since the final raster layers need to be used to drive considerations for identifying potential development areas for proposal and to characterize areas of varying sensitivity, a cell resolution needed to be chosen that would allow users to support both end uses. Therefore, aliquots, which are sub-divided OCS blocks, were chosen since they represent the smallest spatial unit used to delineate offshore leasing areas, and because each aliquot is designated by a unique alphanumeric attribute. A full OCS block measures 4,800 by 4,800 meters, while an aliquot measures 1,200 by 1,200 meters.

3.3.2 Defined Sub-models

As with most overlay models, this model is complex. Breaking the model down into sub-models helps organize data inputs (receptors), define how the relative weights are handled within the model, and determine how results will be represented.

Table 6 presents the 15 sub-models defined for the environmental sensitivity model, which represent the seasonal variations and development phases discussed in Section 2. Each sub-model is a combination of one seasonal (or annual) suite of input rasters and one development-phase relative weighting model plan.

Table 6. Sub-models and Proposed Resultant Rasters

Construction Phase / Season	Pre-construction Weights	Construction Weights	Post-construction Weights
Spring Input Rasters	Pre_Spring	Con_Spring	Post_Spring
Summer Input Rasters	Pre_Summer	Con_Summer	Post_Summer
Fall Input Rasters	Pre_Fall	Con_Fall	Post_Fall
Winter Input Rasters	Pre_Winter	Con_Winter	Post_Winter
Annual Input Rasters	Pre_Annual	Con_Annual	Post_Annual

3.3.3 Determined Representative Input Layers

The sub-models described in Table 6 require a suite of input rasters and weighting model plans that contributes to the overall weighted sum model. For this model, input rasters were created for the receptors identified in Table 1. Receptors constitute groups of species or collections of individual species that were grouped into seasonal or annual input rasters. Data were collected from data originators or downloaded from online data portals and combined, or if required, pertinent attributes were selected to create individual rasters that represent seasonal or annual input rasters. In addition, data were clipped to the AoA (the GIS clip tool extracts a portion of a raster dataset based on a template extent) and assessed for completeness throughout the study area, and both spatial and attribute-related gaps were closed using NODATA (for cells that do not contain data) or 0 (a cell where the actual value of the data is 0), as appropriate. Resultant input rasters used in sub-models are described in Table 7. These sources were used to create the resultant output maps in Section 4 and Appendix A. Due to the numerous input rasters, the sources are listed in Table 7 rather than repeated on each map.

Table 7. Input Rasters

Receptor	Source	Units	Individual Input Rasters Used in Sub-models
Low-Frequency Cetaceans	Roberts et al. 2016. Downloaded from Marine Geospatial Ecology Lab/Duke University	Number of individual animals/km^2	Spring, Summer, Fall, Winter, and Annual
Mid-Frequency Cetaceans	Roberts et al. 2016. Downloaded from Marine Geospatial Ecology Lab/Duke University	Number of individual animals/km^2	Spring, Summer, Fall, Winter, and Annual
High-Frequency Cetaceans	Roberts et al. 2016. Downloaded from Marine Geospatial Ecology Lab/Duke University	Number of individual animals/km^2	Spring, Summer, Fall, Winter, and Annual
North Atlantic Right Whales	Roberts et al. 2016. Downloaded from Marine Geospatial Ecology Lab/Duke University	Number of individual animals/km^2	Spring, Summer, Fall, Winter, and Annual
Phocid Seals	Roberts et al. 2016. Downloaded from Marine Geospatial Ecology Lab/Duke University	Number of individual animals/km^2	Spring, Summer, Fall, Winter, and Annual
Sea Turtles[1]	Navy Operating Area Density Estimates (NODES) predictive density estimates. Downloaded from OBIS-SEAMAP/Duke University	Number of individual animals/km^2	Spring, Summer, Fall, Winter, and Annual
Birds	Curtice et al. 2016; Kinlan et al. 2016. Downloaded from Mid-Atlantic Regional Ocean Council (MARCO) online data portal.	Core abundance richness	Annual
Benthic Species[2]	NOAA Office for Coastal Management (OCM) 2014. Downloaded from NODES online data portal.	High or very high habitat likelihood	Annual
Essential Fish Habitat	The Nature Conservancy (TNC) and NOAA 2015. Downloaded from MARCO online data portal.	Count of EFH for distinct species per 10-minute by 10-minute grid graticule square	Annual

Table notes are on the next page.

Table 7 continued

Receptor	Source	Units	Individual Input Rasters Used in Sub-models
Fish	Marine-Life Data and Analysis Team Curtice et al 2016; Fogarty and Perretti 2016. Downloaded from MARCO online data portal.	Core biomass richness area	Annual

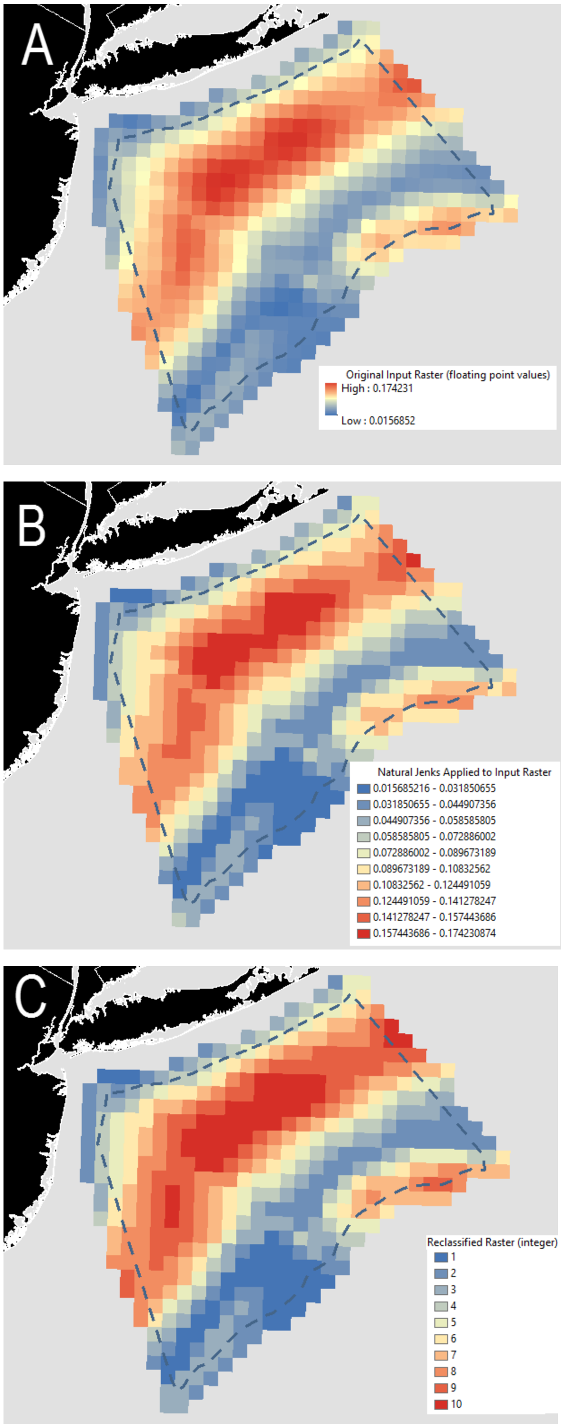
[1] Loggerhead Turtles were chosen to represent the Sea Turtle receptor due to its highest cell resolution in the density raster and having more representative spatial trends across the AoA.

[2] Only deep-sea corals were used; sea grasses were not located within the AoA.

3.3.4 Reclassified Data

This step is important in an overlay analysis because it allows disparate datasets to be compared to one another (using a common "unitless" scale), thereby simplifying interpretation of the results across the study area. For this model, a common scale of 1 through 10 was chosen, where the higher the score, the more probable the environmental sensitivity. Using ArcGIS software, the technical team reviewed each receptor group's raster data layers, spatial trends (for each receptor's relative occurrence/ prevalence), and attributes by grouping values (for non-nominal scaled data) into natural breaks classes, a classification based on the Jenks' Natural Breaks algorithm (de Smith et al. 2015). This algorithm statistically breaks data into classes with the greatest distinction between classes while minimizing differences within a class. Each receptor group's seasonal input rasters were classified using the same class breaks, which allows for an effective comparison across the group as a whole and normalizes the seasonal distribution trends within the study area. Figure 3 serves as an illustrative example of the reclassification process for high frequency cetaceans for spring. Panel A is the original input raster. Panel B shows the original raster classified into 10 Jenk's Natural Breaks classes. Panel C shows how the original raster was *reclassified* into a 1 to 10 scale, based on Jenk's Natural Breaks, resulting in *unitless* 1 to 10 integer values.

Figure 3. Jenk's Methodology.



3.3.5 Weight the Input Data

In Section 2.4., weights were assigned to each receptor group by considering the overall potential sensitivity of a receptor for a particular stressor, in addition to other factors such as the species status, permitting requirements, BOEM recommendations, engineering requirements, existing built environment, and related seasonality. Each reclassified input raster was multiplied by the weight based on its relative importance as defined in Table 8, added together, then divided by a total potential weighted value to allow for comparison *across* each sub-model. The total potential of each sub-model is calculated to be 500, a product of 10 (the highest possible reclassified value) and 5 (the highest possible weight assigned to any layer) for each class (a total of 10 classes).

Table 8. Weight Values for Overlay Analysis

Receptor	Pre-construction Weight	Construction Weight	Post-construction Weight
Low-Frequency Cetaceans	4	5	5
Mid-Frequency Cetaceans	4	5	4
High-Frequency Cetaceans	5	5	4
Pinnipeds	2	3	1
North Atlantic Right Whales	4	5	5
Sea Turtles (Loggerheads)	3	3	3
Birds	1	4	4
Corals	2	2	1
Essential Fish Habitat	2	2	2
Fish Species	3	4	1

Total potential of each development phase model is 10 (maximum reclassified class value) x 5 (maximum possible weight) for each class (total of 10 classes) = 500

3.3.6 Combined the Data Layers and Weights

The ESRI raster calculator tool multiplies each input raster layer's values by the weights presented in Table 8 and then adds the resulting cells values together and divides the result by 500 (total potential). For example, for the pre-construction spring sub-model the following expression is used (representative pseudo code below):

(Low-frequency cetacean spring raster * 4) + (Mid-frequency cetacean spring raster * 4) + (High-frequency cetacean spring raster * 5) + (Phocid seals spring raster * 2) + (NARW spring raster * 4) + (Sea Turtles spring raster * 3) + (Birds annual raster * 1) + (Deep Sea Coral annual raster * 2) + (EFH annual raster * 2) + (Fish annual raster * 3))/500 = Pre-construction spring weighted output raster

The weighted sum output raster was rescaled back to the 1 to 10 scale of the input reclassified rasters, by dividing by 10. This differs from the weighted overlay model, since gradual floating point values are maintained and results are not forced back to an integer scale. Zonal statistics were then calculated for each aliquot-shaped "zone" within the study area to create a final output raster with aliquot-sized cells. Within each aliquot zone, the maximum weighted output raster value was chosen to represent the aliquot's cell values in the final output raster layer.

3.4 Alternative Weighted Sum Models Explored

Two additional weighted sum models were run and studied to understand the effects of rescaling outputs and results (Appendix A). The first weighted sum model presented in Appendix A was developed to allow each development phase sub-model result to be considered standalone. This was achieved by isolating development phase sub-models from one another and distributing weights to equal 100 percent for each. The second weighted sum model presented in Appendix A was developed to allow results to be compared across all seasons and development phases without rescaling outputs. The weighted sum output values of this model are a direct result of first multiplying each input data value by the weight and then adding those multiplied layers (see example code in Section 3.3.6).

4 Results

The results from the weighted sum model for environmental sensitivity are presented below. In general, regions of greater sensitivity shifted seasonally. Sensitivity was lower throughout the AoA during fall and higher during spring. Sensitivity was also consistently greater along the shelf slope and Hudson Canyon.

4.1 Pre-construction

Figures 4 through 8 show pre-construction environmental weighting analysis results depicting 10 input re-classified unweighted raster input data layers and one weighted sum overlay sensitivity analysis result. The data are displayed in relation to the OSA, AoA, Submerged Lands Acts (SLA) State/federal boundary, and the territorial sea boundary. Areas of greatest sensitivity in the results run along the shelf slope, particularly the Hudson Canyon. Sensitivity was lower throughout the AoA during fall and higher during spring. Sensitivity was also consistently greater along the shelf slope and Hudson Canyon.

Figure 4. Pre-construction Spring Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

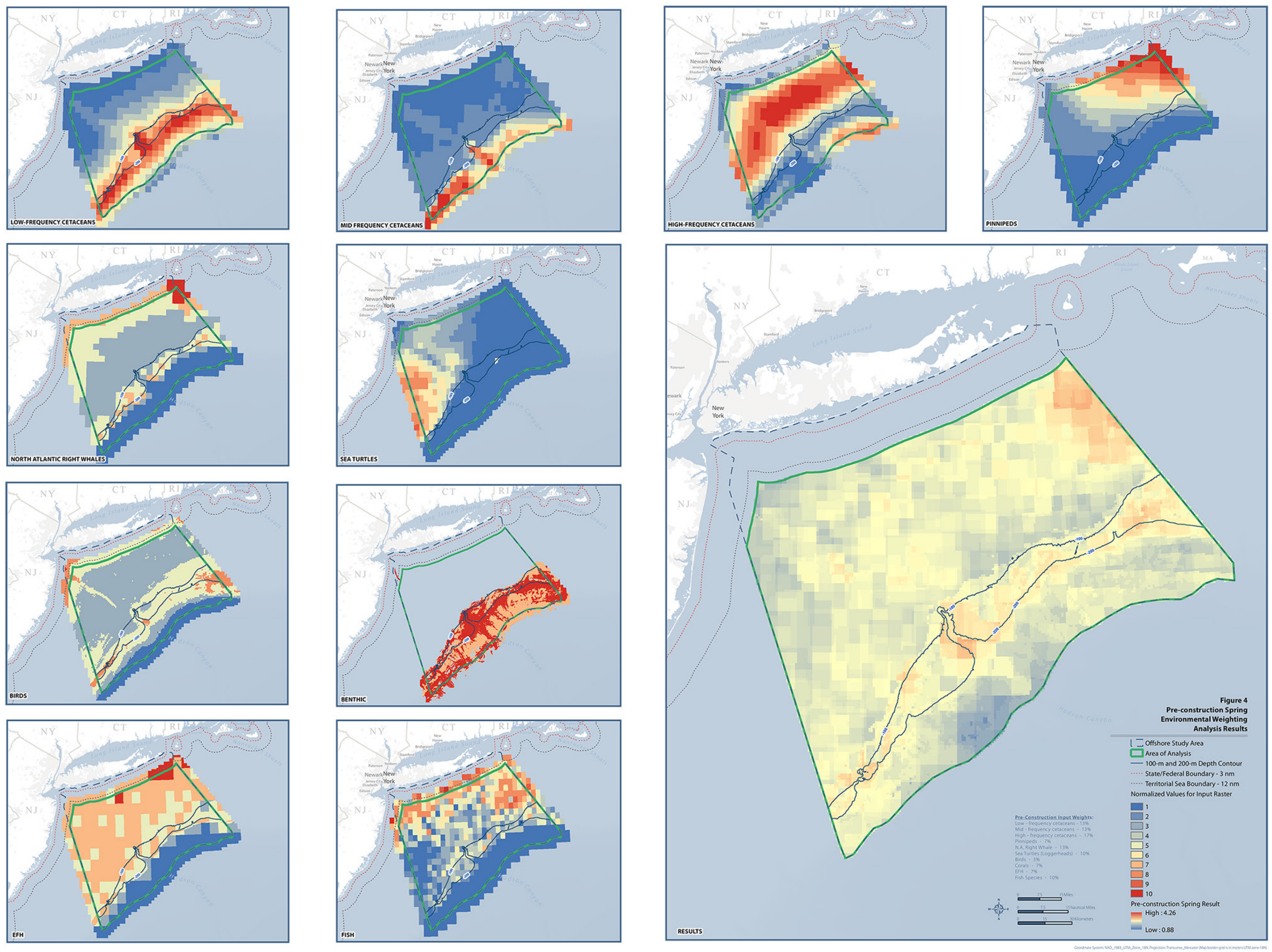


Figure 5. Pre-construction Summer Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

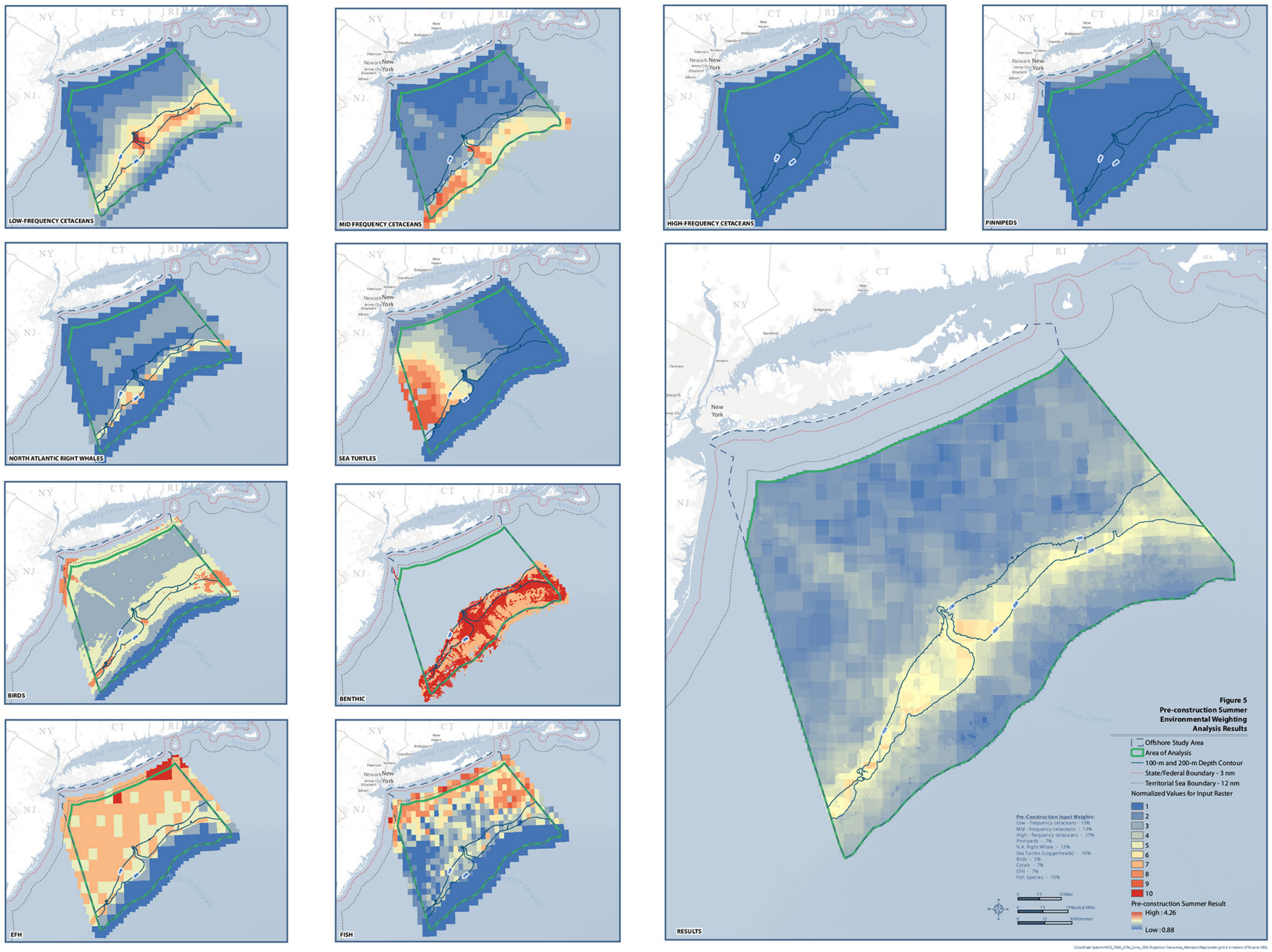


Figure 6. Pre-construction Fall Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

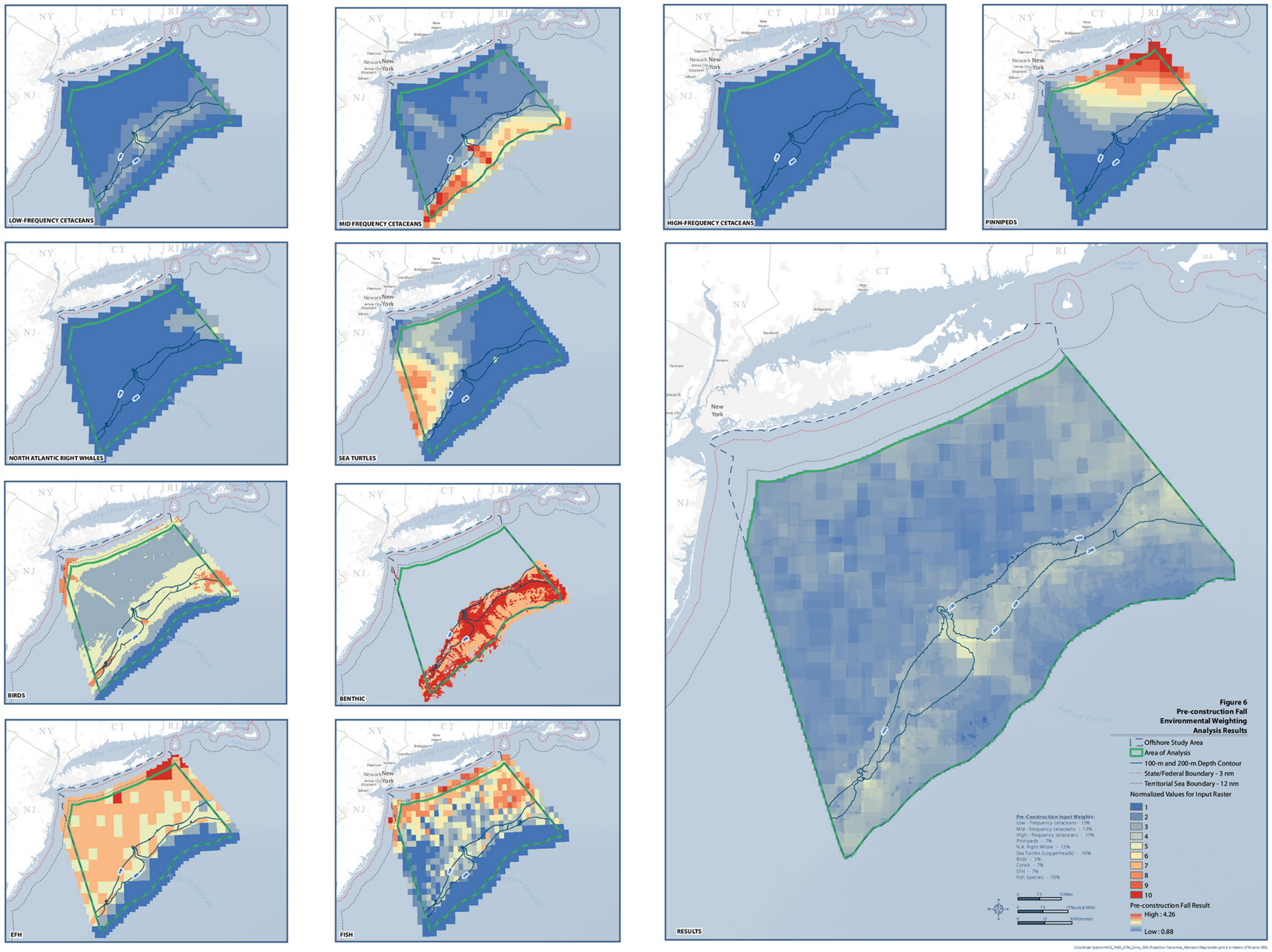


Figure 7. Pre-construction Winter Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

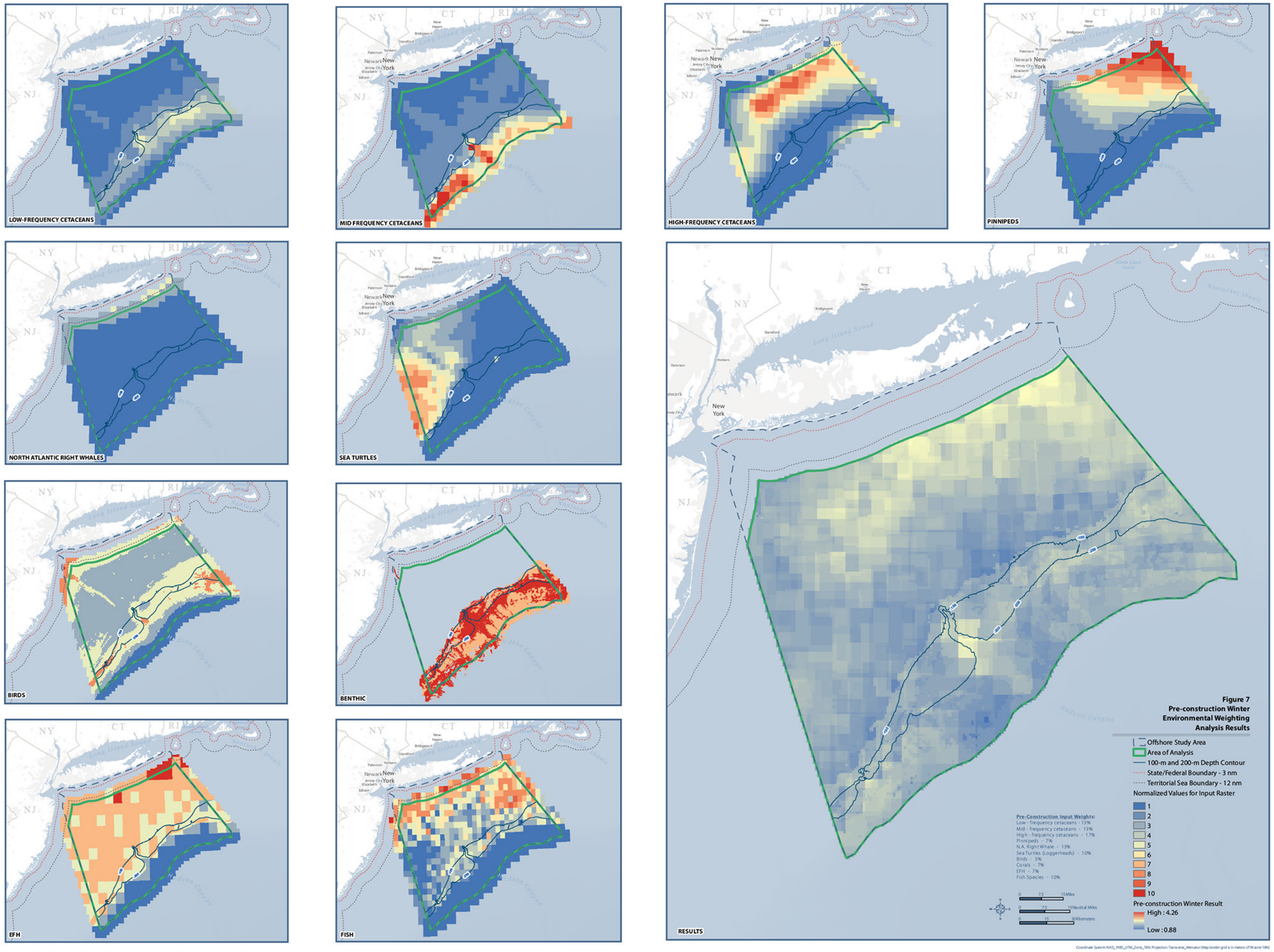
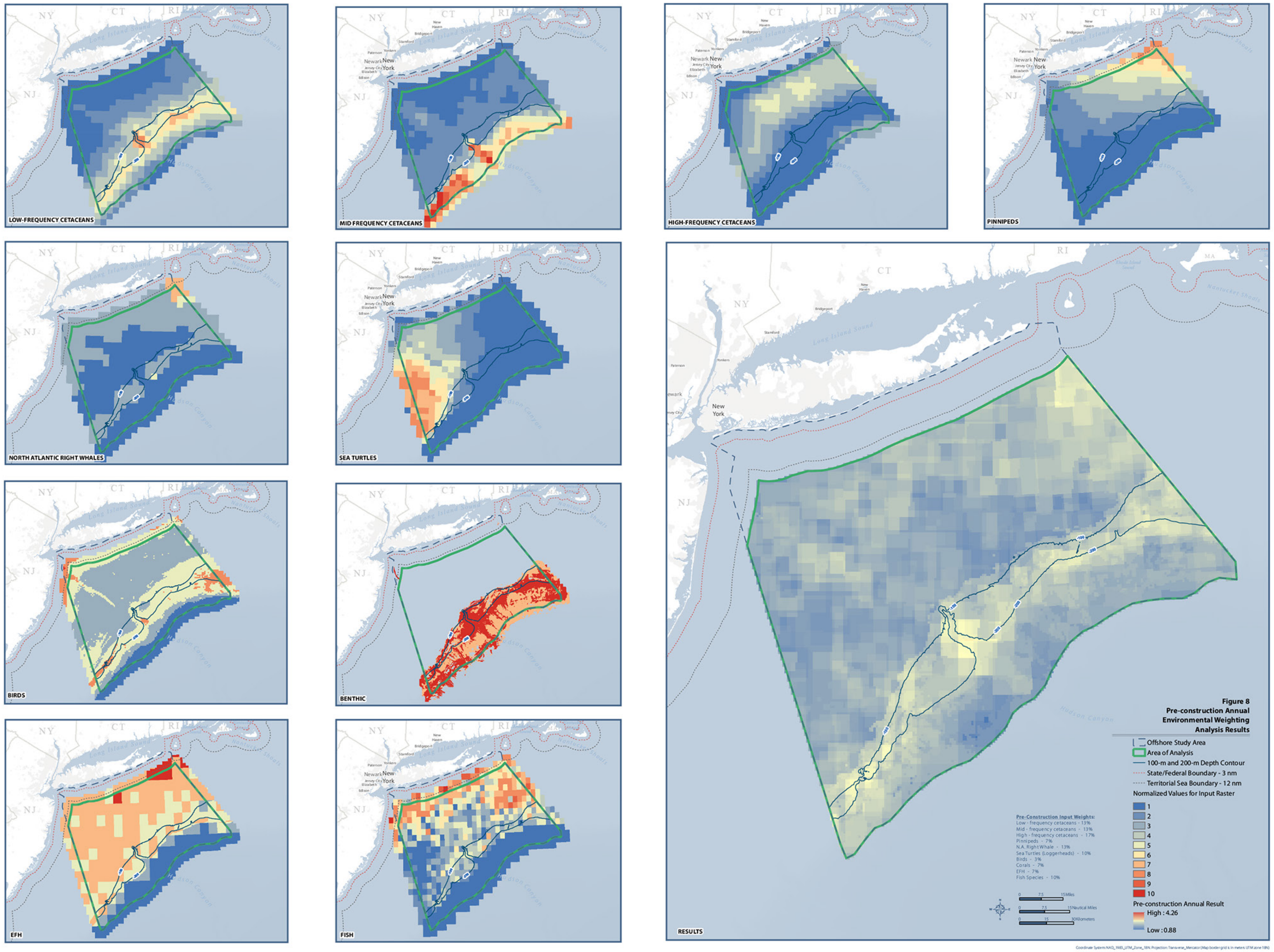


Figure 8. Pre-construction Annual Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c



4.2 Construction

Figures 9 through 13 show construction environmental weighting analysis results depicting 10 input re-classified unweighted raster input data layers and one weighted sum overlay sensitivity analysis result. The data are displayed in relation to the OSA, AoA, SLA State/federal boundary, and the territorial sea boundary. Areas of greatest sensitivity in the results run along the northeastern boundary of the AoA and along the continental shelf slope, particularly the Hudson Canyon. Sensitivity was lower throughout the AoA during fall and higher during spring. Sensitivity was also consistently greater along the shelf slope and Hudson Canyon.

Figure 9. Construction Spring Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

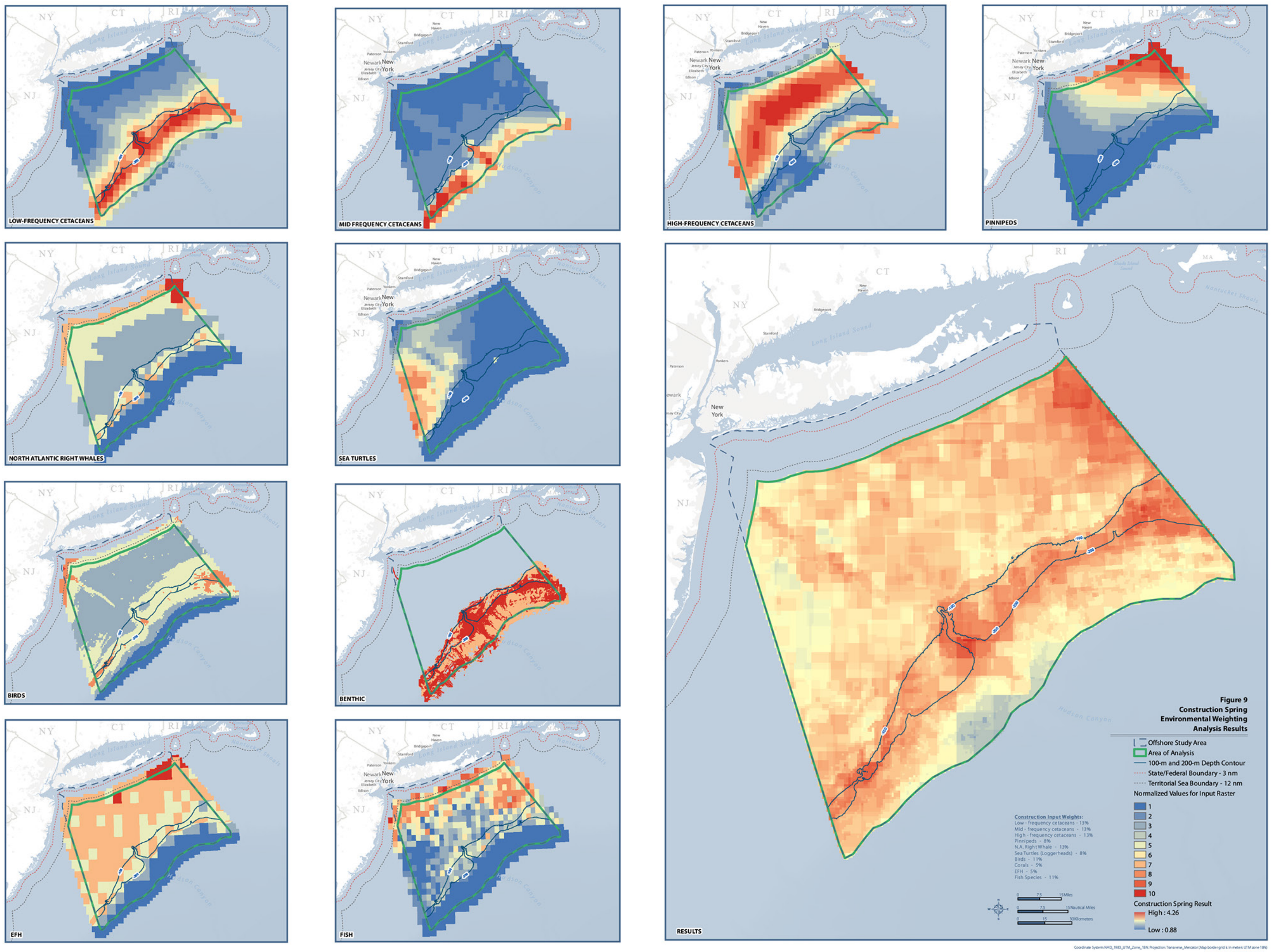


Figure 10. Construction Summer Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

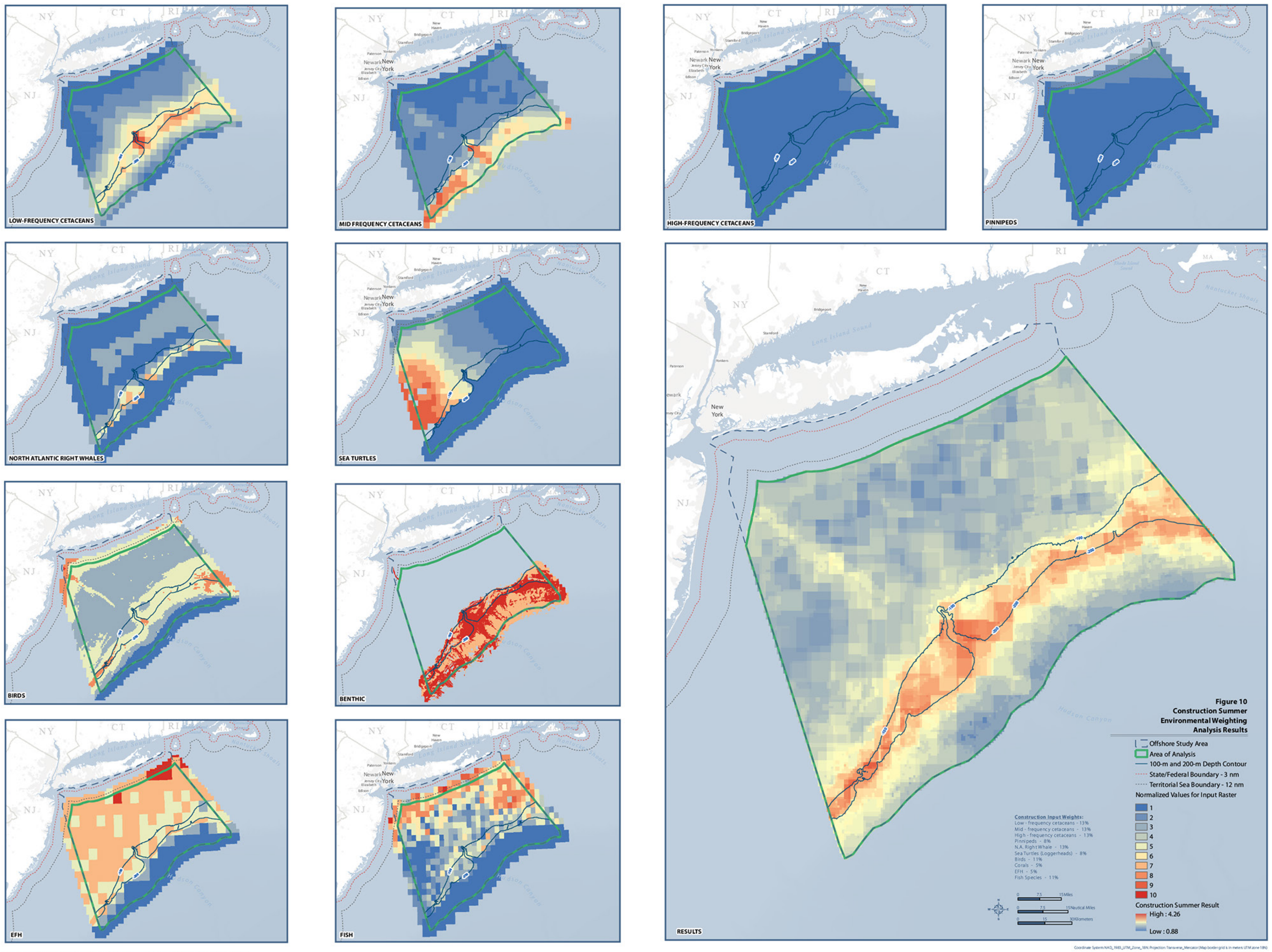


Figure 11. Construction Fall Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

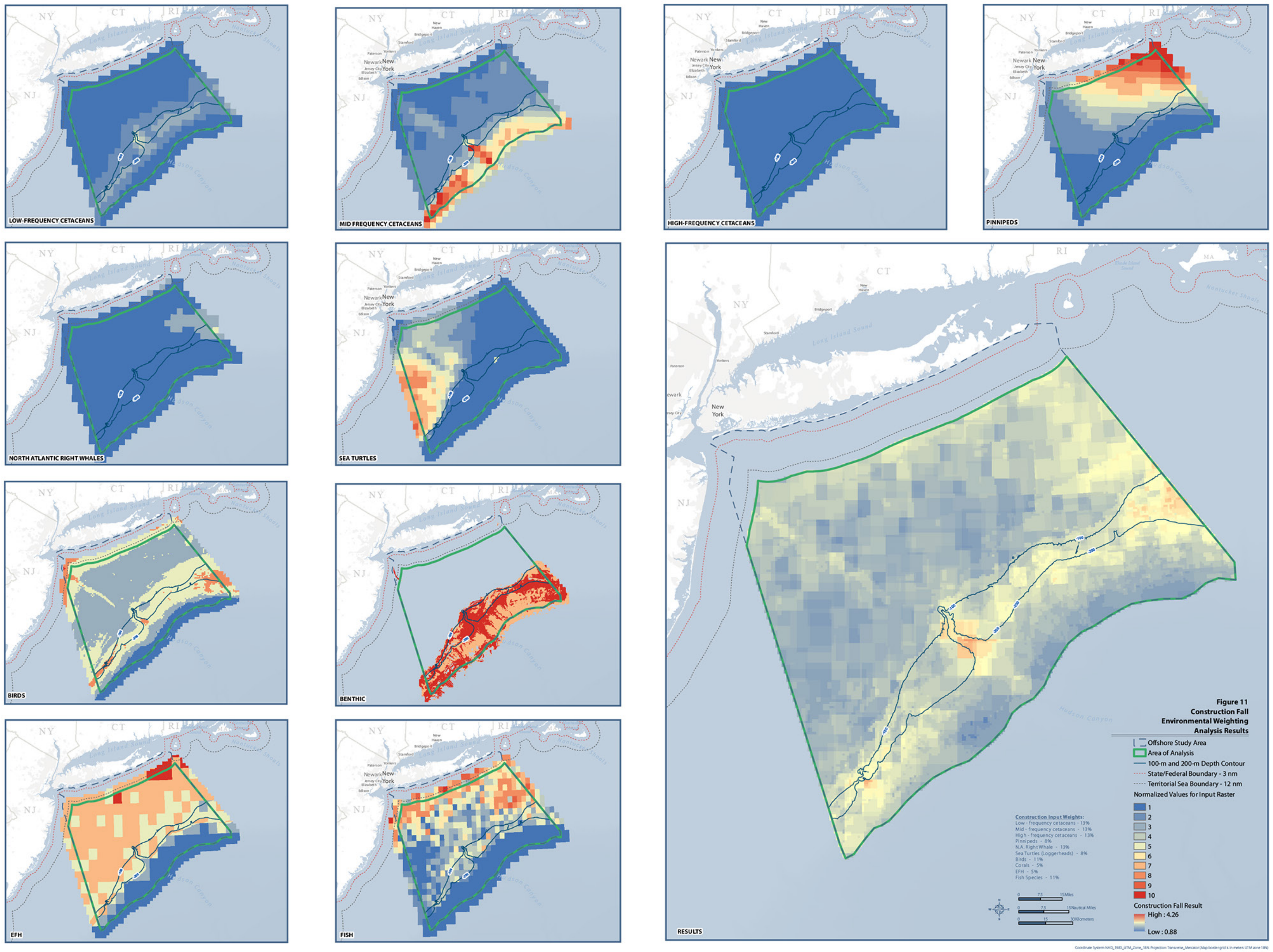


Figure 12. Construction Winter Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

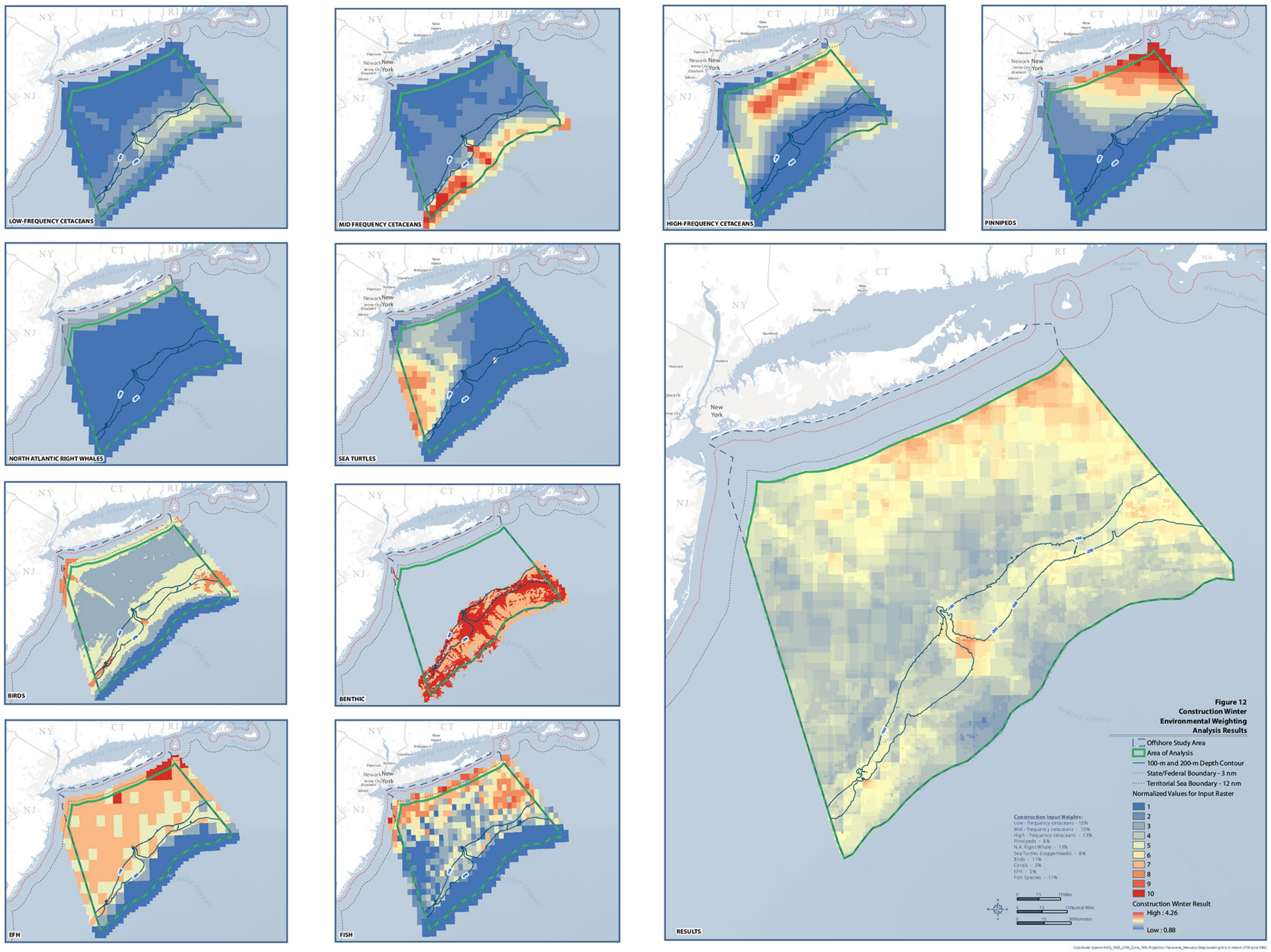
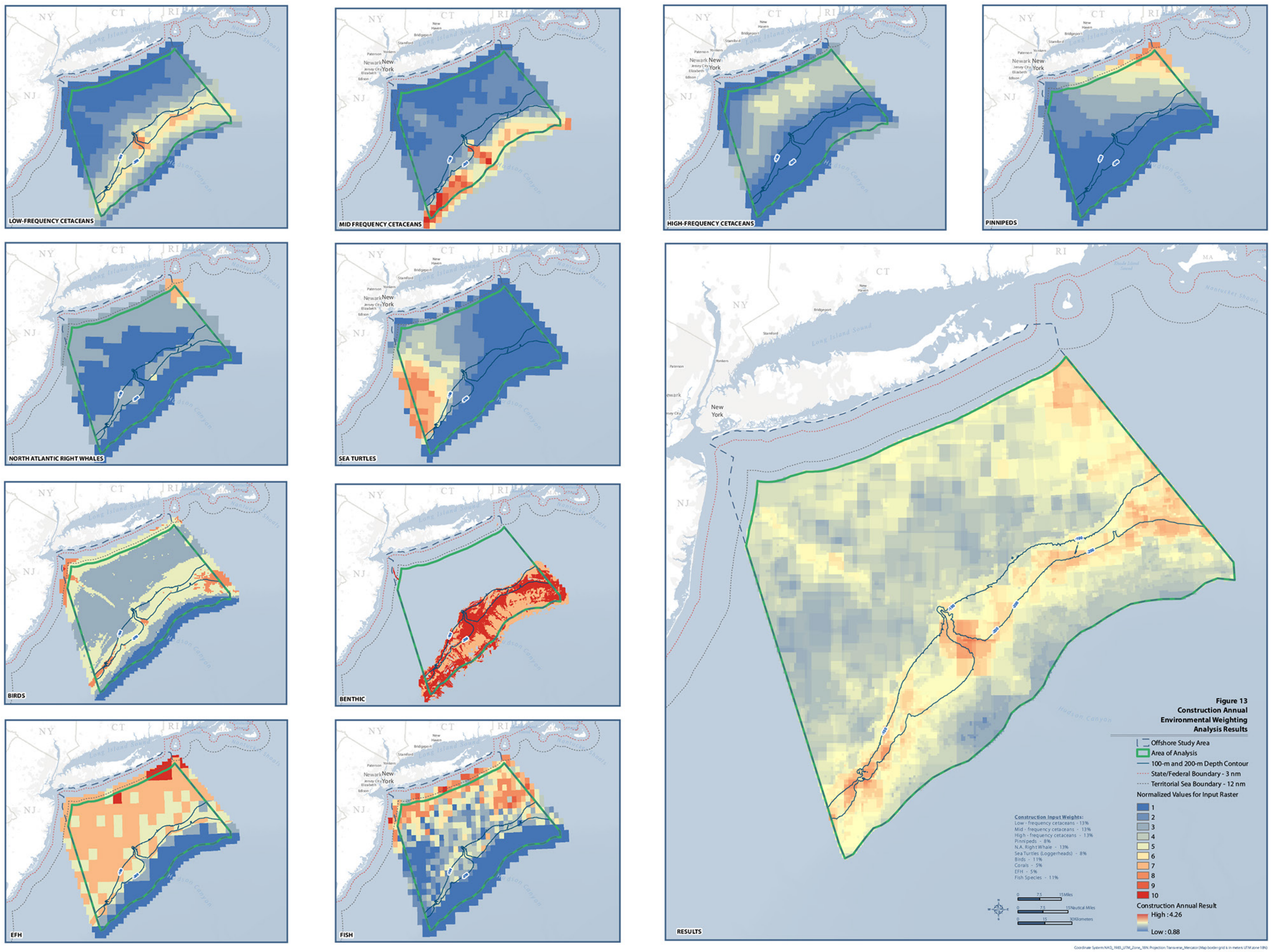


Figure 13. Construction Annual Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c



4.3 Post-construction

Figures 14 through 18 show post-construction environmental weighting analysis results depicting 10 input re-classified unweighted raster input data layers and one weighted sum overlay sensitivity analysis result. The data are displayed in relation to the OSA, AoA, SLA State/federal boundary, and the territorial sea boundary. Areas of greatest sensitivity in the results run along the continental shelf slope, particularly the Hudson Canyon. Sensitivity was lower throughout the AoA during fall and higher during spring. Sensitivity was also consistently greater along the shelf slope and Hudson Canyon.

Figure 14. Post-construction Spring Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

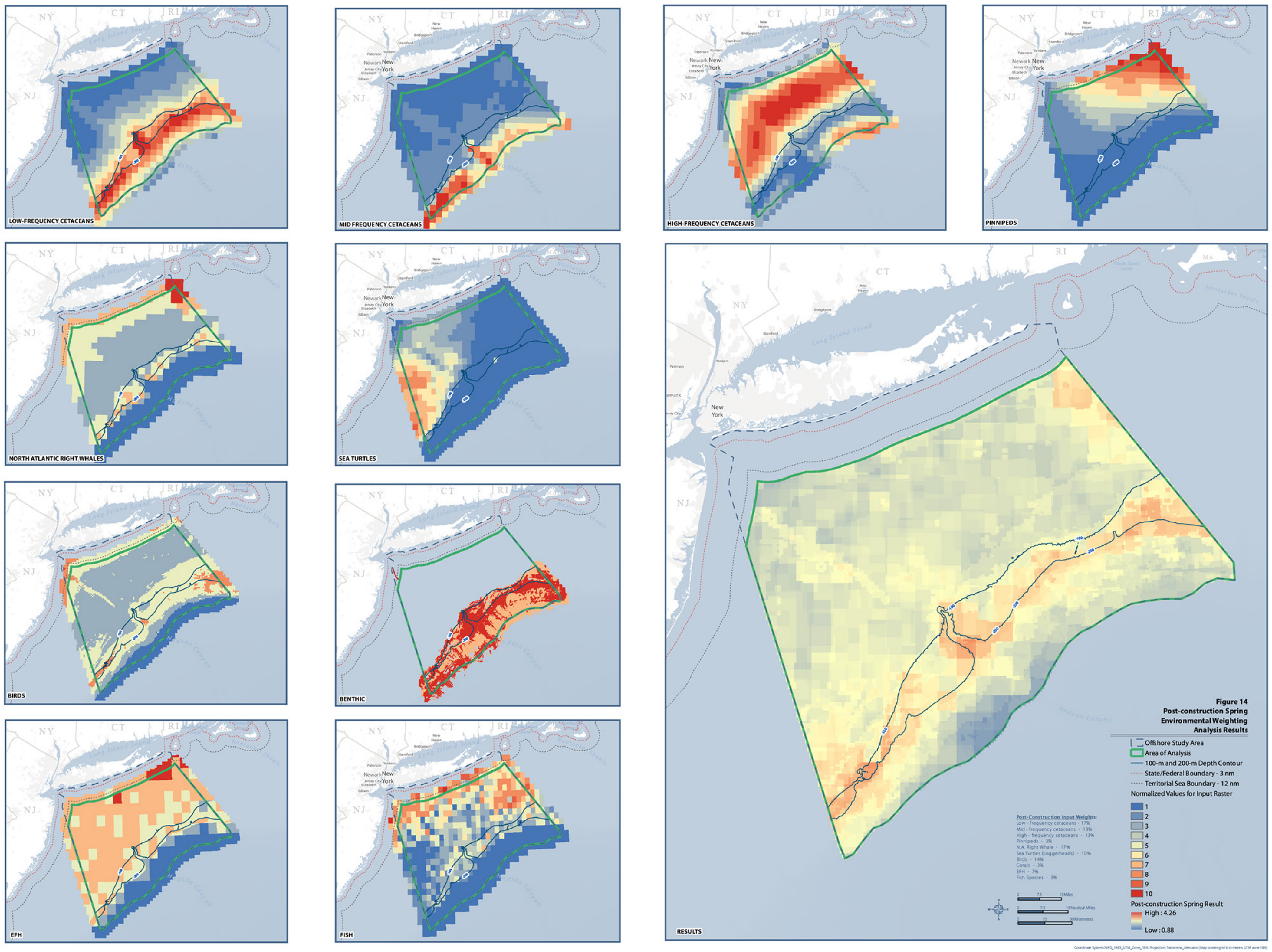


Figure 15. Post-construction Summer Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

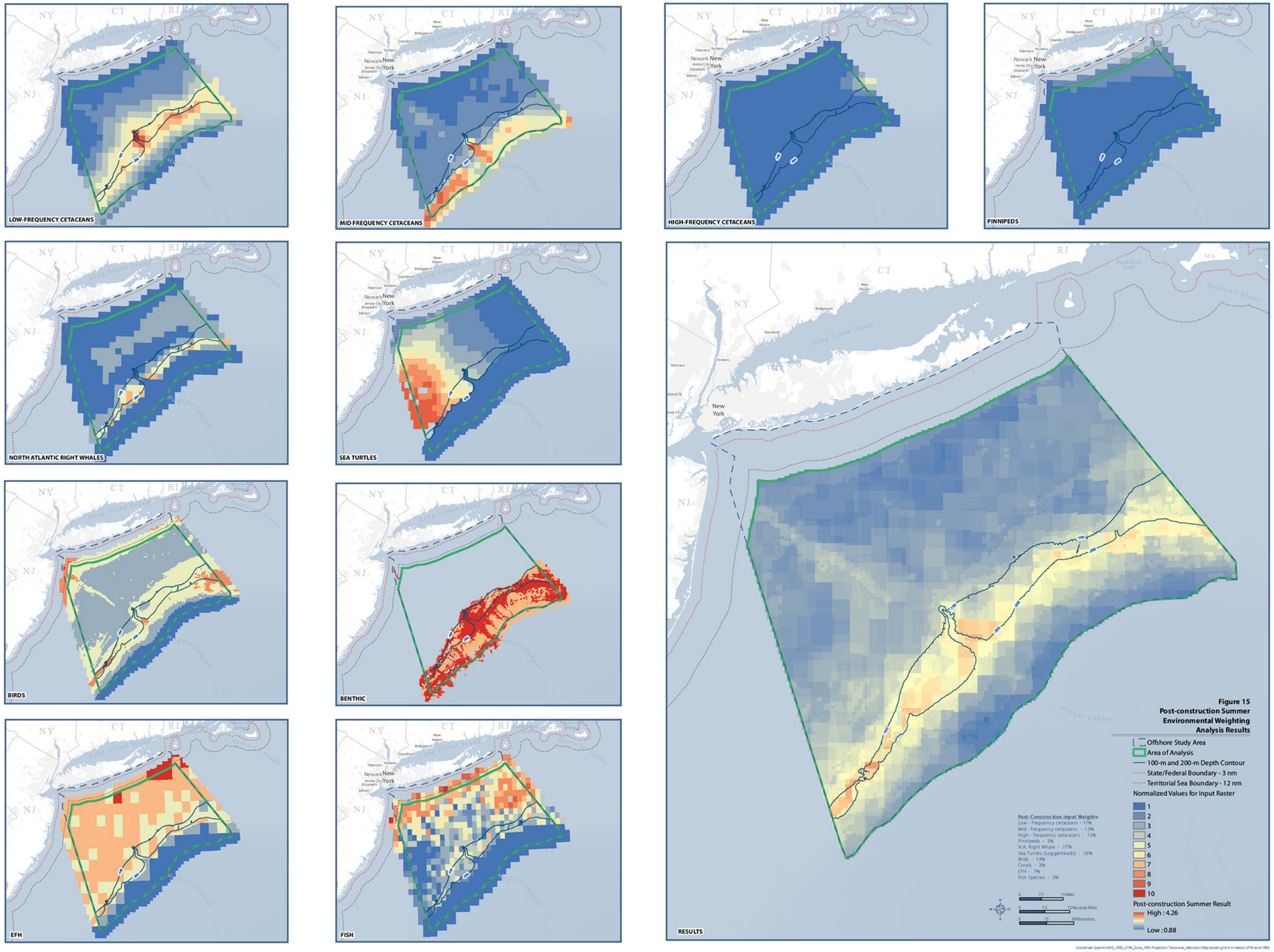


Figure 16. Post-construction Fall Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

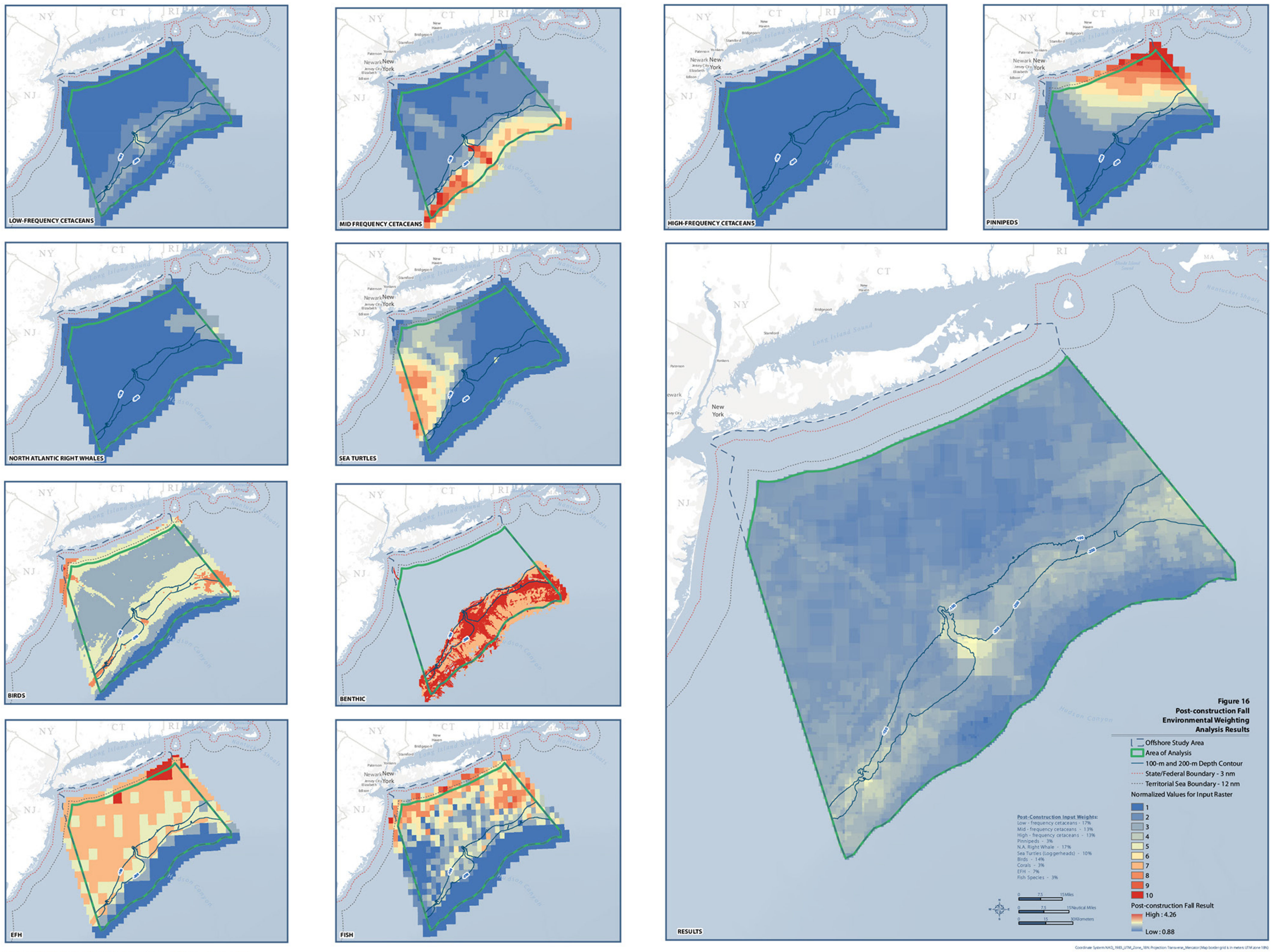


Figure 17. Post-construction Winter Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

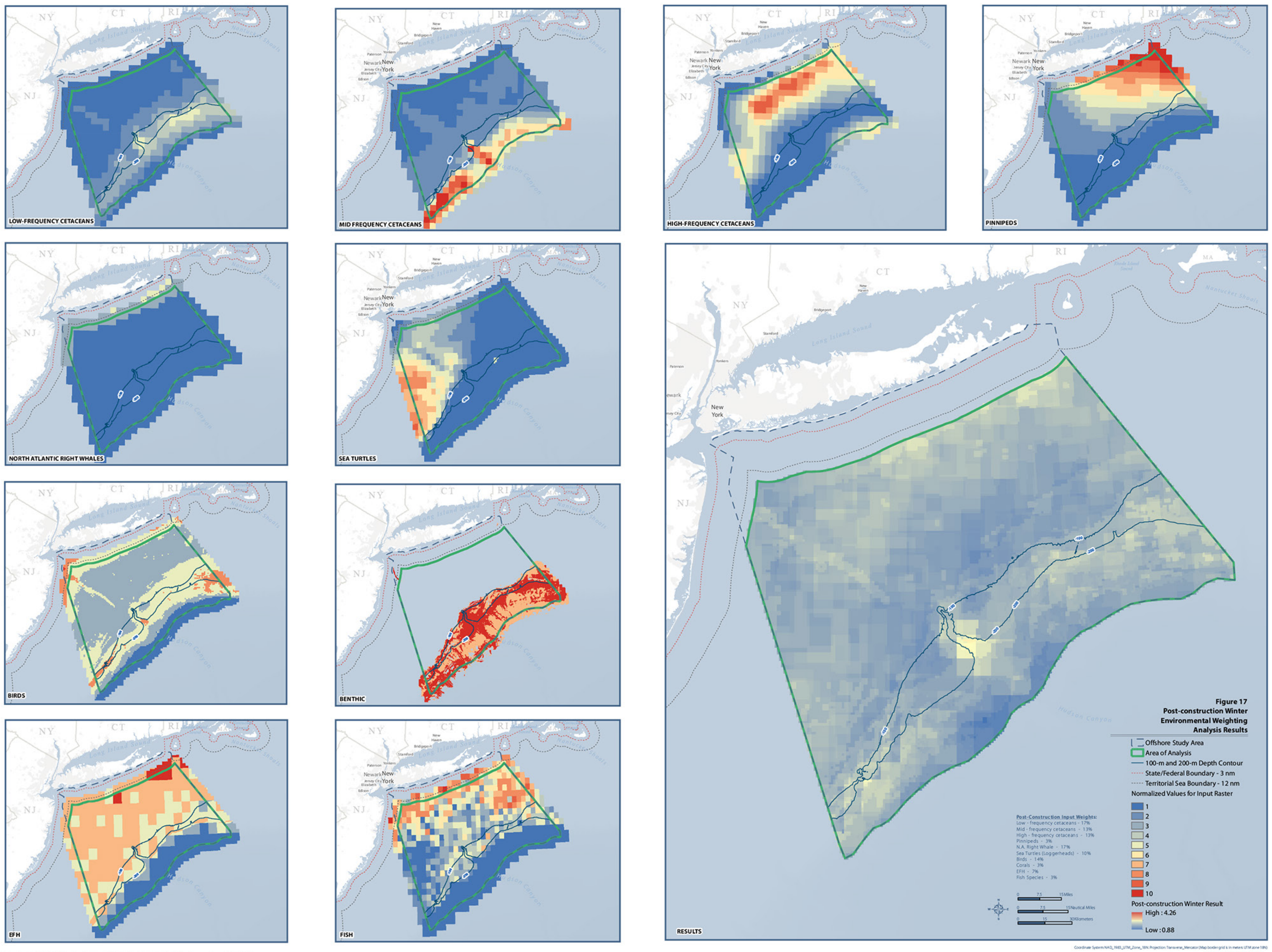
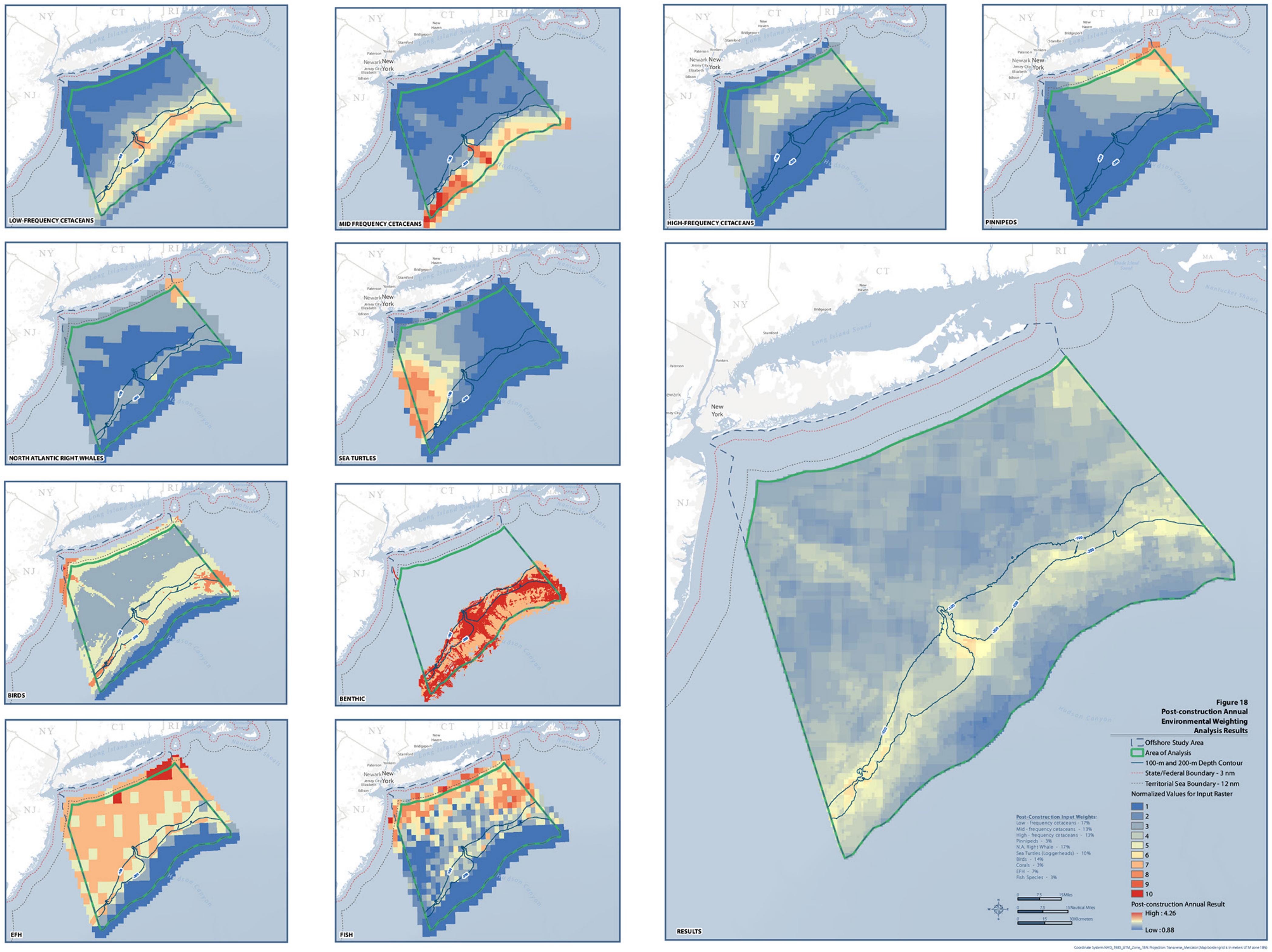


Figure 18. Post-construction Annual Environmental Weighting Analysis Results.

Source: ESRI 2010; BOEM 2016c

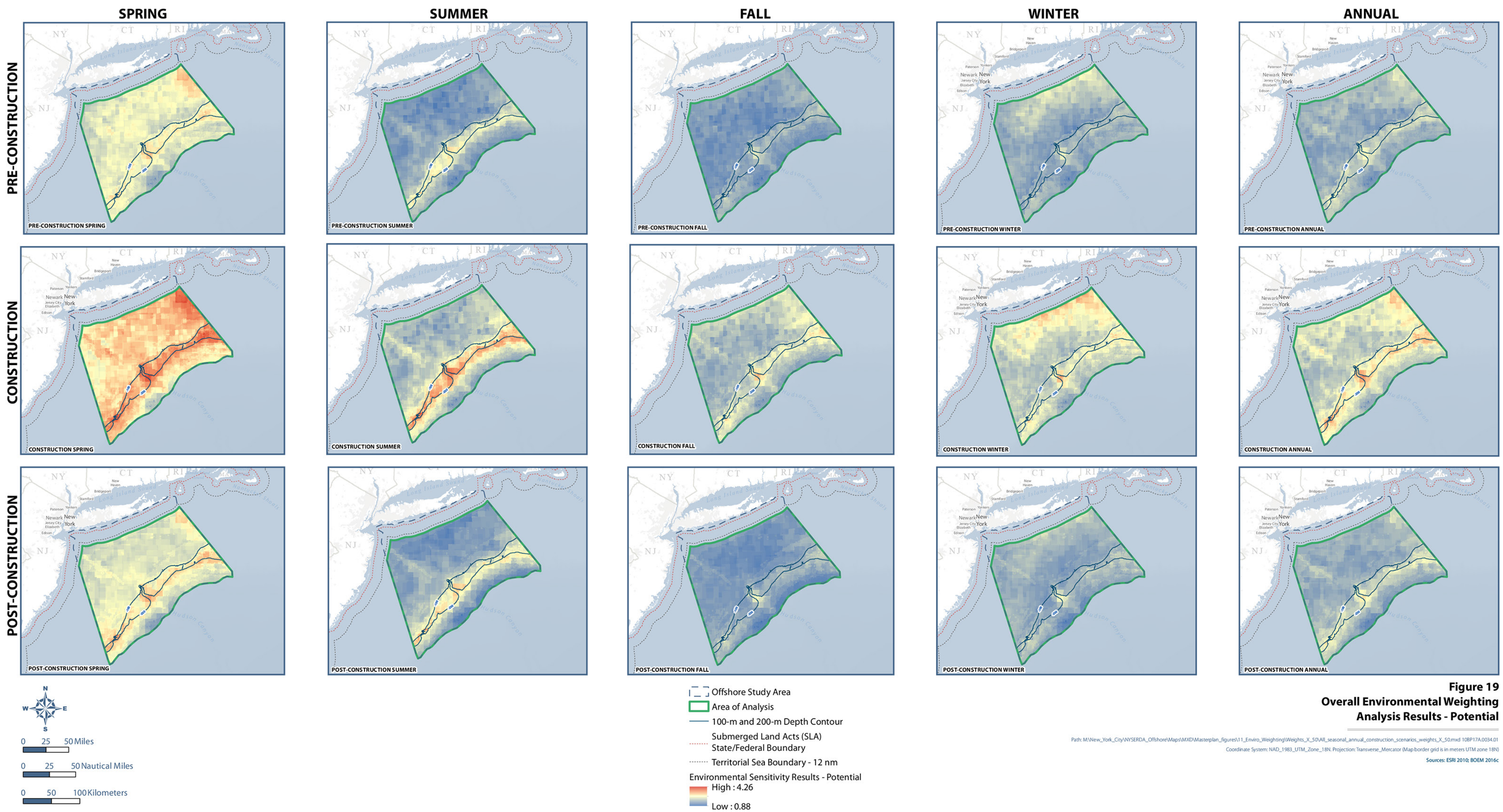


4.4 Overall

Figure 19 depicts 15 raster maps displaying overall environmental sensitivity results in relation to the AoA, SLA State/federal boundary, and the territorial sea boundary on one figure. Sensitivity was lower throughout the AoA during fall and higher during spring. Sensitivity was also consistently greater along the shelf slope and Hudson Canyon. In general, sensitivity was greater during construction.

Figure 19. Overall Environmental Weighting Analysis Results - Potential.

Source: ESRI 2010; BOEM 2016c



5 Conclusions

The high-level sensitivity mapping analysis identified seasonal shifts in regions of relatively higher or lower sensitivity. Certain AoA regions were identified as consistently more environmentally sensitive, including the shelf slope and Hudson Canyon. In general, sensitivity was greater during construction. Note that this Study does not propose that a region with higher sensitivity be excluded from consideration for future offshore wind development, but rather serves as an indication that environmental permitting processes for locating in more sensitive areas may be more complicated than for less generally sensitive areas. Though AoA regions with greater sensitivity may warrant more protective measures or implicate more regulatory processes, those regions may still accommodate offshore wind development if environmental considerations are addressed. Importantly, this analysis is one tool among several that will be used to select areas to propose to BOEM for further analysis.

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Appendix A. Alternative Modeling Methods

A.1 Introduction

Appendix A describes two alternative weighted sum models explored for this sensitivity analysis. Each of the weighted sum model results for all seasons and all phases of construction is also presented for both of these alternative models (see Figures A-1 and A-2). Alternative 1 was originally developed to model sensitivity within the AoA, and was subsequently replaced following review by the stakeholders. This alternative is described below in Section A.2. Alternative 2 is similar to the final model described in Section 3 of this Study, but differs in the weighting methodology as described in Section A.3

A.2 Alternative 1

Alternative 1 is the original methodology developed to model sensitivity within AoA, and the methodology for this model is briefly described below. This method was replaced after obtaining stakeholder feedback with the modeling approach described in Section 3 to allow for comparisons between outputs from the different phases of development (i.e., pre-construction, construction, and post-construction). Otherwise, the general methodology used in Alternative 1 is consistent with that described in Section 3 for the final model, and uses the same defined sub-models, input data, and data reclassification system. Alternative 1 differs from the final model in the weighting of the input data and combination of data layers. The weighted sum model results for Alternative 1 are shown on Figure A-1.

A.2.1 Weight the Input Data

As described in Section 2.4, weights were assigned to each receptor by considering the overall potential sensitivity to a receptor for a particular stressor in addition to other factors such as the species status, permitting requirements, BOEM recommendations, engineering requirements, existing built environment, and related seasonality. Each input raster was weighted as a percentage influence based on its relative importance as defined in Table A-1, which presents the weight values used in this model, converted to a percentage scale. This weighted sum method treats each construction phase sub-model as a discrete model and tunes the weights to be relative to one another, adding to 100 percent. Determining percentage influence typically yields a more nuanced, gradual floating point output result, rather than multiplying each reclassified input layer by its weight—which will yield to simple integer results.

Table A-1. Weight Values for Overlay Analysis

Receptor	Pre-construction Weight	Pre-construction Weight (%)	Construction Weight	Construction Weight (%)	Post-construction Weight	Post-construction Weight (%)
Low-Frequency Cetaceans	4	13%	5	13%	5	17%
Mid-Frequency Cetaceans	4	13%	5	13%	4	13%
High-Frequency Cetaceans	5	17%	5	13%	4	13%
Pinnipeds	2	7%	3	8%	1	3%
North Atlantic Right Whale	4	13%	5	13%	5	17%
Sea Turtles (Loggerheads)	3	10%	3	8%	3	10%
Birds	1	3%	4	11%	4	14%*
Corals	2	7%	2	5%	1	3%
Essential Fish Habitat	2	7%	2	5%	2	7%
Fish Species	3	10%	4	11%	1	3%
		100%		100%		100%

* Birds post-construction was rounded up from 13% to 14%, to allow the sum to equal 100%.

A.2.2 Combine the Data Layers and Weights

The ESRI raster calculator tool multiplies each input raster layer's values by the weights presented in Table A-1 and then adds the resulting cells' values together. For example, for the pre-construction spring sub-model the following expression is used (representative pseudo code below):

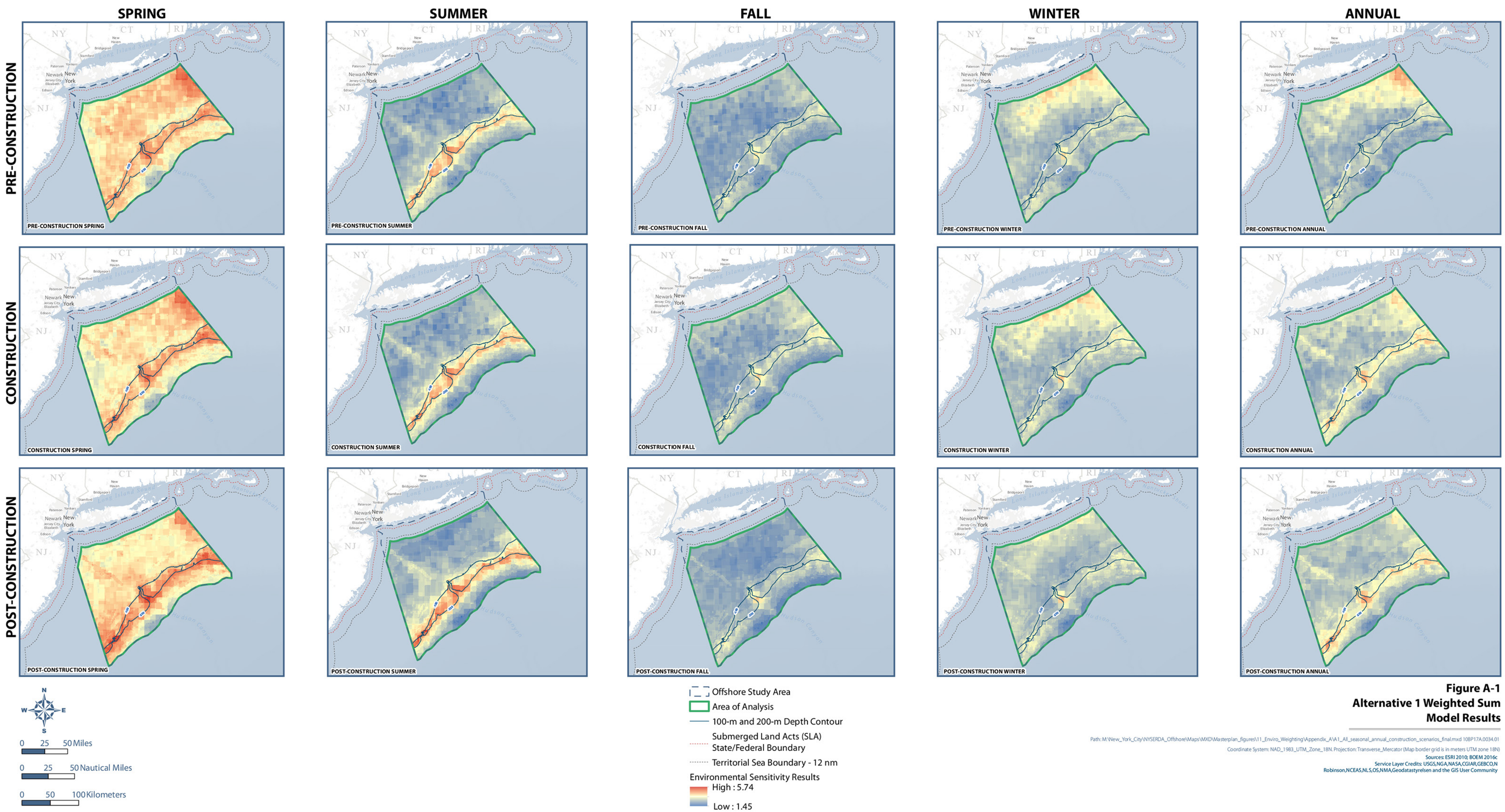
> (Low-frequency cetacean spring raster * 0.13) + (Mid-frequency cetacean spring raster * 0.13) + (High-frequency cetacean spring raster * 0.17) + (Phocid seals spring raster * 0.7) + (NARW spring raster * 0.13) + (Sea Turtles spring raster * 0.1) + (Birds annual raster * 0.03) + (Deep Sea Coral annual raster * 0.7) + (EFH annual raster * 0.7) + (Fish annual raster * 0.1) = Pre-construction spring weighted output raster

This approach differs from the final model for the weighted overlay presented in Section 3, since gradual floating point values are maintained and results are not forced back to the integer scale used for reclassification (i.e., 1 to 10). Zonal statistics were then calculated for each aliquot-shaped "zone" within the AoA to create a final output raster with aliquot-sized cells. Within each aliquot zone, the maximum weighted output raster value was chosen to represent the aliquot's cell values in the final output raster layer.

A.2.3 Results

Figure A-1. Alternative 1 Weighted Sum Model Results.

Source: ESRI 2010; BOEM 2016c



A.3 Alternative 2

Alternative 2 was developed following stakeholder feedback along with the final model described in Section 3 as an option to allow for comparison of sensitivity outputs between phases of offshore wind development. The methodology for Alternative 2 is briefly described below, and the weighted sum model results for Alternative 2 are shown on Figure A-2.

The general method used in Alternative 2 is consistent with that described in in Section 3 and uses the same defined sub-models, input data, and data reclassification system. It differs in the weighting of the input data and combination of data layers. The final model considered the total potential of each phase sub-model with the maximum reclassified class value for 10 multiplied by the maximum possible weight of five for each of 10 classes to yield a total potential for each sub-model of 500. Alternative 2 simply accounts for the weight multiplier. The results of this analysis are presented in Figure A-2.

A.3.1 Weight the Input Data

In Section 2.4, weights were assigned to each receptor by considering the overall potential sensitivity to a receptor for a particular stressor in addition to other factors such as the species status, permitting requirements, BOEM recommendations, engineering requirements, existing built environment, and related seasonality. Each input raster was multiplied by the weights presented in Table A-2, then simply added together.

Table A-2. Weight Values for Overlay Analysis

Receptor	Pre-construction Weight	Construction Weight	Post-construction Weight
Low-Frequency Cetaceans	4	5	5
Mid-Frequency Cetaceans	4	5	4
High-Frequency Cetaceans	5	5	4
Pinnipeds	2	3	1
North Atlantic Right Whale	4	5	5
Sea Turtles (Loggerheads)	3	3	3
Birds	1	4	4
Corals	2	2	1
Essential Fish Habitat	2	2	2
Fish species	3	4	1

A.3.2 Combined the Data Layers and Weights

The ESRI raster calculator tool multiplies each input raster layer's values by the weights presented in Table A-2 and then adds the resulting cells values together. For example, for the pre-construction spring sub-model the following expression is used (representative pseudo code below):

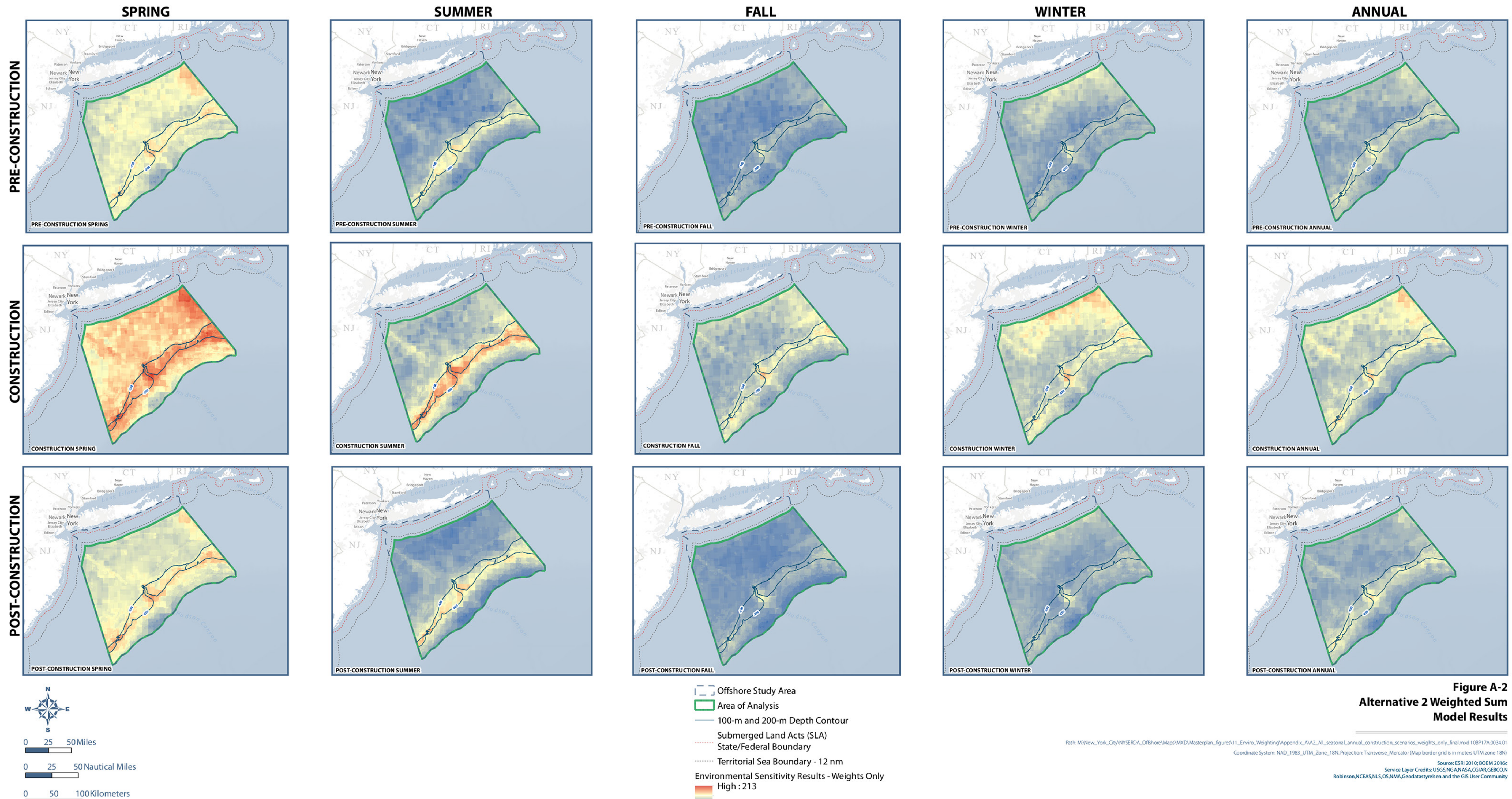
> (Low-frequency cetacean spring raster * 4) + (Mid-frequency cetacean spring raster * 4) + (High-frequency cetacean spring raster * 5) + (Phocid seals spring raster * 2) + (NARW spring raster * 4) + (Sea Turtles spring raster * 3) + (Birds annual raster * 1) + (Deep Sea Coral annual raster * 2) + (EFH annual raster * 2) + (Fish annual raster * 3) = Pre-construction spring weighted output raster

Zonal statistics were then calculated for each aliquot-shaped "zone" within the study area to create a final output raster with aliquot-sized cells. Within each aliquot zone, the maximum weighted output raster value was chosen to represent the aliquot's cell values in the final output raster layer.

A.3.3 Results

Figure A-2. Alternative 2 Weighted Sum Model Results.

Source: ESRI 2010; BOEM 2016c



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