Appendix B
Supplemental Information and Additional Figures and Tables

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Abbreviations and Acronyms

°F	degree Fahrenheit
%	percent
$	dollar
§, §§	section, sections
µPa	micropascal
$\mu Pa^2 s$	micropascal squared second
AMSL	above mean sea level
ANSI	American National Standards Institute
BA	Biological Assessment
BMP	best management practice
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
COP	Construction and Operations Plan
CPT	cone penetrometer testing
CT	Connecticut
D	diameter; animal depth
dB	decibel
dB re 1 µPa	decibels referenced to 1 micropascal
dB re 1 µPa m	decibels referenced to 1 micropascal at 1 meter
dB re 1 $\mu Pa^2 m^2 s$	decibels referenced to 1 micropascal squared meter squared second
DP	dynamic positioning
DPS	distinct population segment
DTH	down-the-hole
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
EIS	Environmental Impact Statement
$ER_{95\%}$	95th percentile exposure-based range
ESA	Endangered Species Act
ESP	electrical service platform
ETRB	Engineering and Technical Review Branch
Fed. Reg.	Federal Register
FMP	Fisheries Management Plan
h/D	water depth divided by pile diameter
HDD	horizontal directional drilling
HFC	high-frequency cetacean
HRG	high-resolution geophysical survey
Hz	hertz
IPF	impact-producing factor
ISO	International Standards Organization
ITA	Incidental Take Authorization
IUCN	International Union for Conservation of Nature
JASMINE	JASCO Applied Sciences Animal Simulation Model Including Noise Exposure
kHz	kilohertz
kJ	kilojoule
km^2	square kilometer
LFC	low-frequency cetacean
LOA	Letter of Authorization
Lpk	peak sound pressure level in units of decibels referenced to 1 micropascal
Lpk-pk	peak-to-peak level
M	animal mass in kilograms
MA	Massachusetts

MBES	multibeam echosounders
MFC	sound exposure level over 24 hours
m/s	meters per second
m/s^2	meters per second squared
MW	megawatt
NA	not applicable
NARW	North Atlantic right whale
NCDC	National Climatic Data Center
NEFSC	Northeast Fisheries Science Center
NJ	New Jersey
NMFS	National Marine Fisheries Service
nm/s	nanometer per second
NOAA	National Oceanic and Atmospheric Administration
NY	New York
OCS	Outer Continental Shelf
OECC	offshore export cable corridor
Pa	pascal
PAM	passive acoustic monitoring
PBR	potential biological removal
PK	peak sound pressure level
PPW	pinnipeds in the water
Project	New England Wind Project
PTS	permanent threshold shift
re	referenced to
RI	Rhode Island
RI DEM	Rhode Island Department of Environmental Management
RI/MA Lease Areas	Rhode Island and Massachusetts Lease Areas
rms	root-mean-square
S	scour
SEL	sound exposure level
SEL_{24h}	sound exposure level over 24 hours
SEL_{SS}	sound exposure level single strike
S/h	scour depth divided by water depth
SPL	sound pressure level
SWDA	Southern Wind Development Area
TTS	temporary threshold shift
UME	unusual mortality event
U.S.	United States
USGS	U.S. Geological Survey
UXO	unexploded ordnance
VMS	vessel monitoring system
VTR	vessel trip report
WDA	Wind Development Area
WTG	wind turbine generator

B Supplemental Information and Additional Figures and Tables

B.1 Environmental and Physical Setting

This appendix discusses the physical, geological, and biological settings in the vicinity of the New England Wind Project (proposed Project). In addition, it addresses potential impacts on these settings as determined from field and laboratory studies within the United States (mainly from the Block Island Wind Farm) and from outside the United States. Although projects in the United States may utilize larger monopile foundations and larger turbines than those used in the well-studied projects of the North Sea, the basic science behind how monopile size, water depth, currents, and waves interact to affect local hydrodynamics and create seabed scour and other effects are well understood and applicable to projects in the United States. The Bureau of Ocean Energy Management (BOEM) recently compared the long-term monitoring results from Europe to monitoring results from the first project in U.S. waters (the Block Island Wind Farm) and found that benthic scour at the Block Island Wind Farm was minor. BOEM has gathered the information in this document through direct outreach and dialogue with European regulatory agencies and private industry partners, as well as by reviewing both peer-reviewed and gray literature.

B.1.1 General Regional Setting

The proposed Project is located in southern New England and includes land areas in the Commonwealth of Massachusetts and adjacent nearshore and offshore waters. Figure B-1 shows the region surrounding the proposed Project.

The geologic history of the Atlantic Coast of the United States is that of a passive margin, where the coastal mountains and continental sediments have been eroded over the millennia and deposited as thick layers of unconsolidated sediments in the Outer Continental Shelf (OCS). More recently in geologic time, periods of glaciation reworked, eroded, and deposited sediments along the northeastern Atlantic, leaving behind glacial formations offshore that include deep infilled channels, glacial moraine deposits, boulder fields, areas of highly consolidated sediments, and highly variable, heterogeneous conditions. Glacial moraines identified on the islands of Long Island (New York), Block Island (Rhode Island), Martha’s Vineyard (Massachusetts), and Nantucket Island (Massachusetts) roughly connect through a series of offshore moraine deposits. Glacial deposits are found in and around BOEM lease areas off the coast of Rhode Island and Massachusetts and lease areas offshore New York. In areas in and around the glacial moraines, sediments are expected to be generally coarser grained, highly variable, and consolidated with erratics such as boulders deposited both on the seabed and in the subsurface.

The proposed Project’s offshore cables would make landfall in south-central Cape Cod in Barnstable County. The Covell’s Beach Landfall Site is located within the Town of Barnstable, the largest community on Cape Cod; the Town of Barnstable includes forests, wetlands, ponds, protected open space, public use areas, low- to medium-density residential development, and some commercial and industrial uses along major roads. The Town of Barnstable management plan prioritizes preserving the historic character of the area and preserving natural resources (Town of Barnstable 2010). The proposed Project would also include office, storage, and port facilities on Martha’s Vineyard. About 2 percent of Martha’s Vineyard is zoned for commercial or industrial use, 40 percent is preserved from development, and nearly all of the remaining land area is developed for residential uses (Martha’s Vineyard Commission 2010).

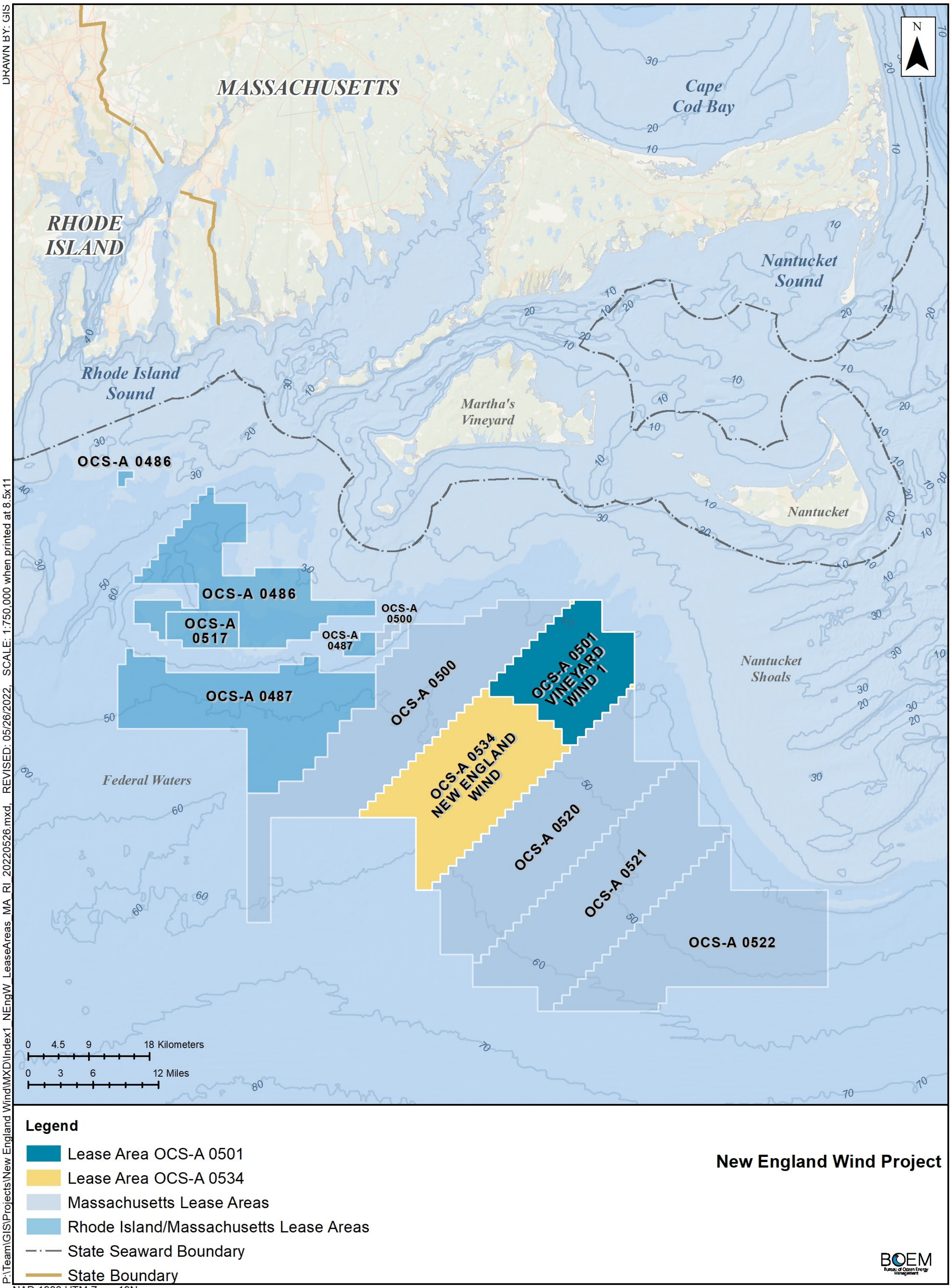


Figure B-1: Proposed Project Region

From the Cape Cod coast, the proposed Project would extend south/southwest through Nantucket Sound, pass between Martha's Vineyard and Nantucket via Muskeget Channel, and continue south offshore. Offshore waters in the proposed Project area would be located within the greater Georges Bank area (though not part of the bank itself) of the Northeast U.S. Continental Shelf Ecosystem. This ecosystem extends from the Gulf of Maine to Cape Hatteras, North Carolina (BOEM 2014). The Southern Wind Development Area (SWDA) and offshore export cable corridor (OECC) would be located within the southern New England subregion of the Northeast U.S. Continental Shelf Ecosystem, which is distinct from other regions based on differences in productivity, species assemblages and structure, and habitat features (Cook and Auster 2007).

B.1.2 Climate and Meteorology

Understanding atmospheric physical processes are vital to offshore wind energy development. National Oceanic and Atmospheric Administration (NOAA) buoys collect site-specific information on air and water temperature, wind speeds and direction, and air pressure via the National Data Buoy Center. Current and historical data is available to the public. NOAA satellites collect a wide variety of atmospheric data over much larger regions. Several lessees are already collecting site-specific data within their lease area(s) using specialized buoy systems to inform their project engineering designs. This data may also provide a baseline for comparison in the future.

The Atlantic seaboard is classified as a mid-latitude climate zone based on the Köppen Climate Classification System. The region is characterized by mostly moist subtropical conditions, generally warm and humid in the summer with mild winters. During the winter, the main weather feature is the nor'easter in the northeastern United States. During the summer, convective thunderstorms occur frequently. The Atlantic hurricane season runs from June 1 to November 30.

The Massachusetts climate is characterized by frequent and rapid changes in weather, large daily and annual temperature ranges, large variations from year-to-year, and geographic diversity. The National Climatic Data Center (NCDC) defines distinct climatological divisions to represent areas that are nearly climatically homogeneous. Locations within the same climatic division are considered to share the same overall climatic features and influences. The site of the proposed Project is located within the Massachusetts coastal division.

B.1.2.1 Ambient Temperature

According to NCDC data for the Massachusetts coastal division, the average annual temperature is 50.5 degrees Fahrenheit (°F), the average winter (December through February) temperature is 31.7°F and the average summer (June through August) temperature is 69.6°F, based on data collected from 1987 through 2019. Table B-1 summarizes average temperatures at the individual recording stations within the general area of the proposed Project. Data for some stations are reflective of different years of weather observations; however, the general pattern shows little difference across the listed locations.

Table B-1: Representative Temperature Data

Station	Annual Average °F	Annual Maximum °F	Annual Minimum °F
Coastal Division	50.5	59.2	41.8
Nantucket	50.7	57.6	43.9
Martha's Vineyard	51.2	59.1	43.2
Hyannis	51.1	58.8	43.4
Buzzards Bay Buoy	50.4	NA	NA
Nantucket Sound Buoy	52.4	NA	NA

Sources: NOAA 2019a (Coastal Division 2019 data; Nantucket 2019 data; Martha's Vineyard 2019 data; Hyannis 2019 data), 2019b (Buzzards Bay Buoy 2009–2019 data; Nantucket Sound Buoy 2009–2019 data)

°F = degrees Fahrenheit; NA = not applicable

B.1.2.2 Wind Conditions

Table B-2 summarizes wind conditions in the Massachusetts coastal division. Table B-2 shows the monthly average wind speeds, monthly average peak wind gusts, and the hourly peak wind gusts for each individual month. Data from 2009 through 2019 show that monthly wind speeds range from a low of 11.97 miles per hour in July to a high of 17.02 miles per hour in January. The monthly wind peak gusts reach a maximum during November at 21.23 miles per hour. The 1-hour average wind gusts reach a maximum during October at 64.65 miles per hour.

Table B-2: Representative Wind Speed Data

Month	Monthly Average Windspeed (miles per hour)	Monthly Average Peak Gust (miles per hour)	Peak 1-Hour Average Gust (miles per hour)
January	17.02	20.97	61.29
February	15.77	19.35	63.53
March	15.91	19.44	64.42
April	14.90	18.12	49.21
May	13.14	15.89	58.16
June	12.31	14.93	44.52
July	11.97	14.49	57.04
August	12.48	15.14	59.95
September	13.92	17.08	51.90
October	16.45	20.40	64.65
November	17.01	21.23	57.71
December	15.99	19.84	59.50

Source: NOAA 2019b (National Data Buoy Center, Nantucket Sound Station 44020, 2009–2019)

Throughout the year, wind direction is variable. However, seasonal wind directions are primarily focused from the west/northwest during the winter months (December through February) and from the south/southwest during the summer months (June through August). Figure B-2 shows a 5-year wind rose for Buoy Station 44020 (Nantucket Sound). Wind speeds are in meters per second (m/s). Percentages indicate how frequently the wind blows from that direction.

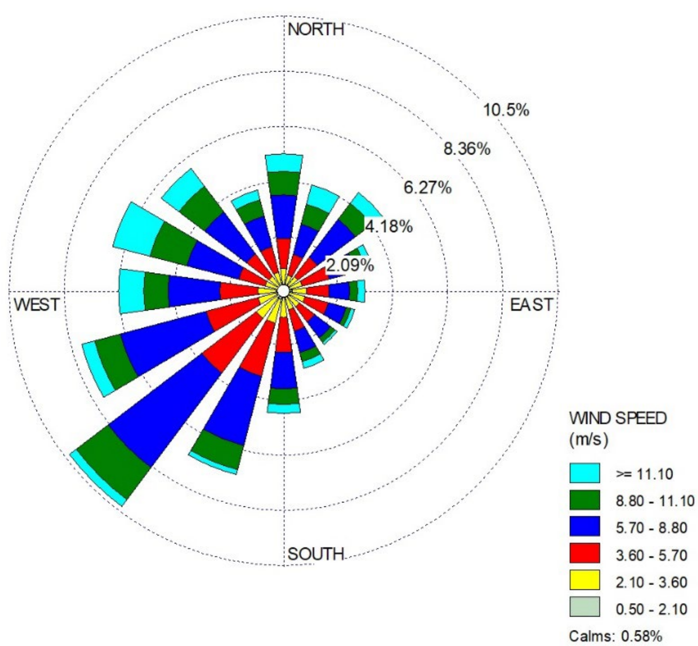


Figure B-2: 5-Year (2015–2019) Wind Rose for Buoy 44020

B.1.2.3 Precipitation and Fog

Data from NCDC show that the annual average precipitation is 49.75 inches in the Massachusetts coastal division. Table B-3 shows monthly variations in average precipitation, which range from a high of 5.59 inches for October to a low of 3.30 inches in May.

Table B-3: Representative Monthly Precipitation Data (2009–2019)[a]

Month	Average Precipitation (Inches)
January	4.04
February	3.86
March	4.67
April	4.14
May	3.30
June	4.20
July	3.72
August	3.67
September	3.56
October	5.59
November	4.15
December	4.87
Annual Average	49.75

Source: NOAA 2019a

[a] Precipitation is recorded in melted inches (snow and ice are melted to determine monthly equivalent). Data are representative of the Massachusetts coastal division.

Snowfall amounts can vary quite drastically within small distances. Data from the Martha's Vineyard Station shows that the annual snowfall average is approximately 23 inches, and the month with the highest snowfall is February, averaging around 8 inches.

Fog is a common occurrence along coastal Massachusetts. Fog is especially dense across the water south of Cape Cod toward the islands of Martha's Vineyard and Nantucket. Fog data were collected from 1997 to 2009 at the BUZM3 meteorological station in Buzzard's Bay, approximately 25 miles from the proposed Project site; and from 2007 to 2009 at the Martha's Vineyard Coastal Observatory meteorological station 2 miles south of Martha's Vineyard (Merrill 2010). The data show that fog is most common in the proposed Project area during the months of June, July, and August, with a typical range of 6 to 11 days per month with at least 1 hour of fog. In the winter, fog is much less frequent, with 3 or fewer days with at least 1 hour of fog.

The potential for icing conditions (i.e., atmospheric conditions that can lead to the deposition of ice from the atmosphere onto a structure) was also predicted based on data collected at the BUZM3 tower (Merrill 2010). Icing is rare when the water temperature is greater than 43°F, so in most months of the year and for many days during the winter months, there is no potential for icing to occur. The data show that moderate icing (defined by the Federal Aviation Administration as a rate of accumulation such that short encounters become potentially hazardous) is unlikely to occur more than 1 day per month, while the potential for light icing is above 5 days per month in December, January, and February. Icing would be unlikely to occur any time from April through October.

B.1.2.4 Hurricanes

During the 160 years for which weather records have been kept, ten hurricanes have made landfall in Massachusetts and five others have passed through the SWDA without making landfall. The latest hurricane that made a direct landfall was Hurricane Bob in 1991. Of those ten hurricanes, five ranked as Category 1 on the Saffir-Sampson Scale, two were Category 2 hurricanes, and three were Category 3 hurricanes. Since records have been kept, no Category 4 or 5 hurricanes have made landfall in

Massachusetts. Of the hurricanes that passed through the SWDA without making landfall in Massachusetts, one was Category 2, one was Category 1, and three were tropical storms when they passed through the SWDA. The most recent of these storms was Beryl in 2006. NOAA 2019c defines the winds speeds and typical damage associated with each category of hurricane.

In addition to hurricanes, Nor'easters (cold-core extratropical cyclones) may occur several times per year in the fall and winter months. Wind gusts during the strongest Nor'easters can cause similar damage to a Category 1 hurricane, although Nor'easters typically are larger and last longer than hurricanes.

B.1.2.5 Mixing Height

Table B-4 presents atmospheric mixing height data from two nearby stations. As shown Table B-4, the minimum average mixing height is 1,276 feet, while the maximum average mixing height is 4,662 feet. The minimum average mixing height is much higher than the height of the top of the proposed rotors (1,171 feet).

Table B-4: Representative Seasonal Mixing Height Data

Season[a]	Data Hours Included[b]	Nantucket Average Mixing Height (feet)[c]	Chatham Average Mixing Height (feet)[c]
Winter	Morning – no precipitation hours	2,559	2,192
	Morning – all hours	2,969	2,149
	Afternoon – no precipitation hours	2,595	2,539
	Afternoon – all hours	2,920	2,451
Spring	Morning – no precipitation hours	1,929	2,234
	Morning – all hours	2,408	2,178
	Afternoon – no precipitation hours	2,448	3,996
	Afternoon – all hours	2,713	3,642
Summer	Morning – no precipitation hours	1,276	1,867
	Morning – all hours	1,470	1,864
	Afternoon – no precipitation hours	1,998	4,662
	Afternoon – all hours	2,188	4,249
Fall	Morning – no precipitation hours	2,051	1,857
	Morning – all hours	2,425	1,913
	Afternoon – no precipitation hours	2,510	3,399
	Afternoon – all hours	2,726	3,100
Annual Average	Morning – no precipitation hours	1,952	2,034
	Morning – all hours	2,320	2,028
	Afternoon – no precipitation hours	2,385	3,678
	Afternoon – all hours	2,638	3,373

Source: MMS 2009

[a] Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November
[b] Missing values not included
[c] Data from MMS 2009

B.1.2.6 Potential General Impacts of Offshore Wind Facilities

A known impact on the atmospheric environment as a result of offshore wind facilities is the wake effect. The presence of a wind facility extracts energy from the free flow of wind, creating a "wake" downstream of the facility. The resulting "wake effect" is the aggregated influence of the wake on the available wind resource and the energy production potential of any facility located downstream. Christiansen and Hasager (2005) observed offshore wake effects from existing facilities via satellite with synthetic aperture radar to last anywhere from 1.2 to 12.4 miles depending on ambient wind speed, direction, degree of atmospheric stability, and the number of turbines within a facility. During stable atmospheric conditions, these offshore wakes can be longer than 43.5 miles.

A less understood impact is the formation of a microclimate. Past modeling studies suggest a change in temperature and moisture downwind of offshore wind energy facilities. From September 2016 to October 2017, a study using aircraft observations accompanied with mesoscale simulations provided a look into the spatial dimensions of micrometeorological impacts from a wind energy facility in the North Sea (Siedersleben et al. 2018). Large offshore wind facilities can potentially have an impact on the local microclimate. However, this potential is fairly low because very specific conditions must be met for the impact to occur. The local redistribution of moisture and heat due to rotor-induced vertical mixing has no influence on the local climate outside of the immediate vicinity of a wind facility. Only a permanent change in the air-sea interactions could change the local climate. For example, warmer air over a cold ocean would result in an increased heat transfer to the ocean, thereby causing more water vapor transport into the atmosphere because of the dryer air within the wake of a turbine/facility. Such events are rare because they can only occur when there is a strong increase in temperature with altitude at or below hub height to create the warming and drying within the wake of large offshore wind energy facilities. The increase of temperature with height is an inversion, better explained as a reversal of the normal decrease of air temperature with altitude. These specific conditions are not likely to occur off the south coast of Massachusetts.

B.1.3 Geology and Seafloor Conditions

B.1.3.1 Historical Formation

The continental shelf off the U.S. Eastern Seaboard and New England today resides on a passive continental margin with minimal tectonic and seismic activity. Prior to this relatively quiescent period, numerous orogenies (continental plate collisions) hundreds of millions of years ago produced the multiple mountain chains that are prominent on the present landscape, including those of the Appalachian (Blue Ridge, Allegheny, Catskill, Berkshire, Green, and White Mountains) and Adirondack systems. Weathering and erosion from various geologic processes have supplied sediment from the bedrock-based mountains and piedmont to the coastal plain regions sloping down toward the Atlantic Ocean. The sediment forms a wedge that thickens toward the sea and is modified by fluvial, estuarine, and coastal processes, as well as sea level rise at lands' edge. In more recent times, a series of glaciations during the Quaternary period (starting approximately 2.6 million years ago) has greatly modified the landscape in the northern latitudes of the United States, scouring, transporting, and depositing materials along the glaciers' paths, with results of the latest Wisconsin glacial stage (110,000 to 11,700 years ago) being the most evident.

Prior to Quaternary glaciation in southern New England, an extensive coastal plain consisting of Tertiary (now Neogene and Paleogene) and Cretaceous rocks and semi-lithified sediments extended seaward from Cape Cod to at least the location of present-day Martha's Vineyard and Nantucket Island, if not farther south. Sea level then varied with glacial and inter-glacial periods from well below to significantly above present-day elevation. During glacial episodes, a mature fluvial drainage system dissected the coastal plain, eroding and transporting sediment southward, while marine sediments accumulated during inter-glacial periods.

B.1.3.2 Current Seafloor Conditions

A wide range of current seabed conditions persist that are a direct result of these historical geologic events. Past geologic processes shaped the stratigraphic foundation of the continental shelf, the upper layers of which have been subsequently reworked during sea level rise by currents, waves, and storms. A limited supply of terrigenous sediment exists in the region, so the surficial sediment layer is primarily sourced from older underlying glacial deposits. A direct correlation between grain size and bottom current velocities is evident moving in the onshore-to-offshore direction, from the strong tidal components in and around Nantucket Sound to the open water, general shelf circulation south of the islands. Where very high current velocities exist in the Nantucket Sound region, abundant bedforms rework the sandy surficial layer, and in highly erosive areas only the coarsest material (gravel, cobbles, boulders) persists (Baldwin et al. 2016; Poppe et al. 2012). Sediment types and bedforms in the SWDA are indicative of post-glacial material mixed with upper continental shelf deposits. These deposits consist primarily of medium- to fine-grained material (sand, silt, clay) that has been winnowed from glacial drift by marine and fluvial processes (Baldwin et al. 2016).

Marine scientific data acquired from five seasons of offshore survey programs have been analyzed to provide information on existing site conditions in the SWDA. Table B-5 and B-6 provide data and results related to geological resources in the SWDA and OECC, respectively.

Table B-5: Geological Survey Data and Results in the Southern Wind Development Area

Data/Results	Summary
Data	• > 12,328 miles of geophysical trackline data • 8 deep boreholes • 56 deep downhole CPTs • 210 seabed CPTs • 187 vibracores • 96 benthic grab samples with still photos • 36 underwater video transects
Surface conditions	• Water depths 141 to 203 feet, offshore slope of < 1 degree toward the south-to-southwest • Minimal seafloor topography, minimal relief • Generally homogenous surficial sediments, varying percentages of sand and silt • Irregular, northeast-to-southwest bathymetric lows up to 16.4 feet deep • Rippled scour depressions 0.7 to 3.3 feet deep with lateral extents ranging from tens to hundreds of feet; contain ripple bedforms < 1.0 foot high and wavelengths 1.6 to 9.8 feet; slopes at edges of ripple scour depressions up to 6 degrees • Benthic habitats of uniform, unconsolidated sediment • Trawler drag marks on the seafloor indicate some fishing • Very few human-made objects (mostly fishing gear and debris); two possible shipwrecks identified in the SWDA
Subsurface conditions	• Consistent stratigraphy underlying the site • Materials range from clay to gravel, with isolated coarse material • Discontinuous coarse deposits associated with lag deposits with possible isolated boulders • Abundant channeling apparent throughout, few other structures • Ravinement surface 3.3 to 19.7 feet below the seafloor • Magnetic variability in localized areas associated with strong sub-bottom reflectors in the upper 6.6 to 23.0 feet, likely associated with natural ferrous-rich deposits
Hazards	• Paleochannels throughout the SWDA, often with gravels at the base of the channel and clays to sands on the channel margins • Peat/organic material in paleochannels scattered throughout SWDA • Boulders possible in subsurface throughout the SWDA, patchy and scattered, approximately 33 to 302 feet below the seabed • Weakly cemented beds are possible throughout the SWDA at depths below 105 feet below the seabed • Two possible wreck sites identified in the western portion of the SWDA

Source: COP Volume II-A, Table 6.0-1; Epsilon 2023

CPT = cone penetrometer testing; SWDA = Southern Wind Development Area

Table B-6: Geological Survey Data and Results in the Offshore Export Cable Corridor

Data/Results	Summary
Data	• > 3,921 miles of geophysical trackline data over a 2,182- to 5,479-foot-wide corridor • 2 deep bore holes • 3 deep downhole CPTs • 134 seabed CPTs • 192 vibracores • 163 benthic grab samples with still photos • 119 underwater video transects
Surface conditions	• Water depths < 3.6 to 150.9 feet; local slopes up to 25 to 30° on bedforms • Numerous natural slopes/topography, < 10-degree gradients • Overall homogenous surficial sediments, mainly sand • Mobile surface layer with sand waves > 6.6 feet high locally • Sand with some gravel, cobbles in shallow, higher current areas • Localized concentrations of boulders with gravel and sand in the northern portion of the OECC • Sand with silt in deeper water areas, less tidal current • Soft surficial layer (biogenic sediments) offshore in deeper water, immediately seaward of the offshore slope south of Muskeget in depths of 82 to 98 feet • Variable benthic habitats due to different substrates; some sensitive habitats possible locally • Rippled scour depressions offshore, bedform fields with isolated, larger sand waves over 16.4 feet in Nantucket Sound • Coarse deposits with boulders in Muskeget Channel area • Overall low concentration of manmade objects with moderate concentration locally • Sediments relatively consistent, sand with coarse material particularly in higher current areas and silt in deeper and quiescent locations
Subsurface conditions	• Abundant buried channels north of Horseshoe Shoal; no unusual sediments of concern identified • Fine-grained, organic-rich layers associated with channel bank/terrace deposits adjacent to some paleochannels • Often acoustically transparent mobile sand layer • Coarse deposits with boulders in Muskeget Channel area
Hazards	• Large sand waves in some areas • Paleochannels with top sections in the upper 6.6 feet; all sediments sampled by geotechnical investigations and pose no threat to cable installation • Localized subsurface gas in Centerville Harbor; no issue for cable installation • Coarse deposits with boulders in Muskeget Channel area • Possible sensitive habitats for avoidance, if possible, mainly Muskeget area • Isolated manmade objects in the corridor, one debris pile/possible shipwreck in the OECC, approximately 6.8 miles southwest of Craigville Beach; one unidentified buried possible cable is located southeast of Martha's Vineyard

Source: COP Volume II-A, Table 6.0-2; Epsilon 2023

CPT = cone penetrometer testing; OECC = offshore export cable corridor

Marine geological resources in this region are very stable on the scale of a human lifetime, except for surficial sediments, which can be dynamic. Surficial sediments, especially clays/muds, silts, and sands are subject to movement by currents driven by tides, storms, and broad-scale circulation patterns. While most of the OECC is very stable, the seafloor running from just south of Martha's Vineyard and Nantucket to north of Horseshoe Shoal in Nantucket Sound is a dynamic environment characterized by highly mobile bedforms, deep (greater than approximately 131 feet) tidal channels, and patches of exposed coarse material (i.e., boulders, cobbles, and gravels derived from glacial till). Volume II-A, Section 2.0 of the Construction and Operations Plan (COP) presents conditions relevant to geological resources (Epsilon 2023). Human activities have the potential to alter sediment structure, slope, and particle size distribution patterns; coastline morphology; exposed or buried channel morphology; patterns of erosion, sediment transport, and deposition; sediment chemical characteristics; weathering processes; surface movements (e.g., landslides); and the shape, structure, and strength of bedrock, as well as physically extract geological resources through mining.

Very homogenous seafloor conditions exist in offshore areas, dominated by fine sand and silt. Water depths range from 114.8 to 170.6 feet over a gently sloping seafloor that dips toward the south/southwest. There is a distribution of localized patches of ripples and sand waves throughout the area. These features represent the only vertical relief in an otherwise relatively flat, featureless seafloor that slopes gradually offshore. These features range from 32 to 656 feet wide by 328 to 1,640 feet long but may exceed 3,280 feet in length. These features are typically less than 3.3 feet in height but can reach up to 22.9 feet.

Seafloor features that are stable and exhibit vertical relief provide a significant rare habitat amidst the broad sand flats. Such habitats include gravel or pebble-cobble beds, sand waves, biogenic structures (e.g., burrows, depressions, sessile soft-bodied invertebrates), shell aggregates, boulders, hard-bottom patches, boring sponge (*Cliona celata*) beds, and cobble beds with and without sponge cover. These coarser substrates provide complex interstitial spaces for shelter and generally exhibit greater faunal diversity. Other special, sensitive, and unique habitats (living bottom, hard/complex bottom, eelgrass beds, and marine mammal habitats) occur in places in and near the proposed Project (COP Volume II-A, Section 5.2; Epsilon 2023).

The seafloor near Muskeget Channel is particularly complex, being composed mostly of sand, but with a variety of slopes, contours, and sand wave dimensions (COP Volume II-A, Section 2.1; Epsilon 2023). This area also includes a significant amount of hard/complex bottom habitat, as well as boulders that are buried shallowly and could be exposed by shifting sands. Water depths in the Muskeget Channel area range from 0 to 100 feet, with the main part of the channel lying mostly between 23 and 65 feet. The seafloor in the proposed OECC is primarily a flat bed of sand and silt, but it includes sparse small patches of minor vertical relief, as well as several eelgrass beds nearby. Water depths in the proposed OECC, which the applicant has routed to avoid shoals and eelgrass beds, are around 40 to 50 feet for most of the route, becoming gradually shallower over the final 2 miles approaching land.

Seafloor habitats can also be classified more broadly as biogenic structures, hard bottom, complex seafloor, and other, which would include the majority of flat sand and mud habitat in the SWDA and OECC (Epsilon 2018). Hard bottom in the OECC typically consists of a combination of coarse deposits such as gravel, cobble, and boulders in a sand matrix. These coarse deposits form a stable surface over which sand waves forced by tidal currents periodically migrate. Certain hard-bottom areas also include piles of exposed boulders, but no bedrock outcrops are present in the OECC or SWDA. Complex seafloor in the OECC and SWDA consists of bedforms such as rugged fields of sand waves; although these mobile features are less amenable to benthic macroinvertebrates, they may be attractive to finfish. Figures 3.5-2 through 3.5-6 in Environmental Impact Statement (EIS) Section 3.5, Coastal Habitats and Fauna, delineate these seafloor areas.

The proposed Project would be located south of Cape Cod in the Atlantic Ocean and Nantucket Sound, where the physiographic regions known as the Seaboard Lowland section of the New England Province and the Atlantic Coastal Plain Province meet. The proposed Project would straddle these two physiographic regions. The Lowland, which includes part of the continental shelf, is a broad belt that extends from south of Rhode Island northeast to central Maine. Erosion and deposition related to glacial processes produced numerous changes in drainage patterns and observed topography over geologic time. The land formations in the coastal plain are low relief and are composed of a wedge of unconsolidated sediments that overlay much older consolidated rock. The north bounds of the coastal plain run from the north side of Long Island through Rhode Island Sound to Martha’s Vineyard. Offshore water depths generally range from approximately 131 to 262 feet, with some areas as shallow as 65 feet. North of Martha’s Vineyard, Nantucket Sound exhibits water depths mostly around 40 to 50 feet, with several shallower shoals, and it generally becomes shallower as one approaches Cape Cod. The sea has also influenced landforms in this region, creating barrier spits and longshore accretions of sandy beaches with the prevailing currents (Fenneman 1938; Denny 1982; Oldale 1992).

Geology and seafloor conditions are a fundamental factor determining whether a potential site could support wind turbine foundations. The major possible factors relating to a seafloor failing to support a pile-driven wind turbine generator (WTG) or other marine structure are liquefaction due to earthquakes or wave action, seafloor suitable for foundation type (monopile), soil cohesion and soil strength, repeat loading (structural), inadequate damping (structural), sediment transport and sand waves, and scour.

Liquefaction is a process in which solid material behaves as a liquid. Earthquakes can produce vibrations that interact with soil particles in such a way that they become suspended while agitated by that energy. While the soil particles are suspended, they behave like a liquid, allowing structures attached or imbedded into the seafloor to sink or tip over. The frequency at which this phenomenon can occur is related to the frequency and intensity of earthquake activity within an area, the composition and depth of the soil, and the underlying stratigraphy of the area. To a lesser degree, wave action can also create shallow liquefaction effects depending on wave and sediment characteristics.

Foundation types for particular offshore wind projects are selected based on the seafloor's characteristics. Seafloor conditions that may be challenging for one foundation type may be well suited for another. Structures that are pile driven into the seafloor are designed to be sited in locations where there is ample loose sediment to allow for it. For these foundation types, some amount of rocks or boulders intermixed within the sediment can be tolerated through avoidance, micro-routing, or drilling, and the depth a pile is driven can be increased to accommodate for looser sediments. For other types of foundations and engineering strategies, rocky seafloor conditions are preferable.

Soil cohesion is how strongly bound together soil particles are, and soil strength is the amount of shear stress a soil can sustain. The underlying layers, types, and depths of soils of a seafloor affect how much strength and stiffness are exhibited by the soil. The particles that make up soil vary in compactness, size, and abundance. Material with different proportions of particle sizes will have different properties. If a seafloor is composed of material that lacks cohesion and soil strength, it may deform or displace around the structure under the forces of pile installation.

Repeat loading refers to repeated, externally applied forces on a structure. Changes in environmental conditions created by wind and wave forces can vary in direction, intensity, and duration. This repeat loading can have a cumulative impact on a structure's ability to stand and must be accounted for within the design of the structure.

Damping is the suppressing of energy or decrease in swaying or swinging. Inadequate damping is when forces are able to create enough movement that can affect the function or integrity of a structure. Structures sway from receiving energy from dynamic wind and wave forces. These oscillations can become amplified over time if they are not mitigated through damping and can potentially compromise the structure. Damping can be done by increasing the size and depth of the foundation and adding components to the structure that act to mitigate or negate loading by absorbing and counter-acting the oscillation.

Sediment transport is the movement of sediment, typically due to a combination of gravity acting on the sediment and/or movement of the water with sediment particles in it. Sand waves are ridge-like structures that are formed by waves or currents of the water. Typically, sand waves are not static. They are migrating bedforms and evidence of active sediment transport.

Scour is the removal of sediment, such as silt, sand, and gravel, from around the base of obstructions due to a current's flow in the sea. An obstruction in a waterbody that is moving may cause flow changes, including higher or lower velocities around the obstructions. Foundations installed in the seabed are subject to scour around the base of the structure where it contacts the seabed.

To determine whether the seafloor can support WTGs, geologic surveys are performed. Geologic surveys can be broadly divided as either physiographic or geotechnical. Physiographic, also known as geophysical, surveys involve passive or remote techniques that provide information about the surface and near-surface of the seafloor, without physically contacting it. Examples of these physiographic surveying techniques include hydrographic, bathymetric, sonar, and magnetometer surveying. Geotechnical surveys physically sample and penetrate the seafloor. These are the surveys that provide the information most pertinent to the ability of the seafloor to support a given type of foundation design. Two types of geotechnical surveys, boring and vibracore, are techniques that extract material from below the seafloor that can have their composition and characteristics analyzed in a laboratory. Cone penetration tests provide information about the layers of material under the seafloor surface, including bearing capacity and soil strength of the sediment, by measuring the pressure and resistance as the instrument is driven into the seafloor. Benthic grabs directly pick up sediment samples at the surface of the seafloor. All these direct samplings and measurements provide input to computer modeling that engineers use to assess the ability of the seafloor to support WTGs.

When selecting the foundation type and design for a wind energy project, water depth and the underlying material of the seafloor are some of the most important considerations. Structural problems can be avoided by matching foundation design to site characteristics. The most widely used foundation type is a monopile that is driven into the seafloor in locations with sufficiently thick sediment above the bedrock, few boulders, and less than 100 feet water depth. The mechanical properties of some sediments can have engineering implications for construction activities and need to be accounted for during planning and design stages. Specifically, glauconite sand in the subsurface has been identified as a potential geohazard due to its susceptibility to crushing, resulting in driving resistance and premature pile installation refusal, which are significant risks to offshore wind farm development (Westgate et al. 2022). The applicant is developing their understanding of glauconite within the SWDA and its potential impacts on proposed Project construction through independent data collection and analysis on geotechnical parameters, soil properties, and pile drivability, as well as through participation in an ongoing Joint Industry Partnership. A preliminary drivability report that was prepared for the Vineyard Wind 1 Project is provided in the COP (Volume II, Appendix II-AS; Epsilon 2023) to provide additional context. The analysis in the report was conducted prior to the collection of detailed, site-specific geotechnical data and does not specifically address glauconite soils. Additional drivability and design analyses have been completed and independently reviewed by National Renewable Energy Laboratory and would be used to support the selection of foundation types and construction techniques for the Project.

Foundations and towers are among the least likely WTG components to require repair or replacement. An analysis of several European offshore wind facilities during the first 10 years of operations was conducted, which included hundreds of WTGs between 2 to 4 megawatts (MW) in size of varying ages (Carroll et al. 2016). At the time the study was published, approximately 80 percent of all offshore wind foundations in European waters were monopiles (EWEA 2016). Failure rates of component groups in the study were examined as a combination of replacements, minor repairs, and major repairs per turbine each year. The study found that the replacement rate of a single foundation and tower was 0.0, indicating there was no occurrence of a foundation and tower failing to stand during this time frame. Foundations and towers had a combined repair rate of 0.181 per year. Repairs to the foundation and tower are among the quickest and cheapest relative to the other WTG component categories (Carroll et al. 2016). A review of cable failures found an average failure rate for offshore alternating current cables of approximately 0.003 failure per kilometer per year (Warnock et al. 2019).

Physiographic and geotechnical surveys have explored the subsurface geological conditions in the proposed SWDA and OECC (COP Volume II-A, Section 2.1.2.2; Epsilon 2023). BOEM's Engineering and Technical Review Branch (ETRB) has reviewed all the geophysical and geotechnical information provided in the New England Wind Project COP and other data submissions from Park City Wind, LLC (the applicant). ETRB concurs with the applicant's conclusion that fixed bottom foundations, as described in the COP, are technically feasible and safe for WTG and electrical service platform (ESP) installations to a depth below the seafloor of up to 279 feet (for pin piles). If the COP is approved and the applicant intends to install foundations beyond these depths, further information from the applicant would be required with the facility design report and fabrication and installation report. This information would then be evaluated by ETRB prior to allowing the installation of components beyond the above stated depths.

If the COP is approved, the applicant must then submit a facility design report and a fabrication and installation report. The facility design report provides specific engineering details of the design of all facilities, including structural drawings, environmental and engineering data, a complete set of calculations used for design, proposed Project-specific geotechnical studies, and a description of loads imposed on the facility. The facility design report must demonstrate that the design conforms to the responsibilities under the lease. The fabrication and installation report describes how the facilities would be fabricated and installed in accordance with the design criteria identified in the facility design report, the COP, and generally accepted industry standards and practices. Both of these reports must be reviewed and certified by a BOEM-approved third-party certified verification agent prior to submittal. BOEM has 60 days to review these reports and provide objections to the applicant. If BOEM has no objections to the reports, or once any BOEM objections have been resolved, the applicant may commence construction of the proposed Project.

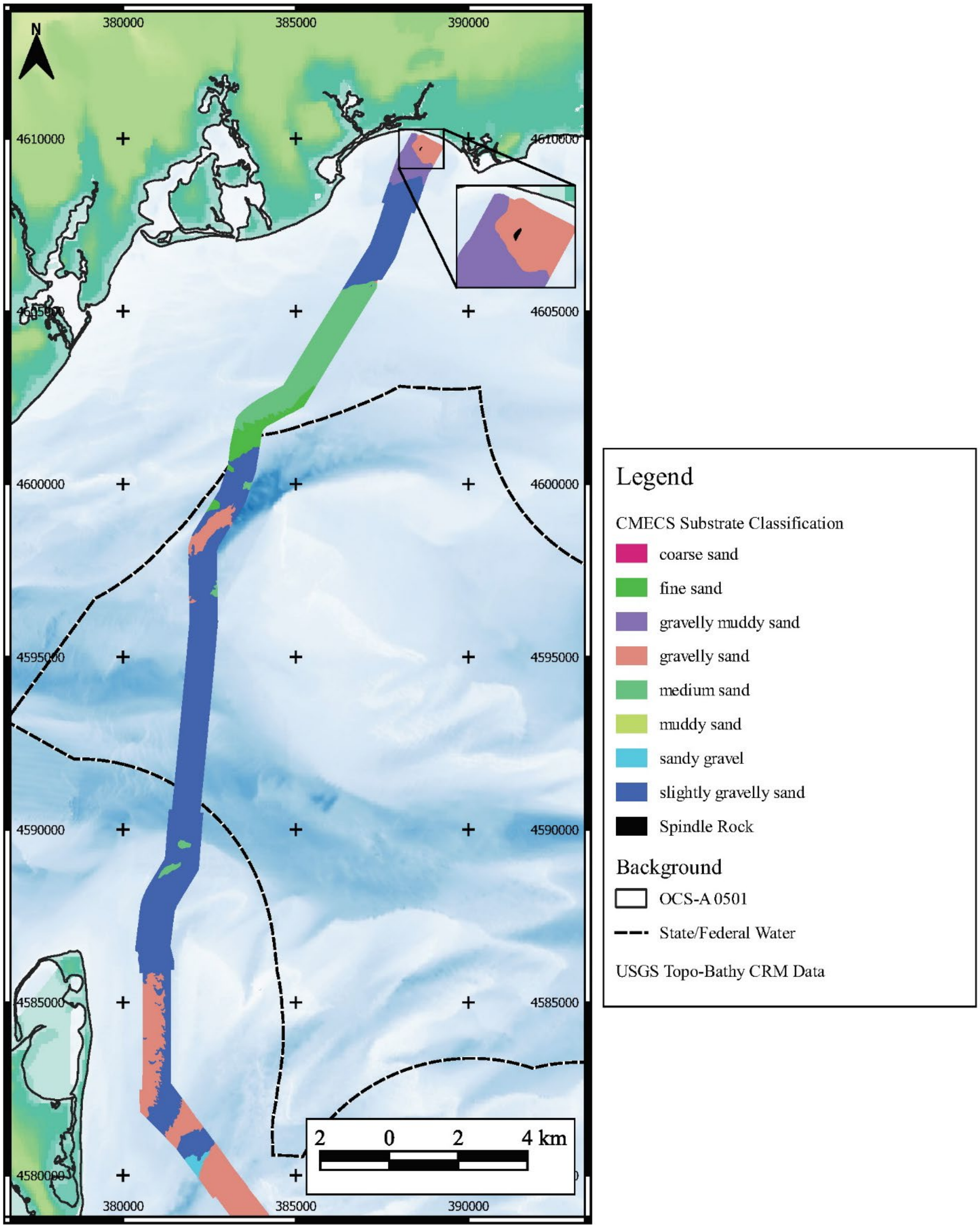
Seafloor conditions can also be described according to the Coastal and Marine Ecological Classification Standard substrate component, which classifies seafloor types based on the composition and particle size of the surface layers of the substrate (FGDC 2012). Maps delineating seafloor conditions according to Coastal and Marine Ecological Classification Standard substrate classifications, based on the results of a 2018 survey reported in Attachment E of Epsilon 2018 (as cited in Vineyard Wind 2020), are shown on Figures B-3 and B-4.

B.1.3.3 Potential General Impacts of Offshore Wind Facilities

Scour, turbidity, and sedimentation are all conditions related to the strength of oceanographic forces, geologic conditions, and sediment processes. Scour occurs when the oceanographic forces are strong enough to mobilize the local sediments away from their current location, without additional sediments being added to the system to replace the mobilized sediments. Turbidity occurs when either sufficient force is present to mobilize sediments from the seabed into the water column, or additional sediments are being put into the system in such a way that they remain suspended for a period of time. Turbid conditions would remain as long as the particles are suspended in the water column. Lastly, sedimentation occurs when the oceanographic conditions are not strong enough to mobilize sediments, and additional sediments are actively being deposited.

Geologic conditions heavily influence the feasibility and technical complexity of installing and operating offshore wind facilities. Geologic conditions such as sediment uniformity, density, and grain size can contribute to the potential for an installation or facility to have occurrences of scour, turbidity, and/or sedimentation. The presence of bedforms, such as ripples and sand waves, indicate local oceanographic forces are mobilizing surficial sediments, and a lack of fine sediment indicates current and tidal forcing can be strong enough to remove smaller sized particles.

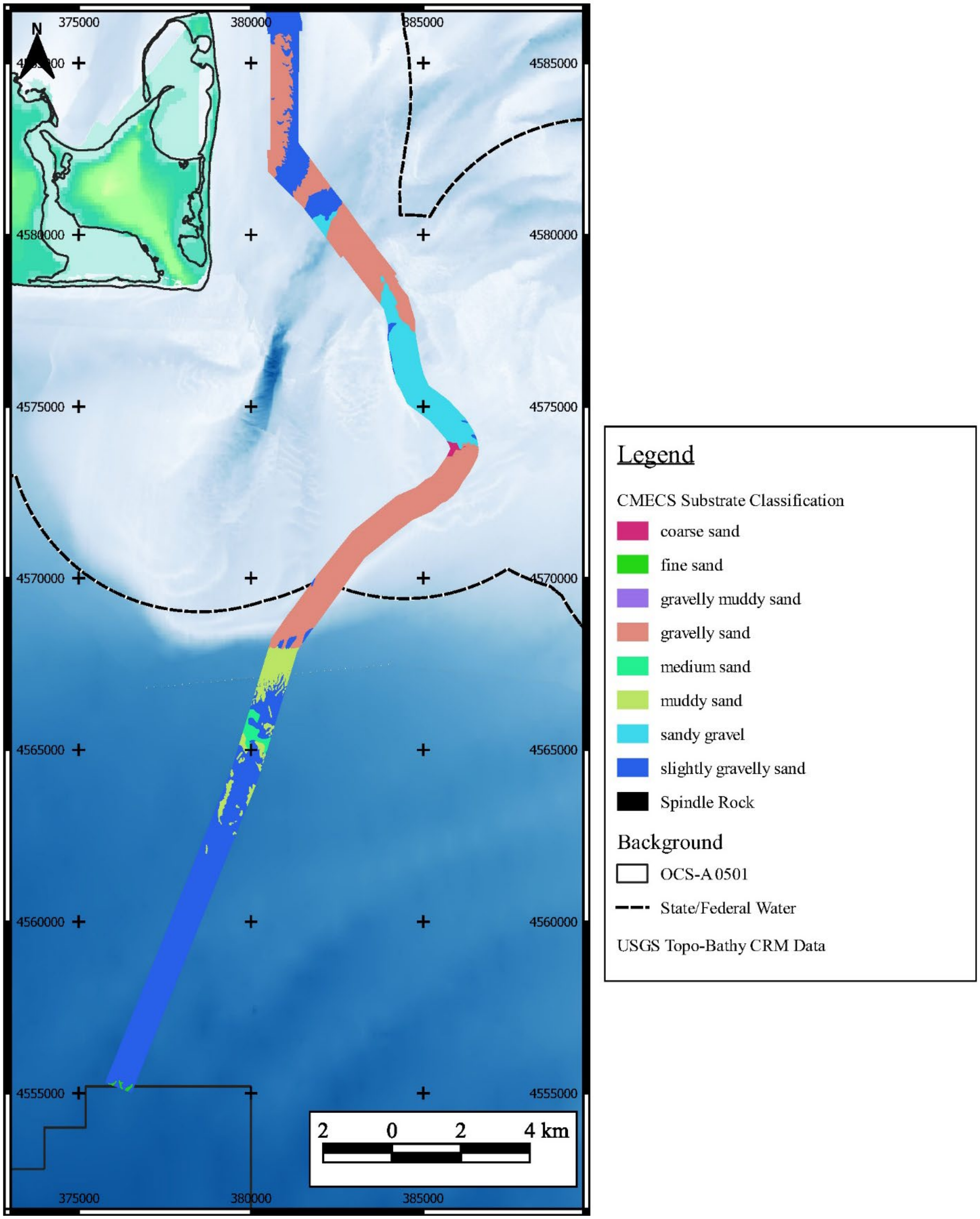
BOEM Atlantic lease areas are described as sediment-starved due to continental geology and the distance from shore, meaning there are no additional sediment inputs to the OCS. Thus, surficial sediments are continually reworked by oceanographic forces such as tides, currents, and storms, and sedimentation is not expected at lease areas. As documented at the Thanet and London Array offshore wind facilities in the United Kingdom, the potential exists for the formation of surficial sediment plumes at WTG monopiles (Vanhellemont and Ruddick 2014). Sediment plumes tend to form when the following conditions are present: shallow water, significant speed of tidal currents, and mobile sediments. The Thanet and London Array offshore wind facilities, which are both located in the Thames River Estuary, are composed of 100 and 175 WTGs, respectively, located in 0 to 82 feet water depths with tidal velocities that vary up to 0.8 to greater than 1 meter per second (Vanhellemont and Ruddick 2014; COP Appendix III-Q, Section 2.1; Epsilon 2023). In contrast, the proposed Project WTGs would be sited in water depths from 141 to 203 feet with tidal velocities less than 0.1 meter per second (0.2 knot) (COP Appendix III-Q, Section 2.1; Epsilon 2023). Sediment transport and mobility is low within the proposed SWDA given the slow tidal current velocity (COP Appendix III-Q, Section 2.1; Epsilon 2023). The lack of conditions required for the formation of sediment plumes are expected to greatly reduce, if not eliminate, the potential for surficial sediment plumes to form. Additionally, the proposed use of scour protection around each of the WTG monopile foundations would be expected to further reduce the already low likelihood of sediment plume formation (Swanson 2019).



Source: Modified from Vineyard Wind 2020

USGS = U.S. Geological Survey

Figure B-3: Coastal and Marine Ecological Classification Standard Substrates within the Vineyard Wind 1 Offshore Export Cable Corridor



Source: Modified from Vineyard Wind 2020

USGS = U.S. Geological Survey

Figure B-4: Coastal and Marine Ecological Classification Standard Substrates within the Vineyard Wind 1 Offshore Export Cable Corridor

Turbidity is most closely associated with activities such as cable installation and pile driving, which occur primarily during installation where seabed sediments are actively being disturbed. The sediments are temporarily suspended and then resettle within a short time period of minutes to hours depending on site-specific conditions such as sediment grain size.

Scour is a highly complex response to a multidimensional set of local conditions that include oceanographic forces, sediment properties, and anthropogenic inputs. Current understanding includes strong associations between scour, structure diameter, water depth, and sediment conditions. In general, the larger the diameter of the structure, the shallower the water depths, the more uniform and sandier the sediment conditions; the stronger the oceanographic forces, the more likely an area is to experience scour (Harris and Whitehouse 2014). Scour in uniform sandy soils is expected to increase over time until reaching an equilibrium, while the scour in non-uniform soils is more variable (Harris and Whitehouse 2014).

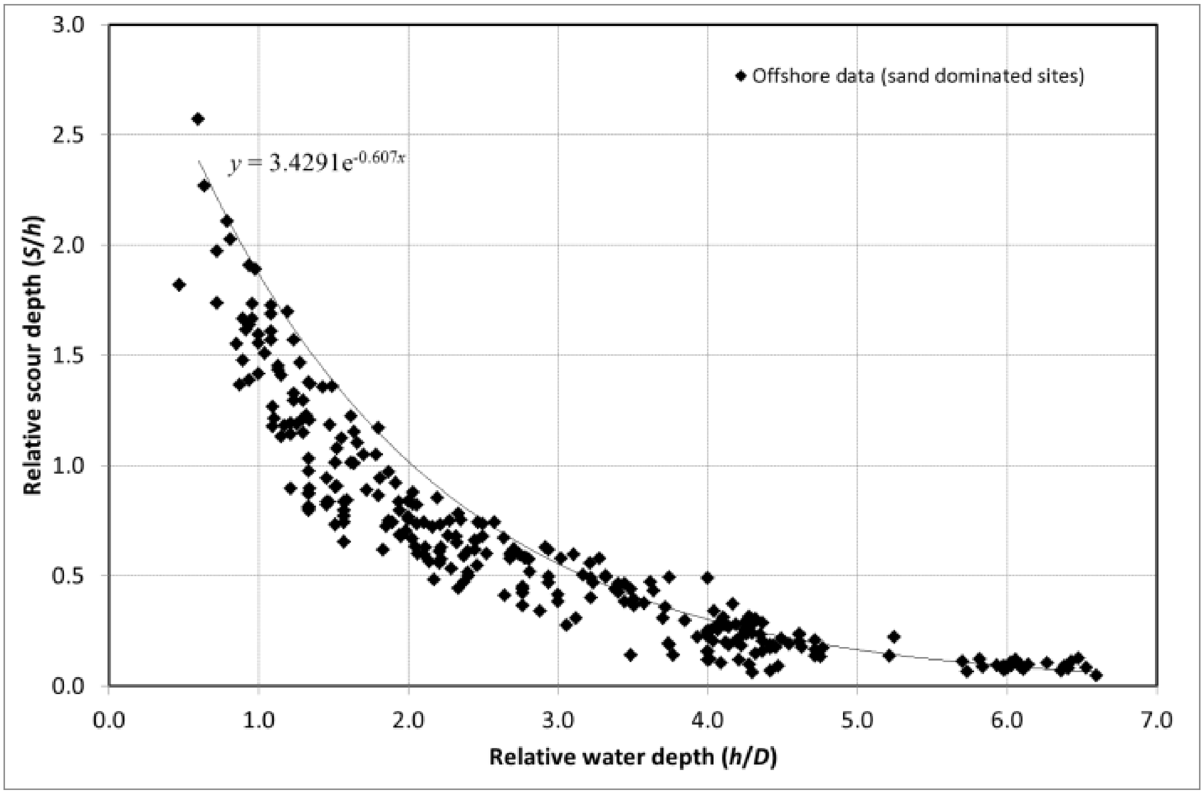
Site conditions and foundation diameter tend to dominate scour potential analysis. Sand-dominated seabeds are more susceptible to severe scour than finer grained or mixed sediments; as the foundation diameters increase, the potential depth (severity) of scour also increases. Based on field measurements at offshore wind energy facilities installed in uniform sand conditions, the relationship between scour and foundation diameter is described as scour (S)/diameter (D) = 1.8 (Harris and Whitehouse 2014). Non-uniform marine soils—a combination of gravel, sand, silt, and clay—respond differently than uniform sandy soils, and scour predictions are more complex. Offshore wind energy facilities with non-uniform soils typically experience scour more slowly.

Scour became a significant issue in early offshore wind development during the 2000s as turbine sizes began to increase and facilities were often located close to shore in shallow waters. The most commonly referenced examples of offshore wind energy facility scour often include observations from North Sea sites Scroby Sands and Arklow Bank (Whitehouse et al. 2011). These two sites were located in water depths ranging from about 6.56 to 39.37 feet with pile diameters of 13.78 and 17.06 feet, respectively. As described above, sandy dominated seabeds, such as those found at Scroby Sands and Arklow Bank, are more susceptible to severe scour than finer grained or mixed sediments. In addition, subsequent research has shown the ratio of the water depth to foundation diameter can be a significant indicator for severe scour and was a major contributing factor to the scour experienced as the Scroby Sands and Arklow Bank offshore wind energy facility sites (Figure B-5). Other case studies on scour at offshore wind energy facilities include field data from three offshore wind energy facilities located in non-uniform marine soils.

The Barrow Offshore Wind Farm scour survey undertaken in a glacial till area showed modest local scour (S/D = 0.04) (Harris and Whitehouse 2014). Values of S/D = 0.4 were found at the Kentish Flats Offshore Wind Farm, located on a coarse sandy seabed with shell gravel and clay outcrops overlying soft to firm clay deposits. North Hoyle Offshore Wind Farm, located in a strongly heterogeneous region with poorly sorted sediments and a sandy gravel or gravelly sand seabed where larger patches of gravel are found offshore, showed limited scour just after installation; however, within a year, no scour was recorded at any foundation. In general, current industry research indicates scour predictions have vastly improved since large scour pits were identified as a significant issue for offshore wind development, and scour protection has been shown to be effective (Harris et al. 2011).

B.1.4 Physical Oceanography

Oceanographic forces such as waves, currents, and tides vary along the Atlantic OCS, depending on bathymetry, winds, and other factors. The Atlantic OCS is generally wide and shallow, with water depths reaching 492 feet. Although there is some data available, BOEM recognizes that in-situ oceanographic data is limited along the Atlantic Coast of the United States. To fill these data gaps, extensive worldwide effort has been invested in developing and refining ocean models capable of providing detailed oceanographic information not only along the U.S. coast but on a global scale. Several ocean models run in real-time on a continual basis, receiving data from buoys, gliders, ships, and satellites, updating results accordingly. These models provide daily and long-term oceanographic data sets that span decades, grounded by in-situ measurements.



Source: Harris and Whitehouse 2014

S/h = scour depth divided by water depth; h/D = water depth divided by pile diameter

Figure B-5: Measured Data from European Wind Energy Facilities Showing a Decrease in Relative Scour Depth with an Increase in Relative Water Depth

Offshore wind developers also contribute to the oceanographic knowledge base through the deployment of data collection buoys during their site assessment phase. Buoys collect data for 1 to 5 years, measuring meteorological and oceanographic (metocean) conditions such as winds, waves, currents, and temperature. Knowing the site-specific metocean conditions is key to facility design and safe navigation and, therefore, a necessity for developers to collect. Some developers have proposed to continue data collection throughout the construction and operations stages.

Key physical factors nearshore include the daily modification of the seabed by tidal currents and episodic extreme storm events that are capable of extensive erosion and redistribution of coastal materials. Offshore, an area immediately west of the proposed Project has been extensively studied, the Rhode Island Ocean Special Area, and the results are informative for the offshore portions of the proposed Project (Rhode Island Coastal Resources Management Council 2010).

B.1.4.1 Water Temperatures

Water temperature is seasonally variable and at the surface ranges from approximately 37°F in winter to 75°F in summer. Offshore temperatures also vary with depth and season due to seasonal stratification and thermoclines; for details, see the COP (Volume III, Section 5.1.2). Although waters on the OCS experience considerable vertical mixing in fall, winter, and spring, an important seasonal feature influencing finfish and invertebrates is the cold pool, a mass of cold bottom water in the Middle Atlantic Bight overlain and surrounded by warmer water. The cold pool forms in late spring and persists through summer, gradually moving southwest, shrinking, and warming due to vertical mixing and other factors (Chen et al. 2018). During summer, local upwelling and local mixing of the cold pool with surface waters provides a source of nutrients, influencing the ecosystem's primary productivity (Lentz 2017; Matte and Waldhauer 1984). The cold pool is a dynamic feature of the middle to outer portions of the OCS, but its nearshore boundary typically lies at depths from 66 to 131 feet (Brown et al. 2015; Chen et al. 2018; Lentz 2017). Offshore wind lease areas are mostly sited within depths less than 197 feet. While offshore wind foundation structures would affect local mixing of cool bottom waters with warm surface waters, the extent to which these local impacts may cumulatively affect the cold pool as a whole is not well understood. Given the size of the cold pool, approximately 11,580 square miles, (NOAA 2020a), future offshore wind structures as described in the expanded planned action scenario would not affect the cold pool, although they could affect local conditions.

B.1.4.2 Regional Ocean Forces

Clockwise movement around Georges Bank and flow toward the equator dominates large-scale regional water circulation, which is strongest in late spring and summer (Whitney 2015). The edge of the continental shelf creates a shelf-break front that encourages upwelling. Weather-driven surface currents, tidal mixing, and estuarine outflow all contribute to driving water movement through the area (Kaplan 2011). Variable temperature-salinity water masses occupying nearshore and offshore regions converge over Nantucket Shoals, creating a persistent frontal zone in the area. Offshore from the islands, shelf currents flow predominantly toward the southwest, beginning as water from the Gulf of Maine heading south veers around and over Nantucket Shoals. Tidal water masses from nearshore transitioning through Nantucket Sound mix with the shelf current generally following depth contours offshore.

Offshore water masses may extend northward onto the shelf toward the islands and through the OCS lease areas offshore Massachusetts at different times of the year (Ullman and Cornillon 1999), while nearshore waters appear to be affected by freshwater runoff in the spring and show increased sea surface temperature gradients extending seaward from Nantucket Sound tidal exit points. A southeasterly flow along the inner shelf depth contours from Nantucket Sound (Limeburner and Beardsley 1982) may be a factor in maintaining the frontal system over Nantucket Shoals. While the dynamics of this system may not be completely understood at this time, the variability observed in shelf water characteristics plays a role in supporting the diverse marine ecology present offshore New England.

B.1.4.3 Tides and Tidal Currents

Tidal range in the Nantucket Sound area is typically 2 to 3.3 feet, and tidal currents can exceed 3.5 knots in Muskeget Channel. Elsewhere, 1- to 1.5-knot flows run west to east in the Main Channel of Nantucket Sound (NOAA 2018a) immediately south of Horseshoe Shoal.

In the SWDA, previous studies found that currents are tidally dominated (Spaulding and Gordon 1982), with wind and density variations playing a smaller role. Data suggest that the depth-averaged current speed is approximately 0.6 knot and the surface current speed is approximately 0.7 knot. While there are no SWDA-specific observational data available, the applicant developed a three-dimensional tide- and wind-driven model described in COP Appendix III-A (Epsilon 2023). In the SWDA, the bottom flood current is predicted to move toward the northeast and the ebb current toward the southwest. Peak predicted current speeds are 0.4 to 0.6 knot (COP Appendix III-A; Epsilon 2023).

B.1.4.4 Waves

In the Rhode Island Ocean Special Area Management Plan, average wave height ranges from 3 to 10 feet, and waves are likely to have little impact on the bottom at depth. Extreme wave height estimates range from 21 to 23 feet in a 10-year span to 29 to 30 feet in a 100-year span. Within the SWDA, the annual average of the monthly average significant wave height is approximately 4.3 feet and a maximum significant wave height of 19.7 feet. The annual average of the monthly average wave period is approximately 5.3 seconds (Rhode Island Coastal Resources Management Council 2010).

In many portions of Nantucket Sound, wave heights are limited by the short distance over which the wind can generate waves. This effect can be dramatic in places close to shore, such as a west wind off Chappaquiddick Island or a north wind offshore from the Cape. In addition, the presence of shoals (e.g., Muskeget area, Horseshoe Shoal) scattered around the area force the waves to increase in height locally and break, thereby diminishing further wave building.

Tidal currents can similarly play a role in modifying wave action nearshore. Wind-generated waves working against the tidal current quickly build and can develop standing waves under certain conditions. Conversely, a strong tidal current flowing in the same direction as the waves can actually diminish wave height as a result of the reduced opposing force. These effects come into play where large volumes of water are moving in and out of the Nantucket Sound, such as through Muskeget Channel and surrounding passages, as well as the channels north and south of Horseshoe Shoal.

The presence of offshore WTGs has the potential to alter wind-driven waves as they pass through the offshore facility (Swanson 2019). Generally, such changes are expected to reduce wave energy and would not be expected to result in increased shoreline erosion. Using computer modeling, Christensen et al. (2014) showed that an offshore wind facility located 2, 3, and 6 miles offshore would have a beneficial impact on shoreline accretion that decreased as the offshore wind facility distance from shore increased. While the general model estimated some parameters that may not be directly comparable to the proposed Project, the model shows that an offshore wind energy facility at any distance will decrease wave energy, with effects similar to a breakwater. As such, shoreline erosion is not expected to increase as a result of the proposed Project (Swanson 2019).

B.1.4.5 Potential General Impacts of Offshore Wind Facilities

There have been relatively few studies to analyze the impact of offshore wind facilities on oceanographic processes, primarily due to the fact that changes to these processes are often highly localized and difficult to measure relative to the natural variability of the environment. Further, the studies that exist tend to focus on direct structural impacts. Even less readily available are analyses on wind-wave interaction impacts because the physics behind this interaction are difficult to quantify, model, and validate. Studies conducted thus far rely heavily on small scale tank testing and ocean modeling rather than actual site measurements. These studies have shown, however, that the magnitude of the impact foundations have on oceanographic conditions depends on pile diameter, turbine density, and facility layout. For example, larger diameter piles have a greater impact than the smaller piles used for jacket foundations.

Tank and modeling tests, such as those conducted by Miles et al. (2017) and Cazenave et al. (2016), conclude that mean flows are reduced/disrupted immediately downstream of a monopile foundation but return to background levels within a distance proportional to the pile diameter (D). These results indicate disruptions for a horizontal distance anywhere from 3.5 D to 50 D, depending on whether it is a current-only regime or a wave and current regime, and a width of 65.6 to 164 feet. Thus, for foundations like those proposed by Vineyard Wind, background conditions would be expected from 164 to 1,148 feet downstream from each monopile foundation. Cazenave et al. (2016) also conducted a shelf-scale modeling exercise on the Irish Sea, home to Walney (+extensions) and west of Duddon Sands, contiguous offshore wind facilities that together contain 297 turbines (with 1.4 gigawatts total power generation capacity). The shelf-scale model of the eastern Irish Sea indicated a 5 percent reduction in peak water velocities and found that this reduction may extend up to approximately 0.5 nautical mile (0.57 mile) downstream of a monopile foundation; impacts varied based on array geometry. In general, modeling studies indicate that water flow typically returns to within 5 percent of background levels within a relatively short distance from the structure. Modeling studies, such as the one conducted by Broström (2008), indicate that the combined impact of wind and oceanographic changes anticipated at offshore wind facilities may have the potential to alter upwelling patterns localized to the wind facility. This experiment was modeled assuming a shallow water depth of 65.62 feet and included additional boundary assumptions. Further modeling studies, such as Carpenter et al. (2016), indicate that offshore wind facilities could impact large-scale stratification in the German Bight but only when they occupy extensive shelf regions, not at current capacity. Nearly all tank and modeling studies indicate that further studies using more realistic systems are required.

As evaluated in Swanson (2019), export cable-laying operations for the Vineyard Wind 1 Project are not expected to have a measurable impact on tidal flows that would result in increased shoreline erosion. The proposed Project export cables are similarly expected to not have measurable impacts because they would be laid adjacent to the Vineyard Wind 1 cables.

Vessel traffic may lead to shoreline erosion from vessel wakes, but this would be limited to approach channels and locations near ports and bays; given the amount and nature of vessel traffic, vessels associated with offshore wind energy would cause a negligible increase, if any, to wake-induced erosion of associated channels (BOEM 2019).

B.1.5 Biological Resources

This section discusses the biological resources present in the vicinity of the proposed Project. Potential impacts on biological resources are assessed in detail in EIS Sections 3.6 through 3.9 and G.2.3 through G.2.5.

B.1.5.1 Sea Life

Moderate productivity and a mostly sand bottom, which has a large impact in shaping the biological resources of the area, characterize the marine areas near the proposed Project.

Marine Mammals

Marine mammals use the coastal waters of the Northwest Atlantic OCS, which include the proposed Project area, for feeding, breeding, socializing, and migration (Stone et al. 2017; Leiter et al. 2017). At least 16 species of marine mammals, many of which are migratory, are likely to occur within the proposed Project area (Table 3.7-1 in EIS Section 3.7, Marine Mammals). Operational activities would overlap with species occurrence in the proposed Project area. The time of year; the type and level of marine mammal activity in the area; and duration of construction, operations, and decommissioning activities of the proposed Project were important factors in determining which marine mammal species would likely be present at the time and place of the various activities associated with offshore wind development on the Atlantic OCS. Furthermore, species occurrence and density data were used to identify the subset of marine mammals for consideration and estimate the distributions of those species. Among marine mammal species that have a reasonable probability of occurrence, in this area, five are listed as endangered: North Atlantic right whale (NARW; *Eubalaena glacialis*), blue whale (*Balaenoptera* *musculus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), and sperm whale (*Physeter macrocephalus*). However, as discussed in EIS Section 3.7, blue whales are rare in the proposed Project area. The low expected occurrence of blue whales in the proposed Project area, combined with the proposed mitigation (EIS Appendix H, Mitigation and Monitoring), results in a very low potential for impacts on blue whales from the proposed Project. Therefore, no impacts on blue whales are expected from proposed Project activities, and this species was not considered further in the EIS. The COP (Volume III, Section 6.7; Epsilon 2023), BOEM (2014), and EIS Section 3.7 present a list of all marine mammals that may occur in the area along with their relative occurrence in the proposed Project area. Corresponding detailed descriptions are included in the COP and Section B.5, Marine Mammals and Underwater Sound.

Marine mammals are highly migratory, and seasonal occurrences near the proposed Project vary for each species. The National Marine Fisheries Service (NMFS) biological assessment (BA) includes distribution maps of the listed species near the proposed Project and details regarding their seasonal occurrence (BOEM 2023a). The applicant also submitted comprehensive acoustic modeling of underwater sound propagation and potential auditory impacts on marine species during noise-producing construction activities for the proposed Project (COP Appendix III-M; Epsilon 2023) that provided detailed information for the pile-driving analysis, unexploded ordnance (UXO) removal analysis, and high-resolution geophysical (HRG) survey analysis. These results are also summarized in Section B.4, Background on Underwater Sound.

Finfish and Other Species of Commercial Importance

Resident and migratory finfish species, as well as demersal (bottom feeders) and pelagic (inhabiting the water column) types, occur in portions of the Rhode Island and Massachusetts Lease Areas (RI/MA Lease Areas) and within the SWDA. Many of these species have designated essential fish habitat (EFH), a delineation of important marine and diadromous (migratory between salt and fresh waters) fish habitat for all federally managed species mandated through the Magnuson-Stevens Fishery Conservation and Management Act in the Code of Federal Regulations, Title 50, Part 600 (50 CFR Part 600) (BOEM 2023b). A complete list of species with EFH near the proposed Project can be found in BOEM 2023b. Table B-7 shows some of the most significant species occurring in this area and indicates species of commercial/recreational importance. For more information on commercial and for-hire recreational fishing activities and species, see EIS Section 3.9, Commercial Fisheries and For-Hire Recreational Fishing, and BOEM 2023b.

Table B-7: Major Finfish and Invertebrate Species in Southern New England

Common Name	Scientific Name	Regional Species	Proposed Project Area Species	Listing Status	Federally Managed, EFH in SWDA	Federally Managed, EFH in OECC	Resident[a]	Migratory[a]	Benthic[b]	Demersal[b]	Pelagic[b]	Commercial/Recreational Importance	Current Condition (Source)
Alewife	*Alosa pseudoharengus*	X	X					X			J A	X	Depleted (NMFS 2019a)
American eel	*Anguilla rostrata*	X	X					X			A	X	Depleted (ASMFC 2017)
American lobster	*Homarus americanus*	X	X					X	E J A		L	X	Declining (ASMFC 2015)
American sand lance	*Ammodytes americanus*	X	X				X			E J A		X	Common (Staudinger et al. 2020)
American shad	*Alosa sapidissima*	X	X					X			J A	X	Depleted (ASMFC 2020)
Atlantic albacore tuna	*Thunnus albacares*	X	X		X	X		X			J A	X	Above target population levels (NOAA undated a)
Atlantic bluefin tuna	*Thunnus thynnus*	X	X		X	X		X			J A	X	Unknown overfished status, not undergoing overfishing (ICCAT 2017)
Atlantic butterfish	*Peprilus triacanthus*	X	X		X	X		X			E L J A	X	Common (Guida et al. 2017)
Atlantic cod	*Gadus morhua*	X	X		X	X		X		J A	E L	X	Significantly below target population levels (NOAA undated b), overfished (NEFSC 2017)
Atlantic croaker	*Micropogonias undulatus*	X					X			J A	E L	X	Stable (CBP undated b)
Atlantic herring	*Clupea harengus*	X	X		X	X		X			L J A	X	Common (Guida et al. 2017)
Atlantic horseshoe crab	*Limulus polyphemus*	X	X				X		E J A		L	X	Neutral (ASMFC 2019b)
Atlantic mackerel	*Scomber scombrus*	X	X		X	X		X			E L J	X	Significantly below target population levels (NOAA undated c), overfished, undergoing overfishing (NEFSC 2018a)
Atlantic menhaden	*Brevoortia tyrannus*	X	X					X			E L J A	X	Stable (SEDAR 2020)
Atlantic salmon	*Salmo salar*	X		X				X			J A		Endangered (BOEM 2023b)
Atlantic sea scallop	*Placopecten magellanicus*	X	X		X	X	X		E L J A		L	X	Common (NEFSC 2018b)
Atlantic skipjack tuna	*Katuwonus pelamis*	X	X		X	X		X			J A	X	Above target population levels (NOAA undated d)
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*	X	X	X				X			A		Endangered (BOEM 2023a)
Atlantic surf clam	*Spisula solidissima*	X	X		X	X	X		J A			X	Above target population levels (NOAA undated e)
Atlantic wolffish	*Anarhichas lupus*	X	X		X	X	X			E J A	L		Overfished, not undergoing overfishing (NEFSC 2017)
Atlantic yellowfin tuna	*Thunnus albacares*	X	X		X	X		X			J A	X	Above target population levels (NOAA undated f)
Barndoor skate	*Dipturus laevis*	X	X		X		X			J A			Depleted (Oceana undated)
Basking shark	*Cetorhinus maximus*	X	X		X			X			J A		Declining (Rigby et al. 2019a)
Bay scallops	*Argopecten irradians*	X	X				X		A	L		X	Depleted (MBA 2017)
Black drum	*Pogonias cromis*	X					X			J A		X	Stable (CBP undated c)
Black sea bass	*Centropristis striata*	X	X		X	X		X		J A		X	Not overfished, not undergoing overfishing (SEDAR 2018)
Blue mussel	*Mytilus edulis*	X	X				X		A	L		X	Abundance levels of moderate concern (Safina Center and MBA 2017)
Blue shark	*Prionace glauca*	X	X		X	X		X			J A		Declining (Rigby et al. 2019b)
Blueback herring	*Alosa aestivalis*	X	X					X			J A	X	Depleted (NMFS 2019a)
Bluefish	*Pomatomus salatrix*	X	X		X	X		X			J A	X	Depleted (ASMFC 2019a)
Channeled whelk	*Busycotypus canaliculatus*	X	X				X		E J A			X	Depleted and declining (MA DMF 2020)
Cobia	*Rachycentron canadum*	X	X		X	X		X			E L J A	X	Above target population levels (NOAA undated g)
Common thresher shark	*Alopias vulpinus*	X	X		X	X		X			J A		Unknown (NOAA undated h)
Dusky shark	*Carcharhinus obscurus*	X	X		X	X		X			J A		Declining (Rigby et al. 2019c), overfished (SEDAR 2016)
Eastern oyster	*Crassostrea virginica*	X	X				X		A		L	X	Stable (CBP undated a)
Giant manta ray	*Manta birostris*	X		X				X			J A		Endangered (BOEM 2023a)
Haddock	*Melanogrammus aeglefinus*	X	X		X	X		X			E L	X	Above target population levels (NOAA undated i)
Jonah crab	*Cancer borealis*	X	X					X	E J A		L	X	Unknown (NOAA undated j)
King mackerel	*Scomberomorus cavalla*	X	X		X	X		X			E L J A	X	Above target population levels (NOAA undated k)
Knobbed whelk	*Busycon carica*	X	X				X		E J A			X	Depleted and declining (MA DMF 2020)
Little skate	*Leucoraja erinacea*	X	X		X	X	X			J A		X	Common (Guida et al. 2017)
Longfin squid	*Doryteuthis pealeii*	X	X		X	X		X	E		J A	X	Common (Guida et al. 2017)
Monkfish	*Lophius americanus*	X	X		X	X	X			J A	E L	X	Above target population levels (NOAA undated l)
Northern sea robin	*Prionotus carolinus*	X	X					X		J A	E L		Stable (CBP undated d)
Northern shortfin squid	*Illex illecebrosus*	X	X			X		X			A	X	Unknown (NOAA undated p)
Ocean pout	*Zoarces americanus*	X	X		X	X		X		E J A		X	Overfished, not undergoing overfishing (NEFSC 2017)
Ocean quahog	*Arctica islandica*	X	X		X		X		J A			X	Above target population levels, declining (NOAA undated m)
Pollock	*Pollachius virens*	X	X		X			X		J	E L	X	Above target population levels (NOAA undated n)
Porbeagle shark	*Lamna nasus*	X	X		X			X			J A		Stable, overfished but not undergoing overfishing (Curtis et al. 2016)
Red hake	*Urophycis chuss*	X	X		X	X		X		J A	E L	X	Common (Guida et al. 2017)
Sandbar shark	*Carcharhinus plumbeus*	X	X		X	X		X			J A		Declining (Musick et al. 2009)
Sand tiger shark	*Carcharias taurus*	X	X		X	X		X			J A		Species of concern, declining (NOAA 2010)

Common Name	Scientific Name	Regional Species	Proposed Project Area Species	Listing Status	Federally Managed, EFH in SWDA	Federally Managed, EFH in OECC	Resident[a]	Migratory[a]	Benthic[b]	Demersal[b]	Pelagic[b]	Commercial/Recreational Importance	Current Condition (Source)
Scup	*Stenotomus chrysops*	X	X		X	X		X		J A		X	Common (Guida et al. 2017)
Shortfin mako shark	*Isurus oxyrinchus*	X	X		X			X			J A		Significantly below target population levels (NOAA undated o), overfished and undergoing overfishing (ICCAT 2017)
Shortnose sturgeon	*Acipenser brevirostrum*	X		X				X		A			Endangered (BOEM 2023a)
Silver hake	*Merluccius bilinearis*	X	X		X	X		X			E L J	X	Common (Guida et al. 2017)
Smooth dogfish	*Mustelus canis*	X	X		X	X		X			J A		Not overfished, not undergoing overfishing (SEDAR 2015)
Spanish mackerel	*Scomberomorus maculatus*	X	X		X	X		X			E L J A	X	Above target population levels (NOAA undated q)
Spiny dogfish	*Squalus acanthias*	X	X		X	X		X		A	A	X	Common (Guida et al. 2017)
Spot	*Leiostomus xanthurus*	X						X		J A	E L J A		Stable (CBP undated e)
Spotted sea trout	*Cynoscion nebulosus*	X					X			E L J A		X	Overfished, undergoing overfishing (ASMFC 2011)
Striped bass	*Morone saxatilis*	X	X					X		J A	J A	X	Significantly below target population levels (NOAA undated r), overfished, undergoing overfishing (NEFSC 2019)
Summer flounder	*Paralichthys dentatus*	X	X		X	X		X		J A	E L	X	Below target population levels (NOAA undated s)
Tautog	*Tautoga onitis*	X	X					X		E L J A	E	X	Overfished, undergoing overfishing (ASMFC 2016)
Tiger shark	*Galeocerdo cuvier*	X	X		X			X			J A	X	Declining (Ferreira and Simpfendorfer 2019)
Weakfish	*Cynoscion regalis*	X						X			E L J A	X	Depleted (ASMFC 2019c)
White hake	*Urophycis tenuis*	X	X		X	X		X		J	E L J	X	Not overfished, not undergoing overfishing (NEFSC 2017)
White shark	*Carcharadon carcharias*	X	X		X	X		X			J A	X	Declining (Rigby et al. 2019d)
Windowpane flounder	*Scophthalmus aquosus*	X	X		X	X		X		J A	E L	X	Not overfished, not undergoing overfishing (NOAA 2018b)
Winter flounder	*Pseudopleuronectes americanus*	X	X		X	X		X		L	E J A	X	Significantly below target population levels (NOAA undated t), overfished, not undergoing overfishing (NEFSC 2015)
Winter skate	*Leucoraja ocellata*	X	X		X	X		X		J A		X	Common (Guida et al. 2017)
Witch flounder	*Glyptocephalus cynoglossus*	X	X		X	X		X			E L	X	Overfished (NEFSC 2017)
Yellowtail flounder	*Limanda ferruginea*	X	X		X	X		X		J A	E L	X	Significantly below target population levels (NOAA undated u), overfished, undergoing overfishing (NEFSC 2015)

A = adult; E = egg; EFH = essential fish habitat; L = larvae; J = juvenile; OECC = offshore export cable corridor; SWDA = Southern Wind Development Area

[a] Migration encompasses movements potentially affecting the presence of a species in the proposed Project area. It includes short inshore/offshore seasonal movements (e.g., flatfish, skates), as well as long-distance migrations (e.g., tuna).

[b] Habitat use was separated by life stage based on information from several sources (ASMFC 1998; ASMFC 2018a; BOEM 2018; Collette and Klein-MacPhee 2002; Miller and Klimovich 2017; Nelson et al. 2018; Roberts 1978). Some species with EFH in the proposed Project area did not have EFH designation for all life stages, while for other species, some life stages may not occur near the proposed Project.

Benthic Invertebrates

Typical invertebrates in the region include polychaetes (bristle worms), crustaceans (particularly amphipods), mollusks (gastropods and bivalves), echinoderms (e.g., sand dollars, brittle stars, and sea cucumbers), and various others (e.g., sea squirts and burrowing anemones) (BOEM 2014). Overall, the region experiences strong seasonality in water temperature and phytoplankton concentrations, with corresponding seasonal changes in the densities of benthic organisms (COP Volume III, Section 6.5; Epsilon 2023).

The SWDA is part of the southern New England shelf as described by Theroux and Wigley (1998), which has a higher biomass and density of benthic fauna than neighboring geographic areas such as the Gulf of Maine and Georges Bank. Common sand dollars (*Echinarachnius parma*) are abundant in the SWDA, as are hydrozoans, bryozoans, hermit crabs, euphausiids, sea stars, anemones, sand shrimp (*Crangon septemspinosa*), nematode worms, pandalid shrimp, and fig sponge (*Suberites ficus*) (COP Volume III, Section 6.5; Epsilon 2023). Polychaete worms and amphipod crustaceans dominate infaunal assemblages. These are all common in the Nantucket Shelf region. Similar communities exist near Cape Cod along the proposed OECCs landfall sites, with abundant nut clams, polychaetes, and amphipods, as well as oligochaetes and nemertean ribbon worms (COP Volume III, Section 6.5; Epsilon 2023). As mentioned in Table B-7, the region is also home to commercially important benthic invertebrates, including American lobster (*Homarus americanus*), Atlantic sea scallop (*Placopecten magellanicus*), Atlantic surf clam (*Spisula solidissima*), and ocean quahog (*Arctica islandica*), among others.

Sea Turtles

Four species of sea turtles may occur within or near the proposed Project area: leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), and green (*Chelonia mydas*). Each of these species is protected under the Endangered Species Act (ESA; EIS Section 3.8, Sea Turtles). Hawksbill sea turtles (*Eretmochelys imbricata*) also occur in the U.S. northwest Atlantic Ocean but typically prefer tropical habitats; sightings are rare north of Florida, though there are few historical records as far north as Massachusetts, most recently as 1999 (NMFS and USFWS 1993; MGEL 2022).

The four sea turtle species that are likely to occur in the proposed Project area are migratory and occur in New England waters primarily in the summer and fall (Kraus et al. 2016a; O'Brien et al. 2021a, 2021b). Some individuals may remain in the region into the winter, but occurrence is less likely when water temperatures are low (i.e., winter and spring) (BOEM 2012; Greene et al. 2010). Sea turtle stranding and sighting data show similar seasonal trends among loggerhead, leatherback, Kemp's ridley, and unidentified sea turtles in the proposed Project area (WBWS 2022, NMFS 2022a). Additional information on sea turtle occurrence in the proposed Project area is available in the proposed Project NMFS BA (BOEM 2023a).

Sea turtles would use the proposed Project area mainly for travel and foraging but may spend extended rest periods on the seafloor or at the sea surface (COP Volume III, Section 6.8; Epsilon 2023; BOEM 2023a). Targeted surveys have been conducted for sea turtles near the proposed Project area, and the results can be found in the *Atlantic Marine Assessment Program for Protected Species* surveys (Palka et al. 2017, 2021), *Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles* (Kraus et al. 2016a), *Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales: Summary Report Campaign 5, 2018-2019* (O'Brien et al. 2021a), *and Megafauna aerial surveys in the wind energy areas of Massachusetts and Rhode Island with emphasis on large whales: Interim Report Campaign 6A, 2020* (O'Brien et al. 2021b). A more detailed discussion regarding aspects of sea turtles potentially affected is available in the proposed Project NMFS BA (BOEM 2023a).

B.1.5.2 Terrestrial Resources

Habitats

The terrestrial portion of the proposed Project is located within the Long Island-Cape Cod Coastal Lowland Major Land Resource Area. Much of this area exhibits sandy soils, mixed hardwood-softwood forests, and scrublands subject to periodic fires (USDA 2006). Pine-oak forest is one of the most common habitat types on Cape Cod. This area also includes important habitats such as coastal wetlands, isolated freshwater wetlands, and a few small streams, although none of these habitats are present at locations where proposed Project work would take place. Table G.2.5-1 in EIS Section G.2.5, Terrestrial Habitats and Fauna, shows some of the threatened and endangered plant species potentially occurring in this area.

Land Animals

Table G.2.5-2 in EIS Section G.2.5 lists terrestrial and coastal faunal resources that are known to occur near the proposed Project. Prominent animal communities include residents of woodlands (e.g., white-tailed deer [*Odocoileus virginianus*], fox [*Vulpes vulpes*], raccoon [*Procyon lotor*], among others), scrub grasslands (e.g., New England cottontail [*Sylvilagus transitionalis*], coyote [*Canis latrans*]), and wetlands (e.g., American beaver [*Castor canadensis*], muskrat [*Ondatra zibethicus*], diamondback terrapin [*Malaclemys terrapin*]). Amphibians and reptiles, including turtles, snakes, and a variety of frogs, may belong to several of these communities and may move between and among them.

B.1.6 Protective Measures and Monitoring

Thus far, there is only one operational offshore wind facility on the Atlantic Coast (Block Island Wind Farm), one under construction (Vineyard Wind 1 Project), and several more in various stages of development. This section highlights some of the lessons learned from the first U.S. project and projects in Europe regarding monitoring and mitigating impacts on the physical environment, including physical habitat.

B.1.6.1 Protective Measures

Scour was a significant concern and focus of the offshore wind facility industry after installation of monopile foundations in relatively shallow waters and mobile sediments resulted in extensive scour pits and scour fields (English et al. 2017). Extensive research was conducted on scour development, and best management practices (BMP) have been established to reduce scour occurrence. Current scour models are consistent with field data collected at offshore wind facilities, and mitigation measures for scour protection (e.g., rock placement) have been shown to be highly effective. At the moment, scour does not appear to be a major concern of offshore wind facility developers due to the effectiveness of scour protection as a mitigation, the accuracy of scour predictions, and the establishment of BMPs.

All COP submittals for offshore wind facilities to date, including the proposed Project COP, have included scour protection to mitigate the possibility of scour occurrence and monitoring programs to monitor scour both on a regular time schedule and with environmentally triggered monitoring, such as post storm event monitoring. These protective measures are in line with BMPs established by international industry stakeholders.

Survey data show the proposed Project seabed consists of fine-grained sediments that overlay coarse-grained sands. The mixed seabed and presence of fine-grained material indicates scour is less likely to occur; however, the applicant has proposed a conservative approach that includes the installation of scour protection around all foundations.

B.1.6.2 Environmental Monitoring

Direct observations of the Block Island Wind Farm show turbidity associated with cable installation to be nearly indistinguishable from background turbidity measurements and 100 times lower than model predictions; overspill levee deposits were in line with model predictions (Elliot et al. 2017).

Scour around the foundation of the Block Island Wind Farm show about 0.66 foot of seabed lowering over 14 months with average monthly variability of up to 1.97 feet. Data appear to suggest a correlation between the greatest levels of scour and the highest significant wave heights, thus raising the possibility that increased wave action leads to increases scour during more extreme winter weather with some recovery during spring and summer months (HDR 2019).

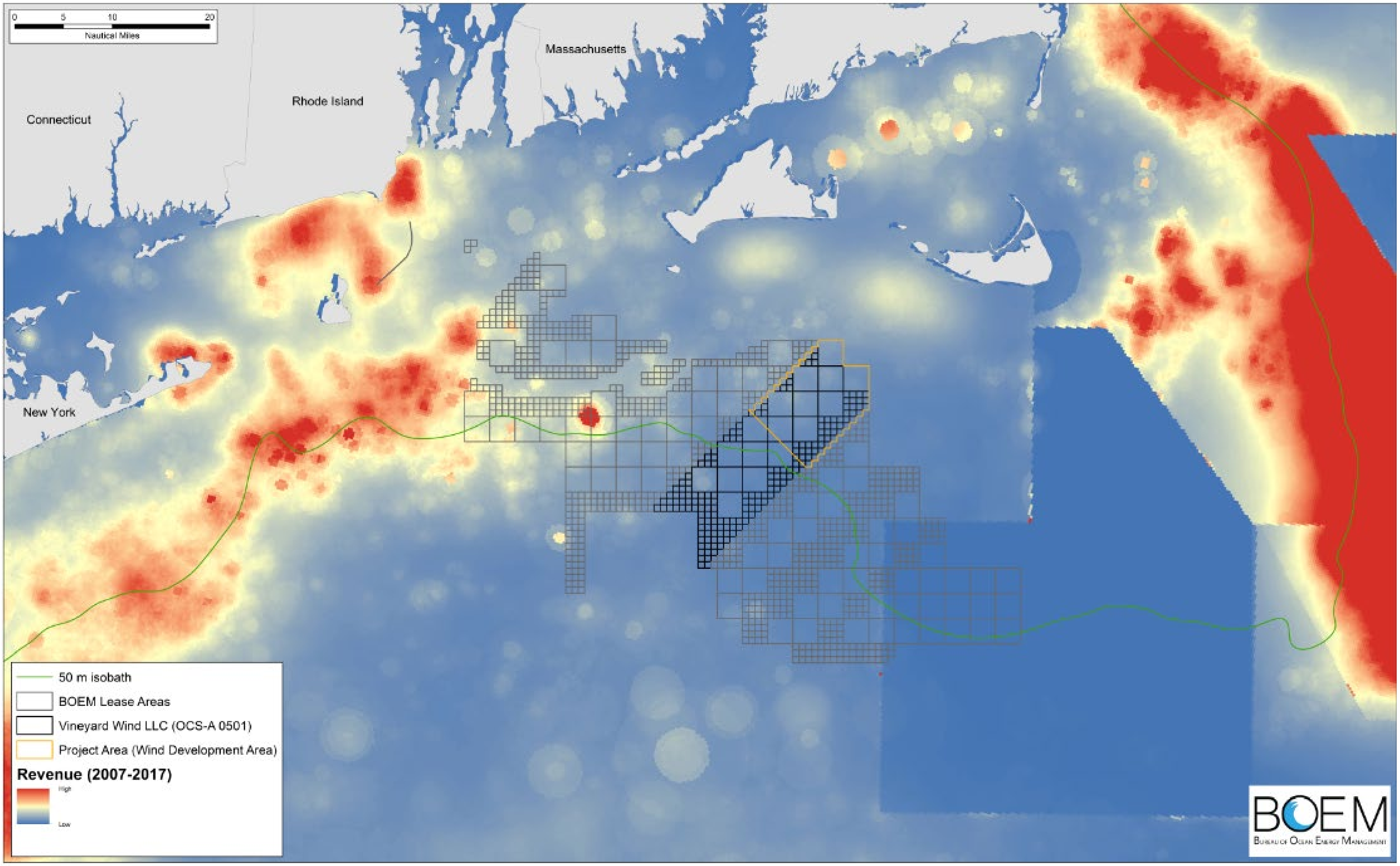
BOEM is working with state and federal partners to develop a regional monitoring strategy that focuses on biological resource impacts and builds off the lessons from Atlantic OCS and European wind development activities. Wind developers will also have site-specific monitoring requirements related to potential impacts that might be anticipated for their project. This includes monitoring of foundations for epibenthic growth, scour, and monitoring of cable burial effectiveness.

B.2 Commercial Fisheries and For-Hire Recreational Fishing Data

The analysis in this section is reprinted (with revisions to clarify geographic locations, project names, and figure and table numbers) from the Final EIS for the Vineyard Wind 1 Project (BOEM 2021) and reflects data, information, and trends through 2018. While more recent data may be available, the Vineyard Wind 1 information remains valid to broadly characterize and support the analysis of the New England Wind Project's impacts on commercial fisheries and for-hire recreational fishing in EIS Section 3.9, Commercial Fisheries and For-Hire Recreational Fishing.

The fisheries resources in federal waters off New England provide a significant amount of revenue. New Bedford, Massachusetts, has consistently been the highest value-producing U.S. fishing port (NOAA 2018c). In 2018, commercial fisheries harvested more than 1.2 billion pounds of fish and shellfish in the North and Mid-Atlantic region, for a total landed value of over $1.8 billion; from 2009 to 2018, average annual landings were 1.3 billion pounds with a value of $1.6 billion (ACCSP 2018). From 2009 to 2018, the value of landings has ranged from $1.2 billion to over $1.8 billion, while landings weight ranged from 1.16 billion pounds to 1.40 billion pounds. In Massachusetts, commercial fisheries harvested over 222 million pounds of fish and shellfish in 2018 for a total landed value of over $630 million.

Commercial fisheries in the northeast United States are known for the large landings of herring, menhaden, clam, squid, scallop, skate, and lobster, as well as being a notable source of profit from scallop, lobster, clam, squid, and other species (NOAA 2019d). Figure B-6 shows fishing revenue intensity in the region around the Vineyard Wind 1 Project Wind Development Area (WDA); the fishing revenue is for all federally managed fisheries aggregated for the years 2007 to 2017 (Geret DePiper, Pers. Comm., April 2019). Commercial fisheries obtained the greatest concentration of revenue from around the 164-foot contour off Long Island and Georges Bank. NMFS excluded mobile gear fishing in parts of Georges Bank for fish stock rebuilding. Moderate revenue fishing areas (yellow on Figure B-6) are apparent within and in the vicinity of the WDA. Chart plotter data submitted by commercial vessels targeting squid and whiting (*Merlangius merlangus)* reflect fishing in these areas.



m = meter; NEFSC = Northeast Fisheries Science Center; VTR = vessel trip report
This is based on federally reported VTRs and conversion by NEFSC (Geret DePiper, Pers. Comm., April 2019). The top 5% of revenue was clipped to lessen high-value scallop revenue skew of regional revenue. Without clipping, the top 5 percent areas important to lesser value fisheries would not appear. Removing the top 5% does not remove any areas that are not already represented in the red (high) end of the color ramp.

Figure B-6: Fishing Intensity Based on Average Annual Revenue for Federally Managed Fisheries (2007–2017)

Over 4,300 federally permitted fishing vessels were in the northeast in 2017, landing fish in several major northeast ports (Table B-8) (NOAA 2019e). In 2018, at the New Bedford port, commercial fishing landed more than 113.5 million pounds of products valued at $438.8 million (Table B-8). Point Judith, Rhode Island, landed 47.5 million pounds in 2017, valued at $64.8 million. Table B-8 lists the value and volume of landings of selected regional ports. The regional setting extends primarily over the fishing ports and waters in Massachusetts, Rhode Island, Connecticut, New York, and New Jersey, although vessels from other ports may occasionally operate in the area. Commercial vessels active in the RI/MA Lease Areas may be homeported and/or land product in ports in those states. Other ports such as Nantucket are much smaller but of importance to vessels homeported in those ports; however, for small ports, landing and fishing revenue data are often confidential because of the small number of fishing vessels involved. Unless noted otherwise, fishing revenue data in tables were converted to 2019 dollars using the quarterly, seasonally adjusted Gross Domestic Product Implicit Price Deflator provided by Federal Reserve Economic Data.

Table B-8: Value and Volume of Commercial Fishery Landings by Port (2019 dollars), 2016–2018

	2016	2017	2018	2016	2017	2018
Port	**Pounds (millions)[a]**			**Value (million $)[a]**		
New Bedford, Massachusetts	106.6	110.8	113.5	346.7	406.0	438.8
Cape May-Wildwood, New Jersey	46.6	101.6	101.2	89.9	84.4	67.5
Point Judith, Rhode Island	53.4	44.3	47.5	59.1	59.8	64.8
Hampton Roads Area, Virginia	12.3	15.5	14.7	64.8	60.6	55.7
Gloucester, Massachusetts	63.4	63.9	59	55.6	54.8	54.2
Provincetown-Chatham, Massachusetts	26.5	22.3	22.5	34.8	35.2	35.4
Reedville, Virginia	321.3	319.9	352.5	33.1	33.9	36.8
Point Pleasant, New Jersey	26.3	37.5	43.3	34.1	36.8	33.0
Long Beach-Barnegat, New Jersey	7.2	7.6	6.3	28.6	25.7	24.7
Atlantic City, New Jersey	24.3	24.7	24.8	20.9	19.4	18.5
Boston, Massachusetts	12.2	15.8	17	18.1	18.0	16.7
Montauk, New York	11.8	10.1	11.3	17.3	15.4	17.6
North Kingstown, Rhode Island	17.6	27	22.8	14.5	18.4	16.3
Accomac, Virginia	7.6	5.9	6.2	21.3	13.3	12.3
Fairhaven, Massachusetts	3.9	3.2	3.2	23.1	10.7	8.6
Newport, Rhode Island	6.6	7.3	5.5	8.5	8.9	8.0
Hampton Bay-Shinnicock, New York	5.2	3.8	3.6	8.5	6.4	5.8
Ocean City, Maryland	4	4.4	4.2	6.1	4.8	4.9
Stonington, Connecticut	2.1	1.8		6.3	6.5	
New London, Connecticut	9	5.6	7.2	5.4	2.8	4.3
Chincoteague, Virginia	2.4	1.9		5.2	4.1	
Belford, New Jersey	2.5	5.1	4.9	3.2	2.8	1.9
Little Compton, Rhode Island			3.1			3.0
Cape Charles-Oyster, Virginia		0.3			1.1	
Greenport, New York		0.2			0.3	

Sources: NOAA 2019f, 2019g

[a] Empty cells indicate that data were not collected or not available.

The commercial fishing fleets contribute to the overall economy in the region through direct employment, income, and gross revenues, as well as products and services to maintain and operate vessels, seafood processors, wholesalers/distributors, and retailers. In 2015, commercial fisheries in Massachusetts, Rhode Island, Connecticut, New York, and New Jersey created 61,865 jobs, generated $2,761 million in sales, and contributed $1,380 million in value added (gross domestic product; NOAA 2017a). In Massachusetts, of the 52,710 jobs created, commercial harvesters held 10,923 and retail created 39,323, with the remaining in seafood processing (1,509) and seafood wholesaling and distribution (955). Further, commercial harvesters received $302.5 million in income, retailers $369.6 million, seafood processors $83.1 million, and seafood wholesalers and distributors $55.2 million. In Rhode Island, of the 4,522 jobs created, 2,016 were held by commercial harvesters, and 2,107 were created in retail, with the remaining in seafood processing (284) and seafood wholesaling and distribution (115); commercial harvesters generated $42.5 million in income (NOAA 2017a).

Input-output models can be used to estimate the economic impacts associated with the harvesting of fish by commercial fishermen and the seafood industry. A study conducted by the University of Rhode Island (undated) on the *Economic Impacts of the Rhode Island's Fisheries and Seafood Sector* investigated the contributions of commercial fishing, charters, processing, professional service firms, retail and wholesale seafood dealers, service and supply firms, and tackle shops to assess their contributions to the state and national economy. The study concluded that the Rhode Island seafood industry generated 3,147 jobs and $538.3 million in gross sales with the total spillover effect to other industries of 4,381 jobs and output of $419.8 million. The vessel landings job multiplier was estimated at 32.43 jobs per $1.0 million, while the vessels landings economic impact multiplier was estimated at 1.98 (value added basis).

Table B-9 was provided by the NOAA Northeast Fisheries Science Center (NEFSC). NOAA NEFSC used the federal vessel trip report (VTR) to collect landings data. VTR data is collected by all NMFS permitted vessels, regardless of where fishing occurs or what species are targeted. The only federally permitted vessels not required to provide VTRs is the lobster fishery. Other non-federally permitted fisheries (e.g., Jonah crab [*Cancer borealis*] and menhaden) also do not have a federal reporting requirement. To compile data listed in Table B-9, NOAA NEFSC queried VTR data for positional data and linked it to dealer data for value and landings information. However, VTR data may misrepresent the actual location where the fish were harvested on a given trip. Fishermen are required to record the haul back position where the majority of fishing occurred, and separate VTRs are required only when fishermen change statistical areas or gear. Consequently, a single location can be used to record multiple tows, and this may not be representative of where fishing actually occurred.

The Rhode Island Department of Environmental Management (RI DEM) analysis (Table B-10) shows substantial variability in catch over time. Point Judith landings varied from just over $550,278 in 2011 to over $3.0 million in 2016, which coincides with a peak year for the squid industry that is primarily based in that port.[1] This information regarding the area's use as a fishery matches Point Judith- and Montauk-based vessel chart plotter data regarding the use of this area (Figure B-7). Similar variability in catch, likely due to squid landings, is shown for New Bedford, which had a landings revenue of $126,017 in 2011 and over $1.5 million in 2016. The RI DEM analysis identified New Bedford and Point Judith ports as having relatively higher value of landings from the Vineyard Wind 1 lease area.

[1] Vessel Monitoring System was not required until 2014 for squid vessels.

Table B-9: Value of Port Landings Harvested from the Vineyard Wind 1 Lease Area (Vessel Trip Report Data, 2019 Dollars), 2008–2017

Vineyard Wind 1 Lease Area	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Montauk, New York								$50,116	$227,598	$84,711
New Bedford, Massachusetts		$46,151	$179,883	$164,171	$108,842		$107,469		$317,624	
Point Judith, Rhode Island	$193,649	$42,152	$58,605	$254,534	$88,828	$372,726	$391,784	$432,069	$1,494,979	$206,102
Other ports	$100,830	$168,845	$214,111	$108,652	$354,925	$473,058	$167,723	$177,539	$429,707	$84,735

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available.

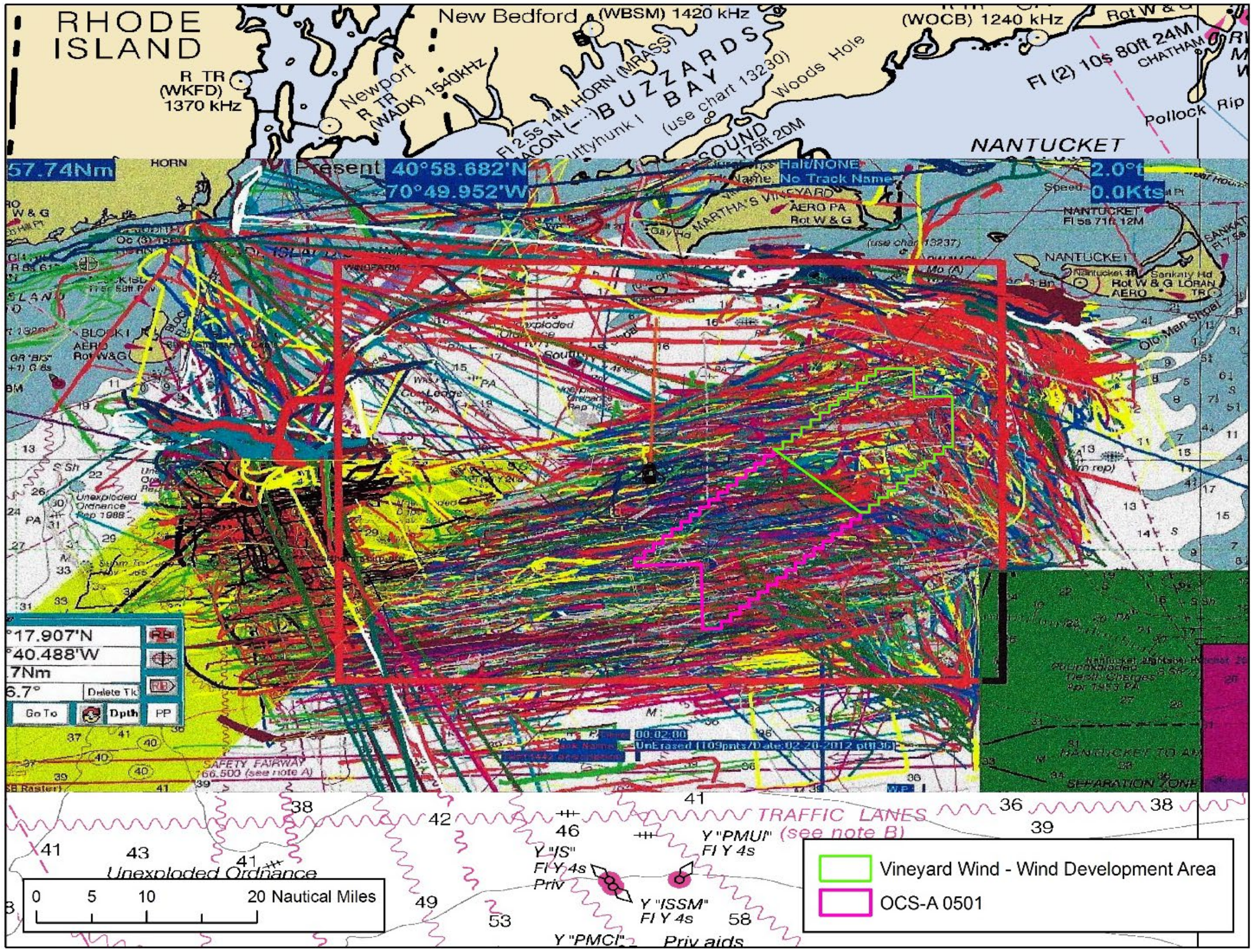
Table B-10: Value of Port Landings Harvested from the Vineyard Wind 1 Lease Area (Vessel Monitoring System Data, 2019 Dollars), 2011–2016

Port	2011	2012	2013	2014	2015	2016
Montauk, New York	Confidential landings (fewer than three vessels)	Confidential landings (fewer than three vessels)	$295,840	Confidential landings (fewer than three vessels)	$160,458	$426,771
New Bedford, Massachusetts	$126,017	$1,768,982	$1,227,439	$793,864	$590,584	$1,547,916
Point Judith, Rhode Island	$550,278	$872,311	$1,341,593	$1,318,362	$1,424,764	$3,165,239
Chatham, Massachusetts	$116,844	$162,645	$78,299	$41,058	Confidential landings (fewer than three vessels)	Confidential landings (fewer than three vessels)
New London, Connecticut	$63,854	Confidential landings (fewer than three vessels)	Confidential landings (fewer than three vessels)	No landings	Confidential landings (fewer than three vessels)	Confidential landings (fewer than three vessels)

Source: RI DEM 2017

The following ports were also considered; however, the data were either confidential (i.e., fewer than three separate contributors to the data) or there were no landings in those ports from the Vineyard Wind 1 lease area: Barnegat Light, NJ; Belford, NJ; Boston, MA; Cape May, NJ; Gloucester, MA; Hampton Bays, NY; Harwich Port, MA; Little Compton, RI; Mystic, CT; Newport, RI; North Kingstown, RI; Point Pleasant, NJ; Providence, RI; Provincetown Wharf, MA; Shinnecock Reservation, NY; Stonington, CT; Wakefield, RI; Westport, MA; and Woods Hole, MA.

Commercial Fisheries Center of Rhode Island - Chart Plotter Tow Tracks



Source: BOEM 2021

A general pattern of east to west or northeast to southwest (following Loran line orientation) fishing activity is apparent; however, a substantial number of tracks proceed in other directions.

Figure B-7: Chart Plotter Tow Tracks near the Wind Development Area

VTR data compiled by the NOAA NEFSC also show substantial variability in the year-to-year revenue (Table B-10). VTRs show that Point Judith landed a revenue of $1.5 million in 2016 compared to $3.2 million recorded by the vessel monitoring system (VMS) data (Table B-9). As another example, VMS data show a revenue of $872,311 in 2012 for Point Judith compared to $88,828 compiled from VTRs. In general, the total landed value in 2016 using VTRs is estimated at $2.5 million, substantially higher compared to the revenue landed in any other year in the investigated period (Table B-10). The differences in values with these two approaches are due to the different spatial data used (VTR point data versus VMS data) and the weighting done in the RI DEM analysis. Specifically, the RI DEM analysis took the raw fishing density maps by species caught to weight the value of fishing location points within each trip. Rather than assuming all fishing activity is equal, to scale the landings by the amount of fishing activity within each area per trip, each individual fishing point within a trip was weighted by the fishing density map for that fishery that year. Weighting the values based on fishing density places higher weights on points where the fishing density was higher. This strategy assumes that fishermen target the most profitable areas (i.e., where species abundances are higher) (RI DEM 2017). Together, these two approaches create a range of harvest revenue that occurred across the entire Vineyard Wind 1 lease area.

Table B-9 and Table B-10 show how various data collection and analysis methods (VMS versus VTR) can provide varying estimates of the fishing activity in the Vineyard Wind 1 lease area. More details about commercial fishing ports are available in the COP (Volume III, Section 7.6; Epsilon 2023).

The ports of Point Judith and New Bedford also support other economic activities through spending and job creation that depend on commercial and for-hire recreational fishing such as preparation and packaging of seafood, wholesale and retail seafood sales, purchase of fishing equipment, accommodation, and other goods and services related to commercial fishing.

Figure B-8 shows the relative squid fishing vessel density between 2015 and 2016 using VMS, both with all recorded squid fishing vessels traveling at any speed and speed filtered to show only those vessels traveling less than 4 knots. Figure B-9 shows the total number of unique squid fishing vessels (92) and orientation of fishing direction (roughly east to west) between 2014 and 2019 across the entire RI/MA Lease Areas. As previously noted, VMS as a source of location data for the squid fishery may underrepresent fishing activity prior to 2017. Also, VMS data show vessel presence but do not indicate whether the vessel is fishing or not. The presence of vessels traveling less than 4 knots may better indicate squid fishing activity because higher-speed vessels are more likely to be transiting.

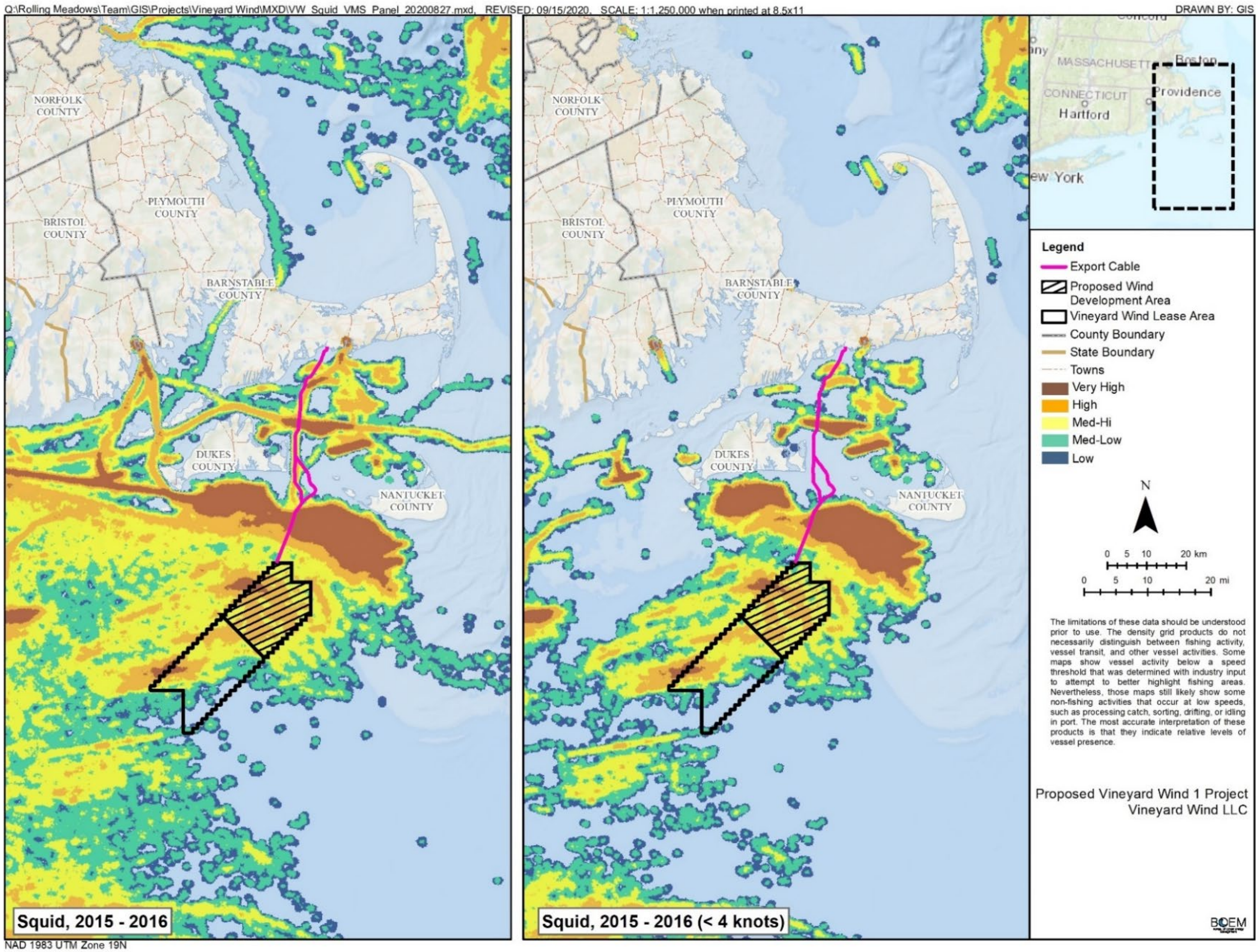
NOAA NEFSC also identified that more than $280,000[2] of lobster pot gear revenue comes from within the Massachusetts Wind Energy Area, which is primarily landed in Massachusetts (Kirkpatrick et al. 2017). After scallops, the state's second most valuable fishery is lobster, which has annual average landings of approximately $61 million. Much of the southern New England lobster fleet has transitioned to a mixed crustacean fishery targeting both Jonah crabs and lobsters (ASMFC 2022). Comments during scoping for the Vineyard Wind 1 and New England Wind EISs indicated that a majority of lobster effort is south and west of the proposed Project area (Figure B-10). However, lobster pot landings may be underestimated due to incomplete reporting for trap vessels that are not subject to mandatory reporting.

BOEM analyzed an expanded data set (Geret DePiper, Pers. Comm., August 2018) that is isolated to federally permitted commercial fishing activity within the WDA. Figure B-11 shows that commercial fisheries harvested $3.67 million in revenue in the Atlantic Mackerel, Squid, and Butterfish Fisheries Management Plan (FMP) and Atlantic surf clam and Ocean Quahog FMP over a 12-year period.

[2] This is based on 2007 to 2012 data and stated in 2015 dollars.

Looking at the value of catch within the WDA for each FMP as a percentage of the total revenue for each FMP in the region, the largest absolute shares occur in the Northeast Multispecies FMP (small mesh) and the Atlantic Mackerel, Squid, and Butterfish FMP, but in each case, less than 0.5 percent of the FMP's total revenue is harvested within the WDA.

Table B-11 and Table B-12 show the annual value of landings (2019 dollars) for the top seven FMPs in the WDA during 2007 to 2018. There has been substantial variability in the year-to-year harvest of various species in the WDA. NOAA NEFSC provided additional data on the value and volume of fishing in the WDA. The data are based on the VTRs; value of fishing is provided in 2019 dollars by species, gear, port, and state, while volume landed is provided in pounds (Table B-11 through Table B-20).



Source: Northeast Regional Ocean Council 2020

Figure B-8: Squid Fishing Vessel Density Based on Vessel Monitoring System Data (2015–2016)

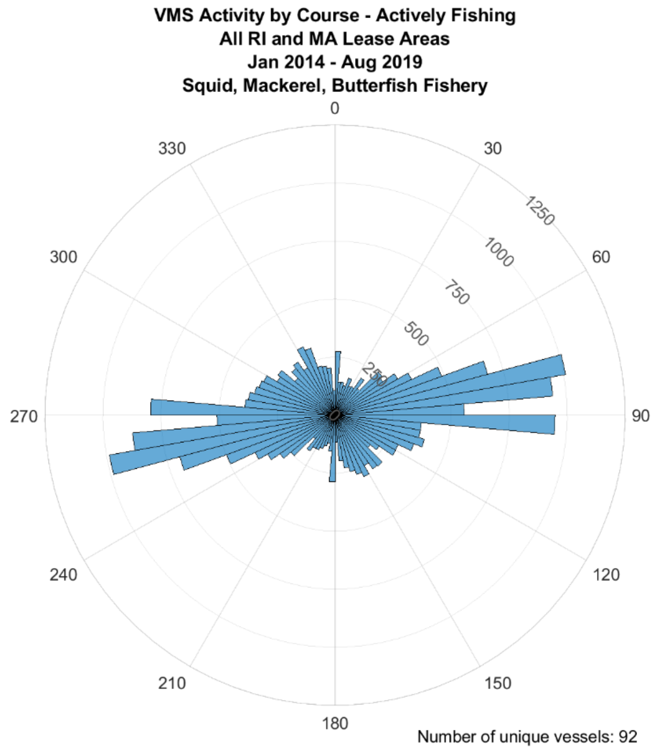


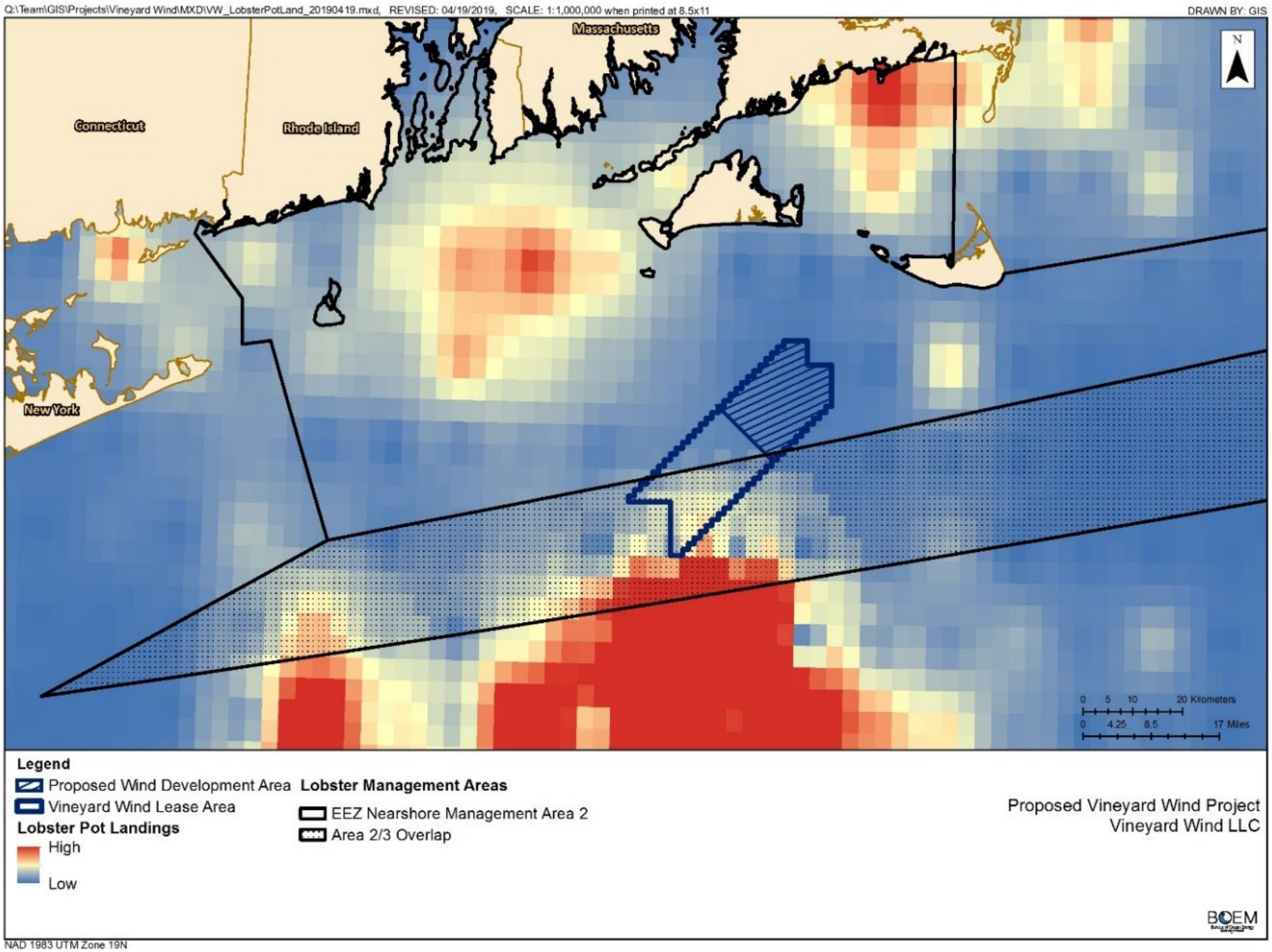
Figure B-9: Squid, Mackerel, Butterfish Fishery in Rhode Island/Massachusetts Lease Areas—Fishing

MA = Massachusetts; RI= Rhode Island; VMS = vessel monitoring system

Although Table B-11, Table B-12, and Table B-13 through Table B-20 are based on the same underlying VTR data, Table B-11 and Table B-12 use a VTR mapping model developed by the NMFS NEFSC. The VTR mapping model allows for a more conservative analysis using VTR data by taking into account some of the uncertainties around each reported point. Using observer data, for which precise locations are available, the model was developed to derive probability distributions for actual fishing locations around a provided VTR point. Other variables likely to affect the precision of a given VTR point, such as trip length, vessel size, and fishery, were also incorporated into the model. This model allows for generating maps that predict the spatial footprint of fishing. In this case, the modeled data indicate greater revenue exposure than that indicated by the VTR reported position alone over the same period.

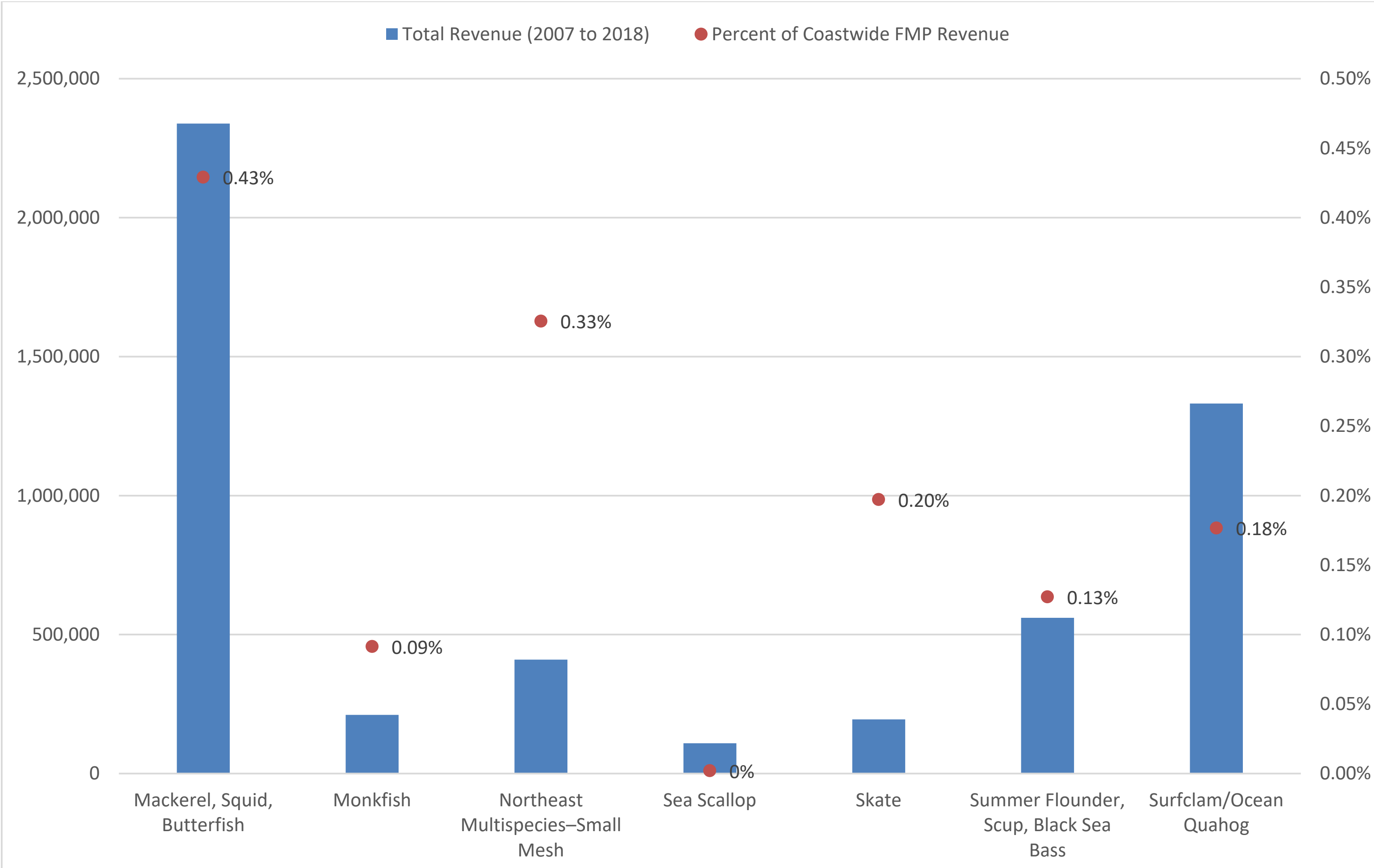
The commercial fisheries active in the proposed Project SWDA encompass a wide range of FMP fisheries, gears, and landing ports. Table B-21 through Table B-24 summarize the RI/MA Lease Areas (OCS-A 0534) commercial fish landings and associated revenue by FMP fishery, individual species, gear type, and total state revenue and landings based on the NMFS-prepared planning level assessment, which describes selected fishery landings and estimates of commercial revenue from each Atlantic Wind Energy Area (NMFS 2023a). Many of the following tables provide data between 2008 and 2021; however, the data from 2020 may not be indicative of historic or future operations. Both harvesters and other businesses reliant on fishing were affected by changes in fishing patterns due to COVID-19 and the associated responses and restrictions in some cases. An overwhelming majority of commercial fishing and for-hire recreational vessel operators and seafood processing and distribution sectors experienced significant impacts on operations during the 2020 operating year, with half the vessel operators indicating they stopped fishing for more than 3 months and nearly 90 percent of the operators reporting revenue losses (Glazier et al. 2022). In the interest of being comprehensive and providing the most recent and relevant data for analysis, the 2020 data are included; however, the entirety of the 14-year period being is used in assessing potential impacts.

Table B-21 and Table B-22 provide data on revenue and landings for 2008 through 2021 for commercial fisheries. Table B-23 provides the revenue (average annual and total) and landings in pounds (average annual and total) in the RI/MA Lease Areas by gear type for the 2008 to 2021 period. When looking at average annual landings and revenue generated by state, Table B-24 shows that ports in Massachusetts and Rhode Island generated the highest landings and revenue.



EEZ = Exclusive Economic Zone

Figure B-10: Lobster Pot Landings 2001–2010



FMP = Fisheries Management Plan
Revenue was converted to 2019 dollars using the monthly, not seasonally, adjusted Producer Price Index by Industry for Fresh and Frozen Seafood Processing provided by the U.S. Bureau of Labor Statistics.

Figure B-11: Top Seven Fisheries Management Plans with Harvests from the Wind Development Area (2007–2018)

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Table B-11: Value of Landings by Fisheries Management Plan for the Wind Development Area (2019 Dollars), 2007–2018

FMP	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	Annual Average
Mackerel, Squid, Butterfish	$11,390	$156,363	$133,246	$36,666	$114,983	$161,675	$98,477	$193,134	$236,455	$978,455	$131,544	$86,104	$2,338,493	$194,874
Monkfish	$24,348	$4,937	$4,927	$16,982	$34,421	$47,055	$17,757	$11,904	$10,631	$22,636	$8,347	$7,111	$211,056	$17,588
Northeast Multispecies–Small Mesh	$32,286	$42,149	$78,763	$22,542	$28,903	$25,763	$31,865	$26,500	$26,832	$35,074	$41,835	$17,359	$409,872	$34,156
Sea Scallop	$12,071	$22,676	$11,266	$5,078	$3,939	$8,185	$1,822	$2,660	$6,992	$28,642	$3,324	$2,224	$108,877	$9,073
Skate	$46,139	$16,181	$19,791	$19,582	$34,594	$10,550	$16,503	$8,390	$4,142	$11,692	$3,427	$3,693	$194,685	$16,224
Summer Flounder, Scup, Black Sea Bass	$27,937	$4,045	$12,543	$13,602	$27,487	$32,310	$62,906	$49,273	$95,594	$96,519	$74,597	$63,547	$560,360	$46,697
Surf Clam/Ocean Quahog	$327,689	$283,269	$306,663	$147,807	$49,682	$6,111	$20,155	$8,738	$17,278	$112,401	$11,222	$40,192	$1,331,207	$110,934
None–Unmanaged	$15,441	$26,504	$23,048	$26,110	$20,744	$20,214	$32,230	$35,094	$33,284	$23,965	$24,104	$25,953	$306,691	$25,558
All Other	$81,215	$11,047	$7,756	$35,880	$7,430	$7,097	$49,817	$40,475	$20,250	$7,036	$6,376	$10,264	$284,643	$23,720
Total	$578,515	$567,172	$598,004	$324,249	$322,183	$318,960	$331,531	$376,168	$451,459	$1,316,420	$304,775	$256,448	$5,745,884	$478,824

Source: Geret DePiper, Pers. Comm., August 2018

FMP = Fisheries Management Plan

Revenue was converted to 2019 dollars using the monthly, not seasonally, adjusted Producer Price Index by Industry for Fresh and Frozen Seafood Processing provided by the U.S. Bureau of Labor Statistics. American lobster and Jonah crab fisheries are included in the "None–Unmanaged" row.

Table B-12: Value of Landings by Wind Development Area Fisheries Management Plan as a Percentage of Total Coast-wide Fisheries Management Plan, 2007–2018

FMP	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mackerel, Squid, Butterfish	0.02%	0.35%	0.31%	0.10%	0.26%	0.36%	0.29%	0.52%	0.62%	1.61%	0.24%	0.14%
Monkfish	0.09%	0.02%	0.03%	0.11%	0.16%	0.22%	0.10%	0.07%	0.06%	0.11%	0.05%	0.05%
Northeast Multispecies–Small Mesh	0.27%	0.42%	0.72%	0.18%	0.25%	0.24%	0.35%	0.24%	0.26%	0.33%	0.51%	0.20%
Sea Scallop	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
Skate	0.44%	0.20%	0.27%	0.23%	0.44%	0.14%	0.13%	0.08%	0.06%	0.18%	0.06%	0.05%
Summer Flounder, Scup, Black Sea Bass	0.07%	0.01%	0.04%	0.04%	0.07%	0.09%	0.16%	0.13%	0.24%	0.24%	0.20%	0.18%
Surf Clam/Ocean Quahog	0.39%	0.38%	0.44%	0.23%	0.08%	0.01%	0.04%	0.02%	0.03%	0.19%	0.02%	0.07%

Source: Geret DePiper, Pers. Comm., August 2018

FMP = Fisheries Management Plan; WDA = Wind Development Area; VTR = vessel trip report

Table B-11 shows the value of landings for the WDA by the FMP; Table B-12 shows the percentage of each FMP's revenue from landings within the WDA compared to each FMP's total revenue from landings in the entire region covered by the FMP. The data represent the revenue-intensity raster developed using fishery dependent landings' data. To produce the data set, VTR information was merged with data collected by at-sea fisheries observers, and a cumulative distribution function was estimated to present the distance between VTR points and observed haul locations. This provided a spatial footprint of fishing activities by FMPs.

Table B-13: Value of Landings by Species for the Wind Development Area (Vessel Trip Report, 2019 Dollars), 2008–2017

Species	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Black sea bass					$1,001	$1,747		$1,307	$795	$5,406	$10,257
Bluefish	$314		$667	$2,920	$547	$162	$637	$855	$276	$1,000	$7,378
Butterfish	$1,754	$1,420	$1,739	$2,004		$8,166	$2,912	$2,170	$3,711	$5,795	$29,673
Crab, Jonah	$645		$2,996	$8,205	$31,405	$92,197					$135,448
Crab, rock				$5,124							$5,124
Dogfish, smooth, fins										$2,122	$2,122
Dogfish, spiny, fins										$287	$287
Eel, conger										$9	$9
Flounders	$10,917			$9,112		$75,535	$33,636	$62,155	$6,571	$32,286	$230,212
Hakes	$68,210	$15,631	$95,466	$37,024		$147,956	$39,432	$40,828	$46,560	$61,734	$552,841
Lobster, American	$35,456	$30,539	$26,600	$89,701	$49,682	$29,094	$5,345		$25,915	$2,897	$295,229
Mackerel, Atlantic									$13		$13
Monkfish	$10,100	$2,587	$36,213	$61,199	$147,521	$48,449	$43,175	$16,387	$32,073	$31,474	$429,179
Scallops/shells	$545					$118,081	$4,542		$1,666		$124,834
Scup			$11,954	$34,878		$17,454		$53,685	$4,502	$80,630	$203,103
Skate, rack	$8,547	$12,904	$17,926	$20,266	$58,747	$44,949	$39,410	$27,723	$32,805	$11,627	$274,905
Squids	$31,252	$7,535	$9,613	$4,925		$79,560	$38,805	$45,661	$526,582	$7,795	$751,728
All others	$8,800	$19,904	$120,677	$8,219	$24,153	$3,754	$67,989	$60,905	$3,567	$1,402	$319,370
Total	$176,542	$90,521	$323,851	$283,578	$313,056	$667,105	$275,883	$311,678	$685,036	$244,464	$3,371,714

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available.

Table B-14: Volume of Landings by Species for the Wind Development Area (Vessel Trip Report, Landed Pounds), 2008–2017

Species	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Black sea bass					218	335		357	149	1,319	2,378
Bluefish	664		1,149	3,899	786	195	891	863	318	1,020	9,785
Butterfish	1,944	2,855	1,944	2,043		15,830	3,100	3,242	9,564	9,426	49,948
Crab, Jonah	994		5,155	10,341	36,458	105,190					158,138
Crab, rock				8,301							8,301
Dogfish, smooth, fins										3,507	3,507
Dogfish, spiny, fins										1,099	1,099
Eel, conger										10	10
Flounders	4,099			3,317		33,274	8,645	23,471	1,286	7,770	81,861
Hakes	93,784	41,015	90,708	53,819		189,158	54,456	66,232	98,906	107,786	795,863
Lobster, American	7,899	7,301	5,857	21,023	12,739	6,320	1,012		4,544	530	67,225
Mackerel, Atlantic									35		35
Monkfish	4,501	1,314	22,487	28,504	70,787	35,890	30,622	10,151	20,735	22,122	247,112
Scallops/shells	62					10,241	353		144		10,800
Scup			22,276	69,464		27,348		58,626	5,053	120,684	303,451
Skate, rack	60,160	35,210	30,287	34,339	88,488	51,991	46,248	43,033	66,971	32,623	489,349
Squids	28,186	5,940	7,075	3,277		67,388	34,440	37,488	405,651	3,878	593,323
All others	8,830	15,629	18,254	8,003	51,526	10,331	65,270	5,463	2,984	967	187,257
Total	211,123	109,264	205,192	246,330	261,002	553,491	245,038	248,926	616,338	312,740	3,009,443

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available. Values are reported in landed pounds.

Table B-15: Value of Landings by Gear Type for the Wind Development Area (Vessel Trip Report, 2019 Dollars), 2008–2017

Gear Type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Gillnet-sink				$78,873		$85,447		$39,135		$37,394	$240,849
Pot		$31,507	$32,495	$102,699	$85,362	$123,203			$27,124		$402,390
Trawl-bottom	$132,630	$46,213	$129,383	$99,829		$341,190	$178,591	$211,315	$595,795	$203,909	$1,938,854
All others	$43,912	$12,800	$161,972	$2,176	$227,696	$117,268	$97,290	$61,228	$62,120	$3,160	$789,623
Total	$176,542	$90,520	$323,850	$283,576	$313,058	$667,109	$275,881	$311,677	$685,039	$244,463	$3,371,715

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available.

Table B-16: Volume of Landings by Gear Type for the Wind Development Area (Vessel Trip Report, Landed Pounds), 2008–2017

Gear Type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Gillnet-sink				68,048		86,257		48,931		44,444	247,680
Pot		8,852	18,358	39,792	54,476	114,160			6,244		241,882
Trawl-bottom	194,035	86,126	124,107	137,741		343,217	157,024	195,226	523,556	267,443	2,028,474
All others	17,088	14,286	62,727	749	206,526	9,857	88,014	4,769	86,539	853	491,408
Total	211,123	109,264	205,192	246,330	261,002	553,491	245,038	248,926	616,339	312,740	3,009,443

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available. Values are reported in landed pounds.

Table B-17: Value of Landings by Port for the Wind Development Area (Vessel Trip Report, 2019 Dollars), 2008–2017

Port	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Montauk										$40,629	$40,629
New Bedford		$46,151	$179,883	$66,084	$13,553		$20,164		$100,867		$426,702
Point Judith	$116,149		$58,605	$83,392		$286,689	$160,234	$242,957	$452,756	$119,803	$1,520,587
Point Pleasant										$26,108	$26,108
Westport				$60,428							$60,428
All others	$60,393	$44,369	$85,361	$73,674	$299,505	$380,418	$95,483	$68,720	$131,416	$57,922	$1,297,260
Total	$176,542	$90,520	$323,849	$283,578	$313,058	$667,108	$275,881	$311,677	$685,039	$244,462	$3,371,713

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available.

Table B-18: Volume of Landings by Port for the Wind Development Area (Vessel Trip Report, Landed Pounds), 2008–2017

Port	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Montauk										56,022	56,022
New Bedford		27,226	58,609	35,007	10,286		17,638		97,357		246,123
Point Judith	137,296		68,664	121,160		208,264	140,186	186,758	378,589	187,326	1,428,241
Point Pleasant										10,975	10,975
Westport				30,113							30,113
All others	73,827	82,038	77,919	60,050	250,716	345,227	87,214	62,168	140,393	58,417	1,237,969
Total	211,123	109,264	205,192	246,330	261,002	553,491	245,038	248,926	616,339	312,740	3,009,443

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available. Values are reported in landed pounds.

Table B-19: Value of Landings by State for the Wind Development Area (Vessel Trip Report, 2019 Dollars), 2008–2017

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Connecticut									$44,948		$44,948
Massachusetts		$49,364	$241,696	$181,889	$210,955	$130,524	$101,223	$53,757	$182,414	$41,400	$1,193,221
New Jersey										$26,108	$26,108
New York										$43,784	$43,784
Rhode Island	$132,736	$40,751	$58,605	$83,392	$94,914	$383,233	$167,113	$242,957	$457,322	$122,733	$1,783,758
All others	$43,806	$405	$23,548	$18,295	$7,187	$153,352	$7,545	$14,963	$354	$10,438	$279,892
Total	$176,542	$90,520	$323,849	$283,576	$313,057	$667,109	$275,881	$311,677	$685,038	$244,462	$3,371,711

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available.

Table B-20: Volume of Landings by State for the Wind Development Area (Vessel Trip Report, Landed Pounds), 2008–2017

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Connecticut									50,935		50,935
Massachusetts		33,979	119,758	108,050	161,338	121,793	94,743	55,763	179,187	47,982	922,593
New Jersey										10,975	10,975
New York										57,619	57,619
Rhode Island	176,776	75,216	68,664	121,160	97,583	310,638	145,876	186,758	386,160	192,486	1,761,315
All others	34,347	69	16,770	17,120	2,081	121,060	4,419	6,405	57	3,678	206,006
Total	211,123	109,264	205,192	246,330	261,002	553,491	245,038	248,926	616,339	312,740	3,009,443

Source: Benjamin Galuardi, Pers. Comm., April 3, 2019

Empty cells indicate that data were not collected or not available. Values are reported in landed pounds.

Table B-21: Commercial Fishing Landings and Revenue of the Most Impacted Species from 2008 to 2021 for the Southern Wind Development Area

Species	14-Year Landings (2008 to 2021; pounds)	14-Year Revenue (2021 U.S. Dollars)	Average Annual Revenue (2021 U.S. Dollars)
Longfin squid *(Doryteuthis pealeii)*	1,297,000	$1,786,000	$127,571.4
Skates	1,168,000	$545,000	$38,928.6
Silver hake *(Merluccius bilinearis)*	1,004,000	$735,000	$52,500.0
All other	906,000	$743,000	$53,071.4
Jonah crab *(Cancer borealis)*	625,000	$576,000	$41,142.9
Scup *(Stenotomus chrysops)*	588,000	$447,000	$31,928.6
Monkfish *(Lophius americanus)*	415,000	$700,000	$50,000.0
Summer flounder *(Paralichthys dentatus)*	142,000	$462,000	$33,000.0
American lobster *(Homarus americanus)*	90,000	$466,000	$33,285.7
Atlantic sea scallop *(Placopecten magellanicus)*	34,000	$374,000	$26,714.3

Source: Developed using data from NMFS 2023a

Table B-22: Commercial Fishing Landings and Revenue of the Most Impacted Fisheries Management Plans from 2008 to 2021 for the Southern Wind Development Area

FMP	14-Year Landings (2008 to 2021; pounds)	14-Year Revenue (2021 U.S. Dollars)	Average Annual Revenue (2021 U.S. Dollars)
Mackerel, Squid, and Butterfish	1,460,000	$1,879,000	$134,214
Small-mesh multispecies	1,130,000	$781,000	$55,786
Summer flounder, scup, black sea bass	741,000	$950,000	$67,857
Atlantic States Marine Fisheries Commission	718,000	$1,045,000	$74,643
Monkfish	415,000	$700,000	$50,000
Skates	1,168,000	$546,000	$39,000
All others[a]	837,000	$679,000	$48,500
Atlantic Herring	562,000	$73,000	$5,214
Northeast Multispecies	102,000	$207,000	$14,786
No Federal FMP	79,000	$68,000	$4,857
Spiny Dogfish	56,000	$13,000	$929
Surfclam, Ocean Quahog	42,000	$34,000	$2,429
Sea Scallop	34,000	$374,000	$26,714
Tilefish	21,000	$86,000	$6,143
Bluefish	18,000	$15,000	$1,071
Highly Migratory Species	8,000	$7,000	$500
SERO FMP[b]	<500	<$500	$36

Source: Developed using data from NMFS 2023a
FMP = Fisheries Management Plan; NOAA = National Oceanic and Atmospheric Administration
[a] All others refers to FMP fisheries with fewer than three permits or dealers affected to protect data confidentially.
[b] SERO FMP is NOAA's Southeast Regional Office Fishery Management Plan.

Table B-23: Commercial Fishing Landings by Gear Type and Revenue of the Most Impacted Species from 2008 to 2021 for the Southern Wind Development Area

Gear Type	14-Year Landings (2008 to 2021; pounds)	14-Year Revenue (2021 U.S. Dollars)	Average Annual Revenue (2021 U.S. Dollars)
Bottom trawl	4,022,000	$4,026,000	$287,571.43
Gillnet-sink	1,151,000	$1,109,000	$79,214.29
Lobster pot	757,000	$1,068,000	$76,285.71
Clam dredge	586,000	$471,000	$33,642.86
Midwater trawl	465,000	$48,000	$3,428.57
All others	341,000	$325,000	$23,214.29
Scallop dredge	32,000	$342,000	$24,428.57
Other pot	27,000	$32,000	$2,285.71
Bottom longline	9,000	$35,000	$2,500.00
Handline	<500	<$500	$35.71

Source: Developed using data from NMFS 2023a

Table B-24: Commercial Fishing Landings and Revenue by State from 2008 to 2021 for the Southern Wind Development Area

State	14-Year Landings (2008 to 2021; pounds)	14-Year Revenue (2021 U.S. Dollars)
Massachusetts	3,456,000	$3,286,000
Rhode Island	3,218,000	$3,139,000
New York	355,000	$476,000
Connecticut	227,000	$239,000
Virginia	54,000	$120,000
North Carolina	40,000	$112,000
New Jersey	28,000	$64,000
Maryland	2,000	$5,000
All others	1,000	$1,000
Maine	1,000	$1,000
Total	**7,382,000**	**$7,443,000**

Source: Developed using data from NMFS 2023a

Analysis prepared by the RI DEM for the WDA, using VMS and VTR data, provides an estimate of the ex-vessel value (the price received at port of landing) of the Rhode Island commercial fishing industry that is derived from the WDA (RI DEM 2019). The study suggests that the value of fishing in the area is $35.6 million for a 30-year period (corresponding to the length of the lease and construction time). The values are premised on existing trips that either fully or partially intersect the WDA area, including a 2-nautical-mile (2.3-mile) section north or south of the WDA. The study further showed that almost $21 million of the total 30-year value would be from the Atlantic Mackerel, Squid, and Butterfish FMP; $4.7 million from the Northeast Multispecies FMP, small mesh species (hakes); $4.6 million from Summer Flounder, Scup, and Black Sea Bass FMP; $2.2 million from groundfish, $1.5 million from American lobster; $1 million from scallops; and the remaining from other species. Again, the RI DEM (2019) analysis was specific to vessels landing in Rhode Island ports.

The Summer Flounder, Scup, Black Sea Bass FMP landed up to 0.2 percent of the total coast-wide revenue (Table B-12). Between 2007 and 2018, annual revenue from landings of summer flounder (*Paralichthys dentatus*), scup (*Stenotomus chrysops)*, and black sea bass (*Centropristis striata*) in the WDA ranged from $4,045 to $96,519, with a total revenue of $560,360 for 2007 to 2018 (2019 dollars, Table B-11). Summer flounder is most often landed from January to September, with the peak in June through August. Three periods comprise the scup's quota. In spring and summer, scup migrate to northern and inshore waters to spawn. The black sea bass peak harvest is typically June through September.

Many potentially affected fisheries, including the whiting, summer flounder, scup, and black sea bass, are not required to use VMS. Therefore, these fisheries are underrepresented in evaluations of impacts from the WDA or the cable corridor. Data from several sources are provided in this section to show how the estimates of catch from the WDA may differ depending on the measurement method.

Data provided by NOAA NEFSC (Table B-13 and Table B-14) that were collected through VTRs show low revenue from the WDA for black sea bass ($10,257 for 2008 through 2017). Revenues for scup total $203,103, and revenues for flounders total $230,212 between 2008 and 2017 (2019 dollars).

The Atlantic Mackerel, Squid, Butterfish FMP covers longfin and illex squid, which make up the majority species landed in this FMP. Bottom and mid-water trawling account for most landings (ASMFC 2018b). As shown on Figure B-8, density was variable in vessels targeting squid throughout the WDA with patches of medium-low to medium-high density, and an area of very high density along the OECC. Revenue from the Atlantic Mackerel, Squid, and Butterfish FMP from the WDA ranged from a low of $11,390 in 2007 to a high of $978,455 in 2016 (Table B-11). For 2007 to 2018, the total revenue for this FMP was $2.3 million (Table B-11). Based on VMS data and the RI DEM analysis, 2016 was also a high revenue year ($5.1 million for the entire lease area around the WDA [Table B-9]) but with higher activity densities also seen north of the WDA.

To the contrary, Table B-8 shows no revenue from Atlantic mackerel (*Scomber scombrus)* from the WDA ($13 for 2008 to 2017), $751,728 in revenue from squids, and $29,673 from butterfish. For the period of 2008 to 2017, the squid fishing revenue from Rhode Island is estimated at $192.1 million with 235.1 million pounds landed. In general, squid landings in Rhode Island represented 53 percent of total squid landings from the Atlantic and 54 percent of total squid revenue from the Atlantic (based on nominal revenue data for 2008 to 2017; NOAA 2019f). With $643,551 in squid revenue from the WDA from 2008 to 2017, the WDA accounts for 0.18 percent of squid revenue from the Atlantic (or 0.33 percent of squid revenue from Rhode Island).

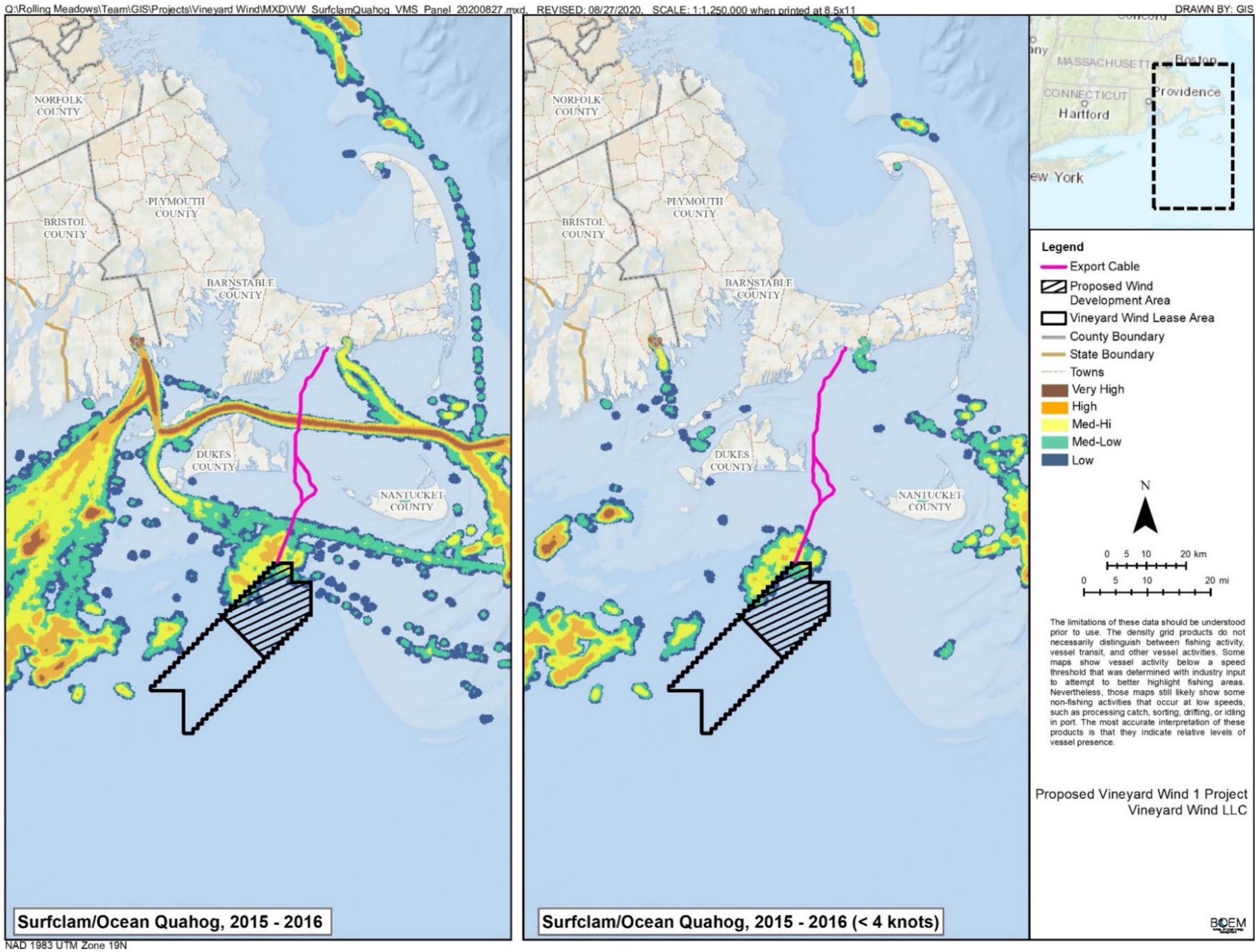
As shown on Figure B-12, VMS data indicate that surf clam/ocean quahog fishing vessels are not typically found within the WDA; however, along the OECC, there were areas where very high density of catch were indicated. Figure B-12 shows the relative surf clam/ocean quahog fishing vessel density during the year 2015 to 2016, with all recorded fishing vessels traveling at any speed, and speed filtered to show only those vessels traveling less than 4 knots. VMS data show vessel presence but do not indicate whether the vessel is fishing or not. The presence of vessels traveling less than 4 knots may better indicate surf clam/ocean quahog fishing activity because higher-speed vessels are more likely to be transiting. Figure B-13 shows a majority of the 24 unique vessels in the surf clam and ocean quahog fishery transiting in a northeast to southwest direction through the southern New England lease areas. Surf clams are harvested principally via hydraulic dredging. The harvest of surf clam and ocean quahog in the WDA provided a high value of landings prior to 2011; however, since then, the harvest has substantially decreased in the WDA, valued at only $17,278 in 2015, increasing to $112,401 in 2016 and down to $11,222 in 2017. From 2007 to 2018, the total revenue for this FMP was $1.3 million from the WDA (Table B-11).

Atlantic sea scallop vessels had medium-low or medium-low to medium-high VMS density in the WDA and higher VMS density (up to high) along the OECC (Figure B-14). Figure B-15 shows the relative sea scallop fishing vessel density between 2015 and 2016, with all recorded fishing vessels traveling at any speed, and speed filtered to show only those vessels traveling less than 5 knots. VMS data show vessel presence but do not indicate whether the vessel is fishing or not. The presence of vessels traveling less than 5 knots may better indicate sea scallop fishing activity because higher-speed vessels are more likely to be transiting. Figure B-15 shows a majority of the 418 unique vessels in the sea scallop fishery transiting in a northwest to southeast direction through the southern New England lease areas. Dredges are the primary fishing gear. Table B-11 shows that the annual revenue for this FMP from the WDA ranged from $1,822 to $28,642, with $108,877 landed from 2007 to 2018. To compare, VTR data show $118,081 in revenue from sea scallops/shellfish from the WDA in 2013; less than $4,600 in 2008, 2014, and 2016; and no revenue in the remaining years (Table B-13).

VTR data inform that other important sources of revenue from the WDA from 2008 to 2017 were Jonah crab (totaling $135,448), hakes ($552,841), American lobster ($295,229), monkfish ($429,179), and skate ($274,905; Table B-13 and Table B-14).

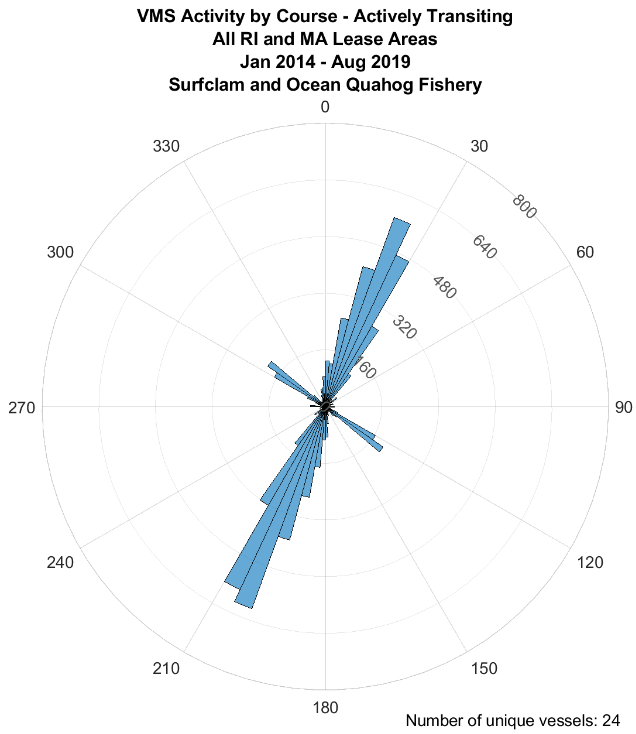
Table B-15 and Table B-16 show the value and volume of landings for the WDA from 2008 to 2017. Bottom trawl is the primary gear type used in the WDA, where an estimated 57 percent of all revenue from the WDA and more than 65 percent of landed fish was caught using bottom trawl. Bottom trawl targets bluefish *(Pomatomus salatrix)*, monkfish, summer flounder, winter flounder (*Pseudopleuronectes americanus*), silver hake (*Merluccius bilinearis*), whiting, spiny dogfish (*Squalus acanthias*), smooth dogfish (*Mustelus canis*), scup, and black sea bass. The nearshore bottom-trawl fishery targets butterfish, bluefish, and other finfish species; the deeper water fisheries target bluefish, Atlantic mackerel, Loligo squid, black sea bass, and scup (NOAA 2019h). Other deployed gear types in the WDA include pot and sink gillnet. Pot targets crabs, lobsters, scup, and black sea bass. Sink gillnet targets species such as yellowtail flounder (*Limanda ferruginea),* winter flounder, witch flounder (*Glyptocephalus cynoglossus*), windowpane flounder (*Scophthalmus aquosus*), spiny dogfish, monkfish, silver hake, red hake (*Urophycis chuss*), white hake (*Urophycis tenuis*), skate, mackerel, and other.

Commercial fishing vessels homeported in Point Judith fish in the WDA most intensively. From 2008 to 2017, Point Judith fishing revenue from the WDA is estimated at $1.5 million with 1.4 million pounds of catch landed in the port (Table B-17 and Table B-18). Most of Point Judith fishing revenue is from squid, lobster, summer flounder, Atlantic sea scallop, scup, monkfish, silver hake, Jonah crab, and yellowtail flounder sales (NMFS 2018a). In fact, 53 percent of fishing revenue from the WDA is landed in Rhode Island, with 35 percent landed in Massachusetts, and the remaining landed in other states (Table B-19).



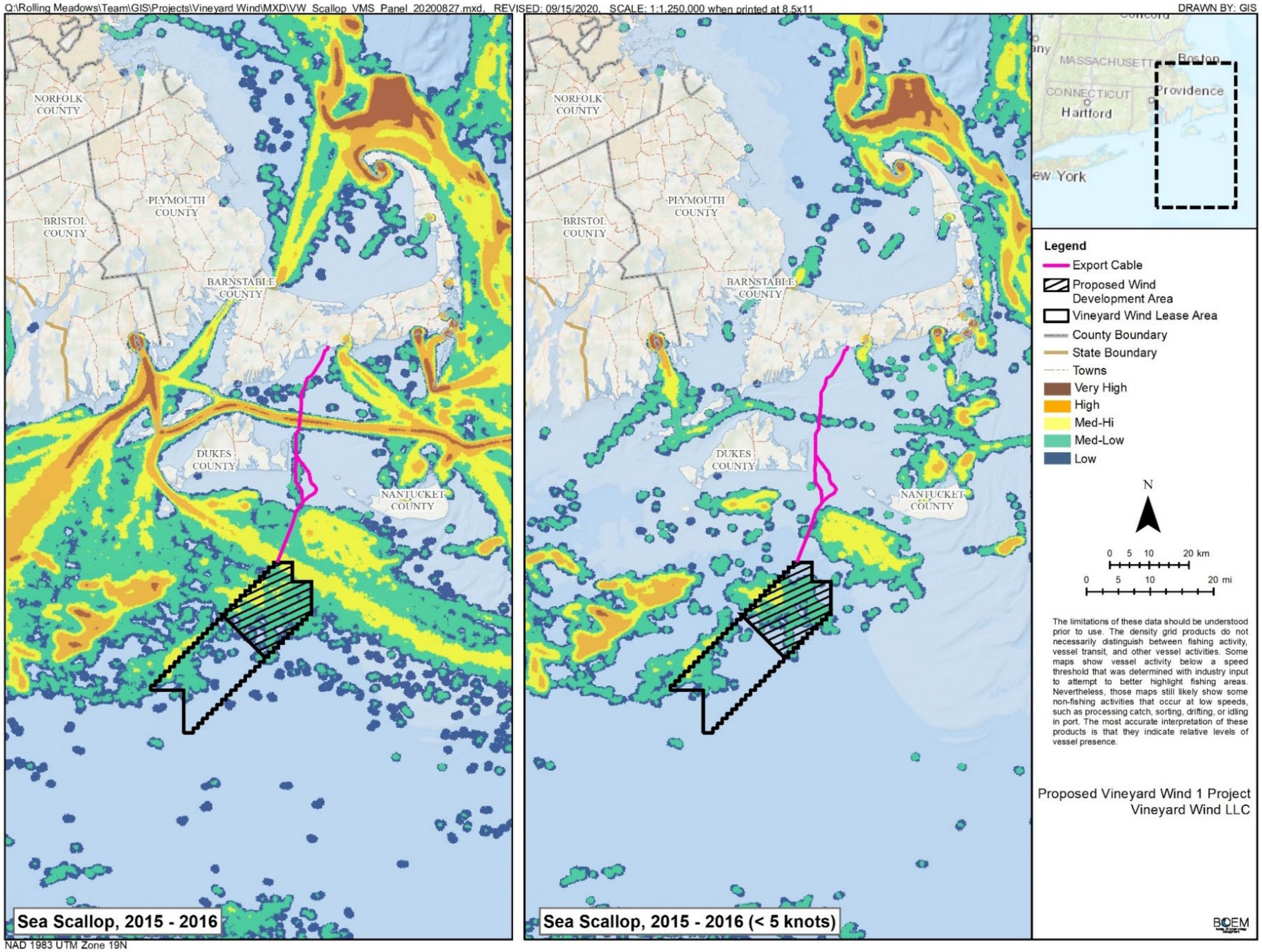
Source: Northeast Regional Ocean Council 2020

Figure B-12: Surf Clam/Ocean Quahog Fishing Vessel Density Based on Vessel Monitoring System Data (2015-2016)



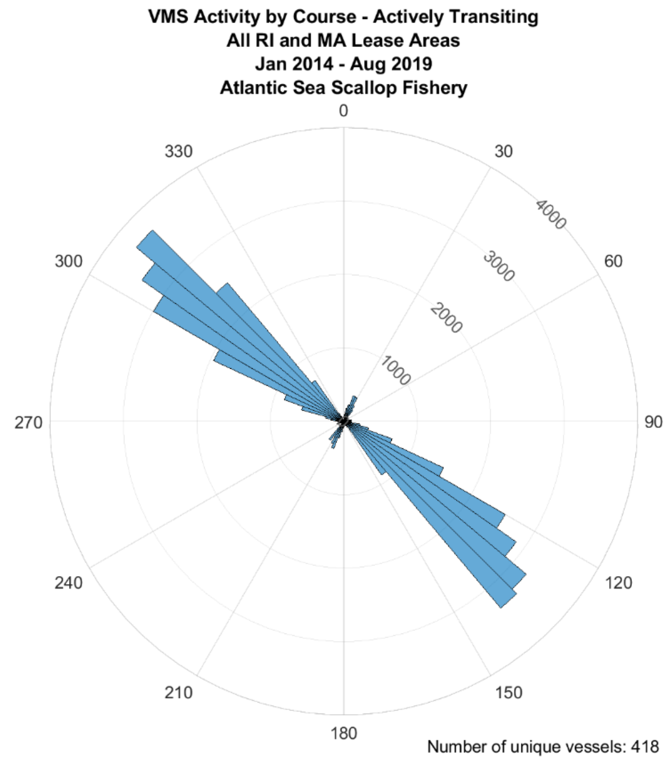
MA = Massachusetts; RI= Rhode Island; VMS = vessel monitoring system

Figure B-13: Surf Clam and Ocean Quahog Fishery in Rhode Island/Massachusetts Lease Areas—Transiting



Source: Northeast Regional Ocean Council 2020

Figure B-14: Sea Scallop Fishing Vessel Density Based on Vessel Monitoring System Data (2015–2016)



MA = Massachusetts; RI= Rhode Island; VMS = vessel monitoring system

Figure B-15: Sea Scallop Fishery in Rhode Island/Massachusetts Lease Areas—Transiting

It is more challenging to quantitatively characterize fishing along the OECC because it is a linear feature. In addition, fewer impacts are expected along the OECC due to the relatively narrow area potentially disturbed. As shown on Figures B-8, B-12, and B-14, the OECC intersects areas with high vessel density for fishermen targeting squid, surf clams/ocean quahogs, and Atlantic sea scallops. In addition, as shown on Figure B-16, part of the OECC within state waters intersects an area of "high commercial fishing effort and value" identified in the Massachusetts Ocean Management Plan (EEA 2015). There is also low, medium-low to medium-high vessel density along the OECC, whereas vessel density in the WDA is characterized as low (Figures B-17 and B-18).

The Massachusetts Division of Marine Fisheries Draft Environmental Impact Report indicates that the OECC would pass through areas of commercial and recreational fishing and habitat for a variety of invertebrate and finfish species, including channeled whelk (*Busycotypus canaliculatus*), knobbed whelk (*Busycon carica*), longfin squid (*Doryteuthis pealeii*), summer flounder, windowpane flounder, scup, surf clam, Atlantic sea scallop, quahog, Atlantic horseshoe crabs (*Limulus polyphemus*), and blue mussel (*Mytilus edulis*) (Epsilon 2018).

Blue mussel and kelp aquaculture operations are also located within Horseshoe Shoals (a subtidal area of Nantucket Sound) (Epsilon 2018). Existing aquaculture operations lie near the southern portion of Horseshoe Shoals, near the Main Channel of Nantucket Sound. However, this is more than 4 nautical miles (4.6 miles) from the OECC. The proposed Project is not anticipated to affect leased aquaculture sites.

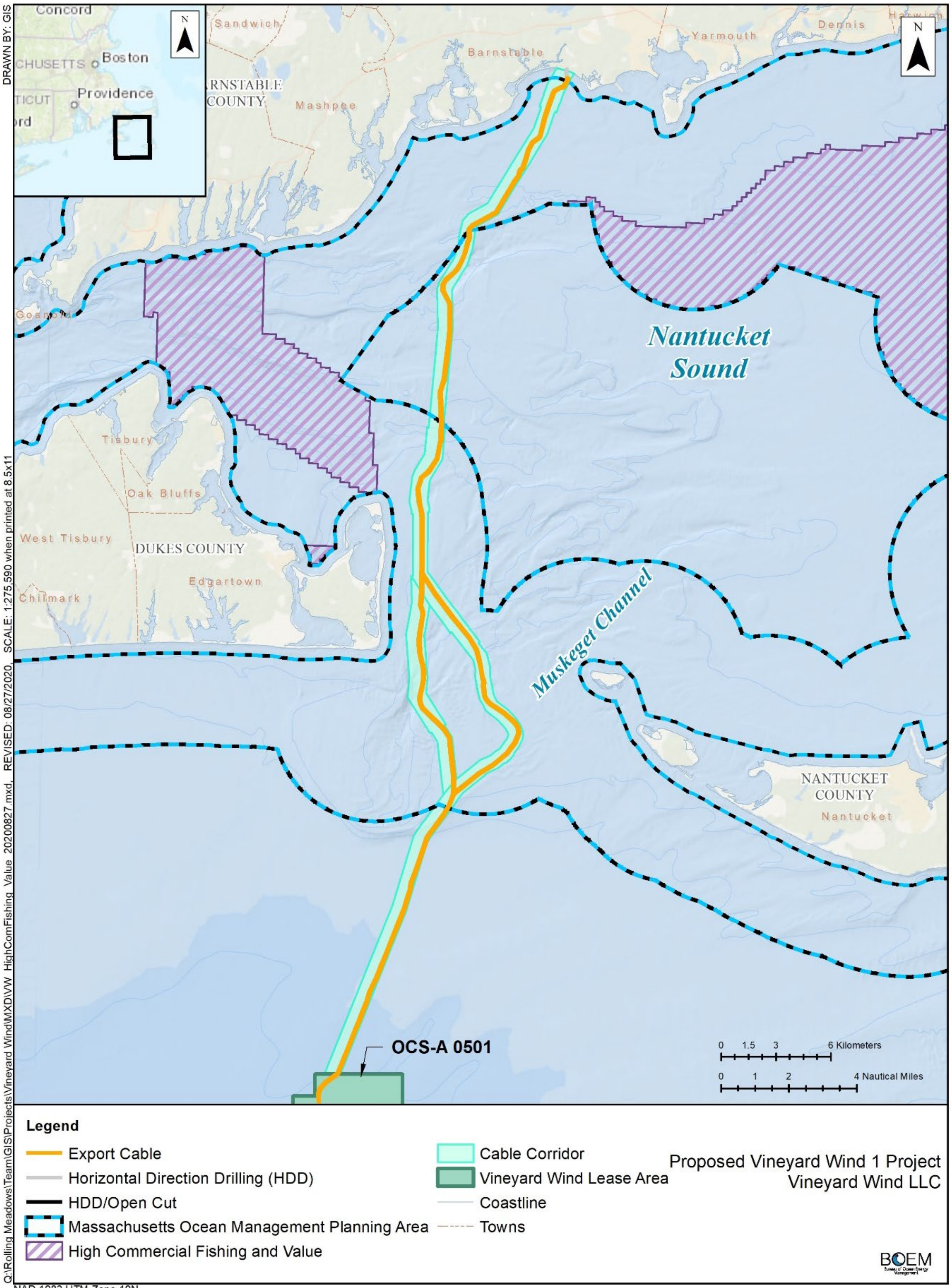
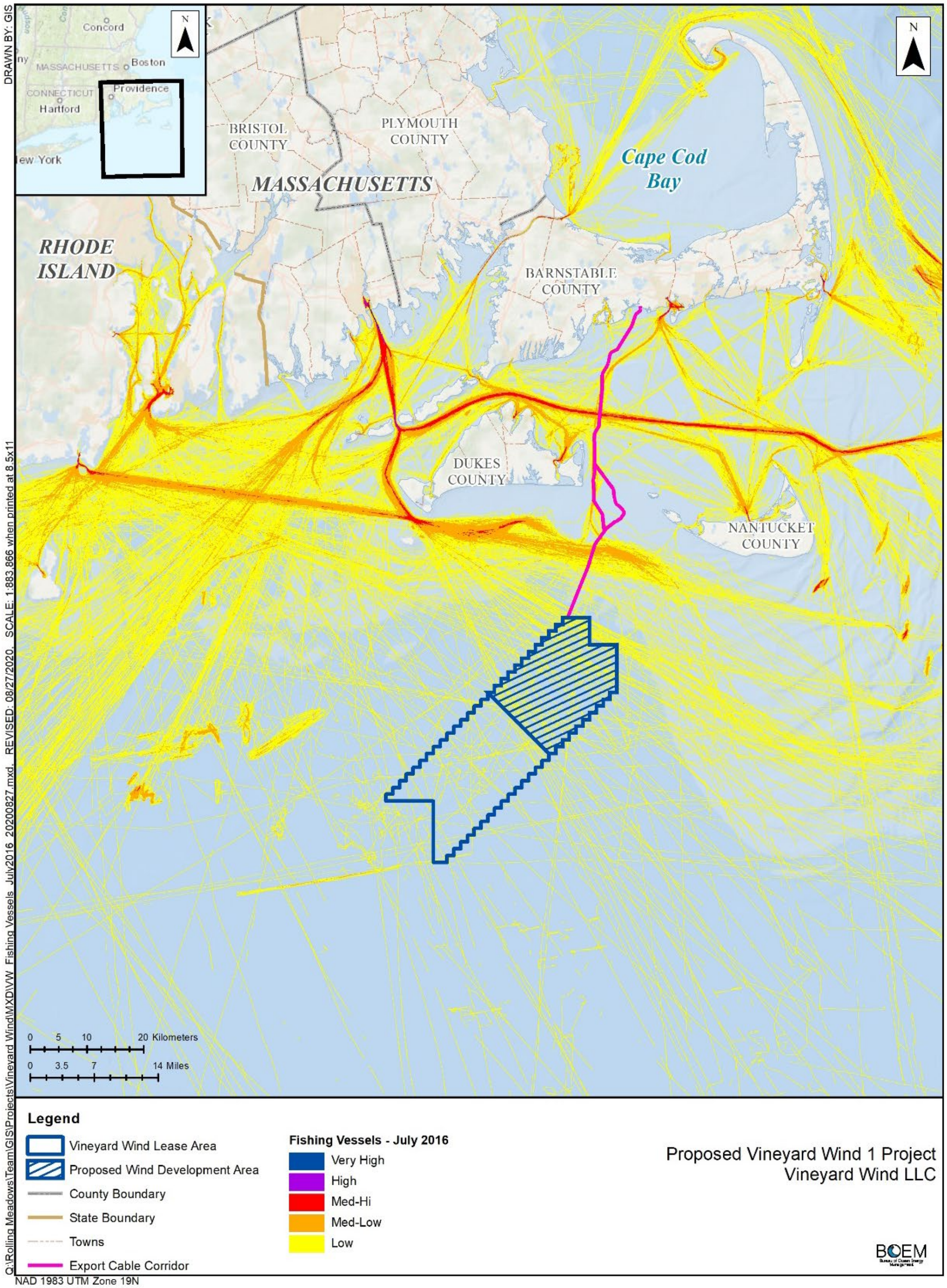
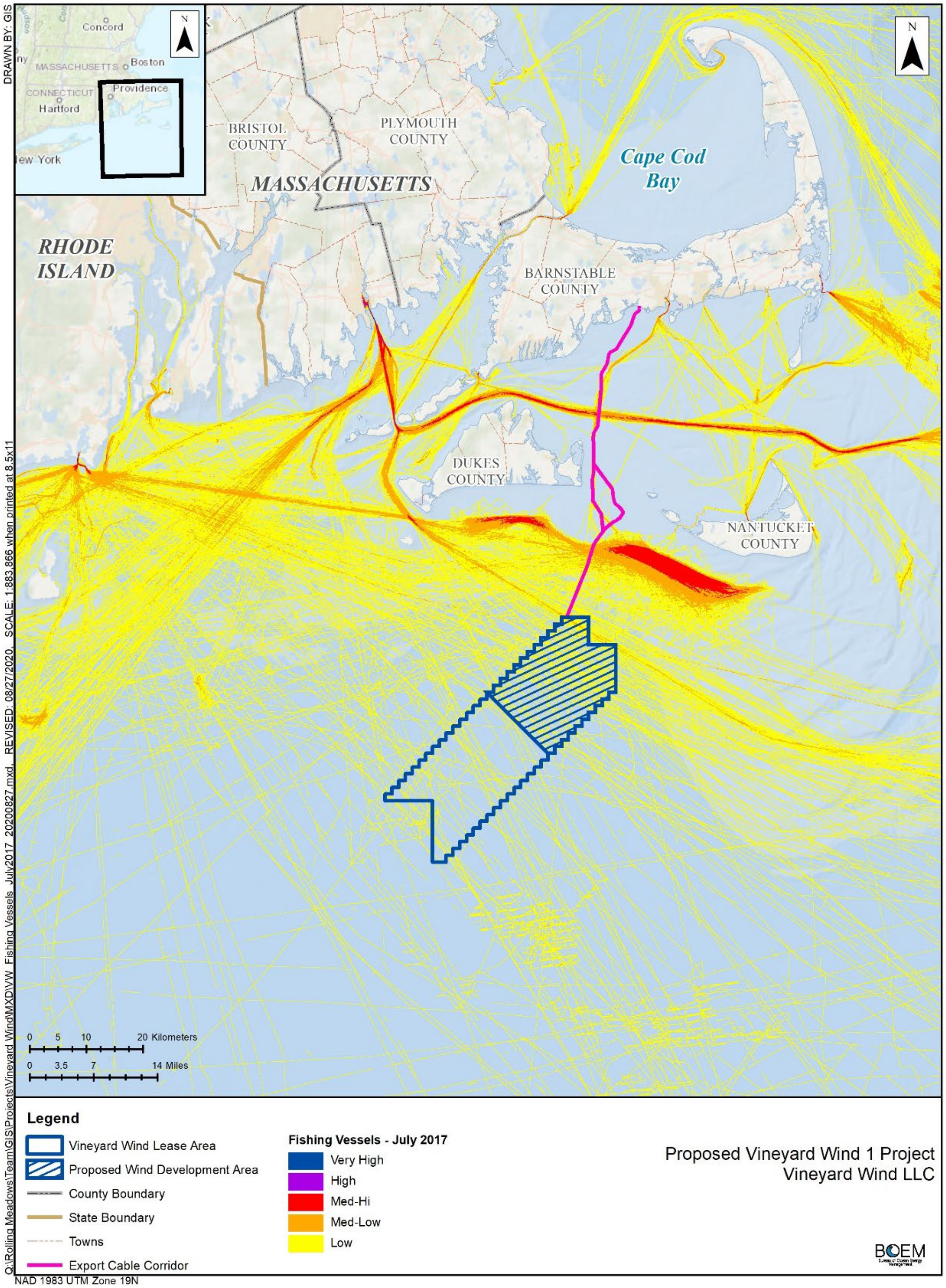


Figure B-16: Massachusetts Ocean Management Plan Areas of High Commercial Fishing Effort and Value



Source: Northeast Regional Ocean Council 2020

Figure B-17: Fishing Monthly Vessel Transit Counts from July 2016 Automatic Identification System Northeast and Mid-Atlantic



Source: Northeast Regional Ocean Council 2020

Figure B-18: Fishing Monthly Vessel Transit Counts from July 2017 Automatic Identification System Northeast and Mid-Atlantic

Fishing for whelk, often referred to locally as conch, is done from Horseshoe Shoals and other areas in Nantucket Sound. This fishery was valued at $4.8 million in 2016. Although this is a relatively new fishery that was not heavily exploited until the early 2010s, signs indicate that the stocks are vulnerable to overfishing and may already be overfished. This fishery operates entirely within state waters, with a plurality of the total catch taken from Nantucket Sound (Nelson et al. 2018). Again, because of the distance from the OECC, proposed Project activities are not expected to affect this fishery.

The lobster fishery in Massachusetts is the most lucrative fishery harvested within the state's waters, but it is now in a depleted condition (Dean 2010; MA DMF 2017). Despite the reduced landings (17.6 million pounds in 2016), rising prices bolster the fishery's value, which was more than $82 million in 2017 (MA DMF 2017). Recently, there has been very little lobster catch from nearshore waters south of Cape Cod; therefore, most vessels from this area now venture far offshore to target lobster in deeper waters (Abel 2017; Dean 2010; MA DMF 2017).

Atlantic horseshoe crab spawning areas are associated with Covell's Beach and Great Island Beach (Epsilon 2018). This fishery, while significant to the state, is patchy and variable from year-to-year. Most of the catch comes from Cape Cod Bay, Nantucket Sound, and near the islands of Nantucket and Martha's Vineyard (Burns 2018; Perry 2017). Surf clam habitat and patchy eelgrass beds also occur in waters offshore of Covell's Beach. For-hire recreational fishing is also an important economic sector regionally with peak activity June through August (NOAA 2017b). Regionally in 2015, the industry created 2,232 jobs, generated $326 million in sales, and contributed $192 million in value added. The Marine Recreational Information Program data show that mackerels, cod, and striped bass (*Morone saxatilis*) were the most-caught species within the Massachusetts for-hire recreational fishery. Black sea bass, scup, striped bass, summer flounder, and tautog (*Tautoga onitis*) were the most-caught species within the Rhode Island for-hire recreational fishery (NOAA 2017c).

In 2018, there were 129,862 party- and charter-boat fishing trips out of Massachusetts and 42,558 out of Rhode Island. However, there is substantial variability year-to-year with as few as 95,000 trips in 2016 and as many as 224,249 trips in 2017 from Massachusetts. Based on the number of trips over the past 10 years, there are, on average, 188,916 party- and charter-boat fishing trips per year out of Massachusetts and 45,648 out of Rhode Island (NOAA 2020b). On average, party and charter boats account for 5 percent of all recreational effort onboard boats off the coast of Massachusetts and 4 percent off the coast of Rhode Island based on the Fishery Effort Survey (NOAA 2020b). NOAA estimated that 97 percent of the 2011 recreational effort from Massachusetts occurred within 3 nautical miles (3.5 miles) of shore (BOEM 2012).

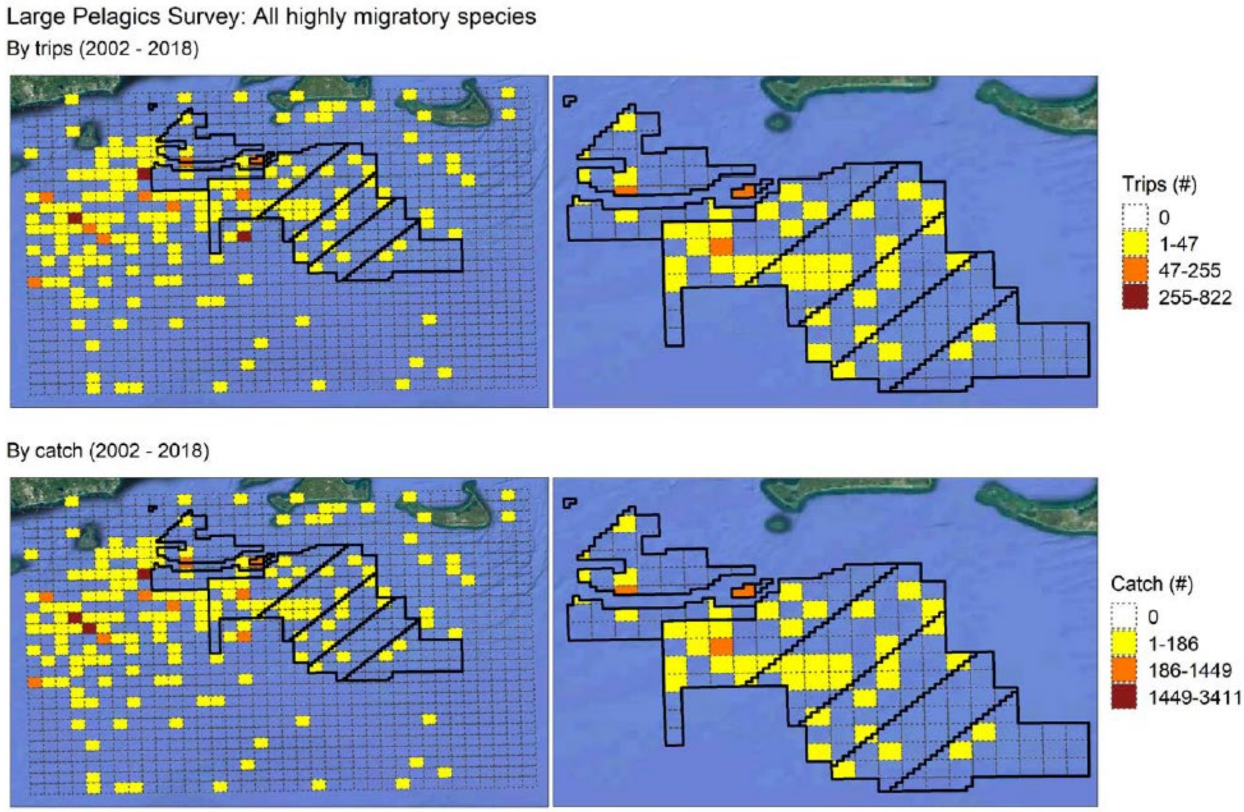
For-hire recreational fishing in the Atlantic provides opportunities for recreational fishing of highly migratory species such as tuna, billfish, swordfish (*Xiphias gladius*), and sharks. Tuna and sharks are found in the WDA where they feed on squid, mackerel, and butterfish found in the area. Tuna and sharks are targeted in the WDA by for-hire fishing boats. Highly migratory species such as tuna and shark are relatively costly to pursue for private anglers, as they require large vessels.

Popular recreational fishing areas across the RI/MA Lease Areas include "The Dump," where recreational vessels harvest Atlantic yellowfin tuna (*Thunnus albacares*), albacore tuna (*Thunnus alalunga*), and mahi-mahi (*Coryphaena hippurus*). Other nearby recreational fishing locations include "The Owl" and the "The Star." "Gordon's Gully" is the only named recreational fishing location within the WDA. "31 Fathom Hole" and the northeast corner of the Dump are wholly and partially in the New England Wind lease area (Figure 3.9-3 in EIS Section 3.9). Species caught by recreational vessels in these areas include bluefin tuna (*Thunnus thynnus)*, shortfin mako shark (*Isurus oxyrinchus*), common thresher sharks (*Alopias vulpinus)*, white marlin (*Kajikia albida*), and Atlantic yellowfin tuna. Along the OECC, harvested species often include striped bass, bluefish, bonito, false albacore (*Euthynnus alletteratus*), and bluefin tuna, as well as summer flounder, black sea bass, and scup (Epsilon 2020). In general, for-hire recreational fishing boats from the Massachusetts area most often catch cod, hake, striped bass, and mackerel (Epsilon 2020).

Figure B-19 shows areas of high recreational fishing (both for-hire and private angler recreational fishing) effort (i.e., number of trips and total catch) for highly migratory species throughout the southern New England region from 2002 to 2018 (Kneebone and Capizzano 2020). Based on the interpolation of trips and catch as reported in the Large Pelagics Intercept Survey, generally, the greatest amount of recreational fishing effort for highly migratory species occurred west of the RI/MA Lease Areas in the waters south and east of Montauk Point and Block Island. Within the RI/MA Lease Areas, a large amount of fishing effort for all highly migratory species occurred in “The Dump,” “Coxes Ledge,” “The Fingers,” and “The Claw.” Fifty-eight members of the Rhode Island Party and Charter Boat Association stated that they fish in the WDA area, particularly Gordon’s Gully for tuna and shark. The Star, The Claw, and the Fingers (inside) are also in proximity. The members are worried that once the proposed Project is in place, shark and tuna would no longer be found there, which could be harmful for business. Tuna and sharks are found in the WDA because they feed on squid, mackerel, and butterfish. If those species are affected, tuna and shark may also leave the WDA. Finding alternative fishing spots could be challenging, as it is uncertain where the species may relocate.

The highest density of recreational vessels is reported within Nantucket Sound and within 1 nautical mile (1.15 mile) of the coastline (Epsilon 2020). Table B-25 shows the average annual number of for-hire recreational boat trips by port group based on federally reported VTRs that come within 1 nautical mile (1.15 mile) of the RI/MA Lease Areas. NOAA NEFSC found only about 0.2 percent of for-hire boat trips and 0.325 percent of for-hire boat trips from Massachusetts, New Hampshire, New York, and Rhode Island were near the Massachusetts Wind Energy Area (i.e., BOEM lease areas OCS-A 0500, OCS-A 0501, OCS-A 0520, OCS-A 0521, and OCS-A 0522) (Kirkpatrick et al. 2017). Also, on average, more for-hire recreational fishing trips to the RI/MA Lease Areas originate from Montauk, New York, than any other port or state.

There is substantial variability in the volume and value landed of various species fished within the WDA. For example, as stated in Table B-11, surf clam/ocean quahog harvested from within the WDA was valued at $6,111 to $327,689, depending on the year. Similarly, Atlantic Mackerel, Squid, and Butterfish FMP from within the WDA varied from $11,390 to $978,455 per year. In general, based on catch data for the last decade, the total annual revenue from landings within the WDA usually varied from about $300,000 to $600,000 but peaked in 2016 at a high of $1.3 million. Year-to-year variation in available catch and fishing effort, as well as quotas set for commercial and recreational fisheries to protect stocks and prevent overfishing, introduce significant fluctuations in how much is landed every year from within the WDA, the Massachusetts Wind Energy Area, and other locations. As a result, it is challenging to predict what the commercial fishing revenue from specific fishing areas, such as the RI/MA Lease Areas, would look like going forward. However, the activity and value of fisheries in recent years, as described in the previous sections, are expected to be indicative of future conditions and trends.



Source: Kneebone and Capizzano 2020

Figure B-19: Recreational Fishing Effort for Highly Migratory Species over the Southern New England Grid (left) and Rhode Island/Massachusetts Lease Areas (right), 2002–2018

Table B-25: Average Annual For-Hire Recreational Trips Within 1 Mile of Rhode Island/Massachusetts Lease Areas, 2007–2012

Port Group	Exposed For-Hire Boat Trips
Barnstable, Massachusetts	2
Falmouth, Massachusetts	1
Nantucket, Massachusetts	1
Oak Bluffs, Massachusetts	1
Onset, Massachusetts	1
Tisbury, Massachusetts	~0
Montauk, New York	16
Narragansett, Rhode Island	8
South Kingstown, Rhode Island	2
Westerly, Rhode Island	1

Source: Kirkpatrick et al. 2017

B.3 Potential Impacts on Scientific Research and Surveys

The analysis in this section is reprinted from the Final EIS for the Vineyard Wind 1 Project (BOEM 2021) and reflects input from NOAA and other agencies that occurred as part of the Vineyard Wind 1 Project. While more recent data may be available, the Vineyard Wind 1 information remains valid to broadly characterize and support the analysis of the New England Wind Project's impacts on scientific research and surveys in EIS Section 3.14, Other Uses (National Security and Military Use, Aviation and Air Traffic, Offshore Cables and Pipelines, Radar Systems, Scientific Research and Surveys, and Marine Minerals).

Research activities may continue within the Vineyard Wind 1 WDA during construction, as permissible by survey operators and boat captains. Vineyard Wind 1 would impact survey operations by excluding certain areas within the WDA occupied by project components (e.g., WTG foundations, cable routes) from potential sampling and by impacting survey gear performance, efficiency, and availability. Agencies would need to expend resources to update scientific survey methodologies due to construction and operations of Vineyard Wind 1, as well as to evaluate these changes on stock assessments and fisheries management. NOAA's Office of Marine and Aviation Operations determined that the NOAA ship fleet will not operate in wind facilities with 1 nautical mile (1.15 mile) or less separation between turbine foundations.

The following provides NOAA's evaluation of the potential impacts on these survey operations based on likely foreseeable actions, including the WDA and all other existing federal lease areas from Maine to mid-North Carolina.

Fish and shellfish research programs: Randomized station selection methodologies that are employed by most of the shipboard scientific fish and shellfish surveys would not be applied in wind energy areas. Loss of survey areas would increase the uncertainty in estimates of fish and shellfish stock abundances and oceanographic parameters. If abundances, distributions, biological rates, or environmental parameters differ inside versus outside wind energy areas but cannot be observed, resulting survey indices could be biased and unsuitable for monitoring stock status. Similarly, resulting regional oceanographic time series could also be biased. A broad analysis for the NMFS bottom-trawl surveys that considered current and planned wind areas found that 9 out of 14 offshore strata that contribute most of the area sampled in the southern New England Mid-Atlantic region would likely be affected. Strata for fish and shellfish surveys are defined based on depth and alongshore features to delineate areas of relatively homogeneous species distributions. Random sampling within a stratum is a key attribute of statistical performance of these and many other typical survey designs.

The Vineyard Wind 1 lease area alone overlaps strata associated with three different coast-wide NEFSC fishery resource monitoring surveys. For the spring and fall multi-species bottom-trawl surveys, 6 percent of the area in one stratum would be within the Vineyard Wind 1 lease area. For the ocean quahog survey, 3 percent of the area in one stratum would be within the lease area. As a result, Alternative A would result in major impacts on NOAA's scientific surveys.

The impacts of other offshore wind projects would be similar, over an extended area. For the spring and fall multi-species bottom-trawl surveys, 16 of the southern New England Mid-Atlantic strata would be affected, although overlap is less than 1 percent in 2 strata. Between 3 and 60 percent of each remaining 14 stratum's area would be covered by offshore wind lease areas, including Vineyard Wind 1. The percent of area made unavailable would be higher in inshore strata (mean of 18 percent) than offshore strata (mean of 11 percent). Of the 14 offshore strata that contribute most of the area surveyed in the region, 9 are affected. In the case of offshore stratum 9, for example, which includes Vineyard Wind 1 and contiguous lease areas, up to 37 percent of the area could be unsampleable. For the integrated benthic/Atlantic sea scallop survey, four routinely sampled strata would likely be affected, with 3 to

12 percent of the stratum areas potentially unsampleable. For another two strata that are intermittently dredge sampled through the Virginia Institute of Marine Science Research Set Aside program, 21 to 56 percent of the area within those two strata would potentially be unsampleable. For the ocean quahog survey, 4 of 12 strata would include offshore wind lease areas, with 3 to 19 percent of the stratum areas potentially unsampleable. For the surf clam survey, 3 of 12 survey strata would include offshore wind lease areas, with 7 to 14 percent of the stratum areas potentially unsampleable. Low percentage overlaps for these two shellfish surveys may still have substantial impacts because there are only a few large strata in both surveys. Areas occupied by OECCs, which could not be trawled or dredged, are not included in these estimates. In summary, depending on the survey, up to 33 percent of strata within a survey would potentially be affected, and up to 60 percent of a single stratum within a survey would potentially be affected.

As noted above, removing survey effort to remaining areas that can be sampled would not mitigate the impacts. Without new alternative sampling methods and statistical designs, relocation of survey efforts would affect sampling accuracy. In addition, impacts could extend to operations outside wind energy areas, decreasing remaining survey precision. Based on layout and spacing of WTGs and current survey vessel operation policies, NMFS-supported vessels would not transit through wind energy lease areas. Alteration of survey vessel routes and resultant increased travel times would reduce survey productivity and precision.

Protected species (cetaceans, sea turtles, and pinnipeds) research programs: Aerial survey track lines at the altitude used in current cetacean and sea turtle abundance surveys (600 feet above mean sea level [AMSL]) could not occur in offshore wind areas because the planned maximum-case scenario WTG blade tip height (837 feet AMSL for Vineyard Wind 1 and 853 feet AMSL for other projects) would exceed the survey altitude with current surveying methodologies. The increased altitude necessary for safe survey operations could result in lower chances of detecting marine mammals and sea turtles, especially smaller species. At a minimum, NOAA Office of Marine and Aviation Operations pilots maintain a safe distance of at least 500 vertical feet from structures and hazards. The RI/MA Lease Areas comprise less than 1.5 percent of the aerial survey stratum, although the visual aerial abundance surveys for this stratum contributes to the estimates of 30 or more stocks of cetaceans and sea turtles. Thus, if animal distribution is not affected by offshore wind activities and NMFS surveys do not include these areas, the reduction in survey stratum area would have a minimal impact on abundance estimates for protected species. Impacts would be more substantial if the distribution and/or abundance within the RI/MA Lease Areas was different than the surrounding areas that continue to be surveyed.

Considerable survey efforts have been underway for years using digital aerial surveys for protected species in offshore wind areas. NMFS has begun investigating whether photographic abundance/monitoring surveys flown at a higher altitude are practical, reliable, and result in appropriately accurate and precise distribution and abundance estimates. More work is needed to confirm whether higher-altitude photographic survey methods are appropriate for abundance and monitoring surveys for all cetaceans, sea turtles, and pinnipeds.

A recent study found that the seven contiguous lease areas offshore Massachusetts and Rhode Island encompass important habitat that is utilized by NARWs (Leiter et al. 2017). Over one third of the current population, including up to 30 percent of known calving females, visited the RI/MA Lease Areas between 2010 and 2015. NMFS uses aerial surveys to collect photographs of the NARWs and other species to estimate abundance and monitor the health and status of individuals and populations. Shipboard surveys and small boat work also collect detailed data on NARWs, including photographs and drone images, biopsy samples, fecal samples, acoustic recordings, and other data types. Prey sampling in the vicinity of NARWs and in areas where they are not aggregating is being used to better characterize the habitat drivers behind their distribution. Finally, passive acoustic technology is used to monitor the presence of vocally active NARWs and other endangered large whale species throughout sites along the U.S. East Coast.

Development of offshore wind in the RI/MA Lease Areas would impact approximately 60 percent of the NARW aerial survey blocks in the area. NARW aerial surveys are currently conducted at 1,000 feet AMSL but would need to be conducted at higher altitudes to provide safety margins, as discussed above. The inability to continue flights at current altitudes (600 or 1,000 feet AMSL) over offshore wind areas would have a significant impact on the ability to use current data collection techniques to monitor the distribution and abundance of marine mammals and sea turtles that may be caused by or are related to offshore wind. Alternative techniques to monitor these species could include high-altitude photographic surveys, passive acoustic monitoring (PAM), and data collection on small vessels (including those used by the industry) that can safely navigate within the WTGs.

The inability to implement shipboard surveys in current NARW habitat in offshore wind areas could significantly affect NMFS' ability to monitor the health, status, and behavior of individuals within this region, as well as NMFS' ability to monitor changes in prey distribution and other factors affecting NARW habitat use. With the operational restrictions on NOAA vessels entering developed lease areas, surveys within WDAs would necessarily require wind development-compatible vessels and equipment, which could lead to changes in survey methodology, available tools, and appropriate staffing of shipboard fieldwork. This would lead to less effective and efficient on-water data collection. Finally, the impact of collecting passive acoustic data in the region once offshore wind projects are developed is unknown. The use of autonomous vehicles, such as gliders, has been an important component in NMFS' near-real-time monitoring of NARW distribution, and the use of archival recorders has been important for documenting habitat use over time. It is unclear how this would change after the installation of WTGs, whether these data collection methodologies would still be feasible in these areas and how noise from operations (i.e., construction or vessel noise from long-term turbine maintenance) would affect NMFS' ability to continue to acoustically detect animals reliably. In summary, additional work is needed to develop and implement appropriate strategies to collect, analyze, interpret, and share data to monitor the impacts of wind energy activities on all protected species.

Significant resources would be required to quantify and account for the complexity and scope of impacts on NMFS core scientific surveys and the management advice that relies on these surveys and implement necessary survey adaptations. Potential challenges would include identification of appropriate sampling protocols and technology, development and parameterization of new statistical survey models, and calibration of new approaches to existing ones in order to continue to sample within areas occupied by turbine foundations and submarine cables. Preliminary analyses of the impacts on survey areal coverage shows substantial impacts on NMFS' ability to continue using current methods to fulfill its mission of precisely and accurately assessing fish and shellfish stocks for the purpose of fisheries management and assessing protected species for the purpose of protected species management. Changes to protected species survey methodologies could introduce biases or inaccuracies that could impact marine mammal abundance estimates and dedicated NARW studies. These changes could result in management implications for NARW and other protected species, as well as fisheries and shipping industries that impact these species. Similarly, changes to existing survey methodologies or disruption to the long-term survey time series of fish and shellfish would have implications for stock assessments by increasing uncertainty in biomass estimates and other parameters used in projecting fishery quotas. Uncertainty in estimating fishery quotas could lead to unintentional underharvest or overharvest of individual fish stocks, which could have both beneficial and adverse impacts on fish stocks, respectively. Based on existing regional Fishery Management Councils' acceptable biological catch control rule processes and risk policies (e.g., 50 CFR §§ 648.20 and 21), increased assessment uncertainty would likely result in lower commercial quotas that may reduce the likelihood of overharvesting and mitigate associated biological impacts on fish stocks. However, such lower quotas would result in lower associated fishing revenue that would vary by species, which could result in impacts on fishing communities. Development of new survey technologies, changes in survey methodologies, and required calibrations could help to mitigate losses in accuracy and precision of current practices due to the impacts of wind development on survey strata. Until a plan is established to holistically mitigate impacts on NMFS core surveys, information generated from project-specific monitoring plans may be necessary to supplement or complement existing survey data. Such monitoring plans must be developed in a comprehensive and integrated manner consistent with NOAA and NMFS' long-standing surveys. To address this need, these fisheries monitoring plans should be developed collaboratively with NOAA and NMFS and incorporate NMFS survey standards and requirements to ensure collected data is usable. BOEM will continue to work with the NMFS in regard to survey guidelines and update guidelines as appropriate to reflect standard data collection protocols and methodologies.

Federal Survey Mitigation Program: To address Vineyard Wind 1's impacts on NMFS trust responsibilities under the Magnuson-Stevens Fishery Conservation and Management Act, ESA, and Marine Mammal Protection Act, NMFS, in partnership with BOEM, is considering a mitigation program to establish resources for the NMFS NEFSC to design and implement effective survey adaptations. The intent of this mitigation program would be to minimize or avoid impacts from Vineyard Wind 1. If successful, this mitigation program could potentially be applied to future offshore wind projects. Specifically, NMFS recommends implementation of a mitigation program that includes the specific elements listed below to address Vineyard Wind 1's impacts on the multi-species bottom-trawl surveys, Atlantic scallop surveys, ocean quahog and Atlantic surf clam surveys, ecosystem monitoring surveys, marine mammal and sea turtle ship-based and aerial surveys, and NARW aerial surveys. While this mitigation is focused on Vineyard Wind 1, impacts from future offshore wind projects on NOAA scientific surveys would be mitigated through future coordination between BOEM and NOAA, as well as measures included in future National Environmental Policy Act analyses. These analyses would include consideration of the following mitigation measures as they apply to impacts from future projects:

- Evaluate survey designs—Evaluate and quantify Vineyard Wind 1's impacts on the listed scientific survey operations and on provision of scientific advice to management.
- Identify and develop new survey approaches—Evaluate or develop appropriate statistical designs, sampling protocols, and methods while determining if scientific data quality standards for the provision of management advice are maintained.
- Calibrate new survey approaches—Design and carry out necessary calibrations and required monitoring standardization to ensure continuity, interoperability, precision, and accuracy of data collections.
- Develop interim provisional survey indices—Develop interim ad hoc indices from existing non-standard data sets to partially bridge the gap in data quality and availability between pre-construction and operational periods while new approaches are being identified, tested, or calibrated.
- Wind energy monitoring to fill regional scientific survey data needs—Apply new statistical designs and carry out sampling methods to mitigate Vineyard Wind 1's survey impacts over the operational life span of Vineyard Wind 1.
- Develop and communicate new regional data streams—New data streams would require new data collection, analysis, management, dissemination, and reporting systems. Changes to surveys and new approaches would require substantial collaboration with fishery management, fishing industry, scientific institutions, and other partners.

The research and surveys listed above are a subset of all scientific research and surveys that may be executed in the geographic analysis area. Other scientific research surveys utilizing fixed data recorders, automated underwater vehicles, and small vessel research platforms may not be similarly impacted. There are currently no federal requirements to monitor or research construction and operations of offshore wind projects or for advancing new survey technologies. BOEM will continue to work with survey operators to better define and understand these impacts, including whether effective mitigation options could be available to compensate for the potential loss of some scientific surveys. Construction and decommissioning of Alternative A could lead to increased opportunities to study impacts of construction and operations of the offshore components, perform other oceanographic research, and develop or adapt new approaches to research including, but not limited to, use of unmanned aerial vehicles or vessels and remote sensing and digital technologies. Operations activities may present an opportunity to collaborate with researchers on data collection, thus potentially reducing survey costs. NOAA's Uncrewed Systems Strategy (NOAA 2020c), which aligns with the Commercial Engagement Through Technology Act of 2018 (Public Law 115-394), is intended to "directly improve the understanding, coordination, awareness and application of [unmanned systems]." In addition, sampling, monitoring, and/or research contributions from the offshore wind industry and other non-NOAA stakeholders (e.g., other federal or military agencies, industry partners, and academia) could play a key role in development of innovative approaches that would enable to scientific research and surveys to continue in offshore wind development areas. These approaches and opportunities help inform certain types of scientific research and surveys in the long term, but Alternative A would still have major impacts on existing NMFS scientific research and surveys conducted in and around the WDA because long-standing surveys would not be able to continue as currently designed, and extensive costs and efforts would be required to adjust survey approaches, potentially leading to impacts on fishery participants and communities (EIS Sections 3.6, Finfish, Invertebrates, and Essential Fish Habitat, and 3.10, Cultural Resources), as well as potential major impacts on monitoring and assessment activities associated with recovery and conservation programs for protected species. The loss of precision and accuracy would be a significant hurdle, as new data collection methods are tested and become usable and robust over time. Implementing mitigation measures, including the development of survey adaptation plans, standardization and calibration of sampling methods, and annual data collections following new designs and methods, would help reduce uncertainty in survey data and associated assessment results and increase the utility of additional data collected as part of any required project-specific monitoring plan.

In context of planned environmental trends, the impacts associated with ongoing and planned activities, including Alternative A, would have major impacts on NMFS' scientific research and surveys and the resulting stock assessments, which could lead to potential beneficial and adverse impacts on fish stocks when management decisions are based on biased or imprecise estimates of stock status. Alternative A would contribute to the overall impact rating primarily through placement of structures in the long term within the WDA that pose navigational hazards to survey aircraft and vessels and restrict access to survey locations, thus impacting statistical design of surveys and causing a loss of information within the wind development areas as previously described. Alternative A impacts are similar to those of other planned offshore wind development, but impacts would be spread across the RI/MA Lease Areas, affecting additional survey strata and survey areas. In context of planned environmental trends, the overall impacts on scientific research and surveys from ongoing and planned activities, including Alternative A, would qualify as major because entities conducting surveys and scientific research would have to make significant investments to change methodologies to account for unsampleable areas, with potential long-term and irreversible impacts on fisheries, the commercial fisheries community, protected species research, and programs for the conservation and management/recovery of fishery resources and protected species. While new research approaches and technologies may lessen impacts on scientific research and surveys in the long term, their results and applicability specific to the impacted NOAA and NMFS surveys are not planned at this time.

B.4 Background on Underwater Sound

B.4.1 Sources of Underwater Sound

Ocean sounds originate from a variety of sources. Some come from non-biological sources such as wind and waves, while others come from the movements or vocalizations of marine life (Hildebrand 2009). In addition, humans introduce sound into the marine environment through activities like oil and gas exploration, construction, military sonars, and vessel traffic (Hildebrand 2009). The acoustic environment or "soundscape" of a given ecosystem comprises all such sounds—biological, geophysical, and anthropogenic (Pijanowski et al. 2011). Soundscapes are highly variable across space, time, and water depth, among other factors, due to the properties of sound transmission and the types of sound sources present in each area. A soundscape is sometimes called the "acoustic habitat," as it can be a vital attribute of a given area where an animal may live (i.e., habitat) (Hatch et al. 2016).

B.4.2 Physics of Underwater Sound

Sounds are created by the vibration of an object within its medium (Figure B-20). When the object's vibration is coupled to the medium (e.g., water, in the case of underwater sound), that vibration travels as a propagating wave away from the sound source (Figure B-20). As this wave moves through the water, the water particles undergo tiny back-and-forth movements (i.e., particle motion), essentially oscillating in roughly the same location. When the particle motion results in more particles in one location (depicted as the area of compression on Figure B-20), that location has relatively higher pressure. Particles are then accelerated away from the higher-pressure region, causing the particles to transfer their energy to surrounding particles and propagating the wave. Acoustic pressure is a non-directional (scalar) quantity, whereas particle motion is an inherently directional quantity (a vector). The total energy of the sound wave includes the potential energy associated with the sound pressure, as well as the kinetic energy from particle motion.

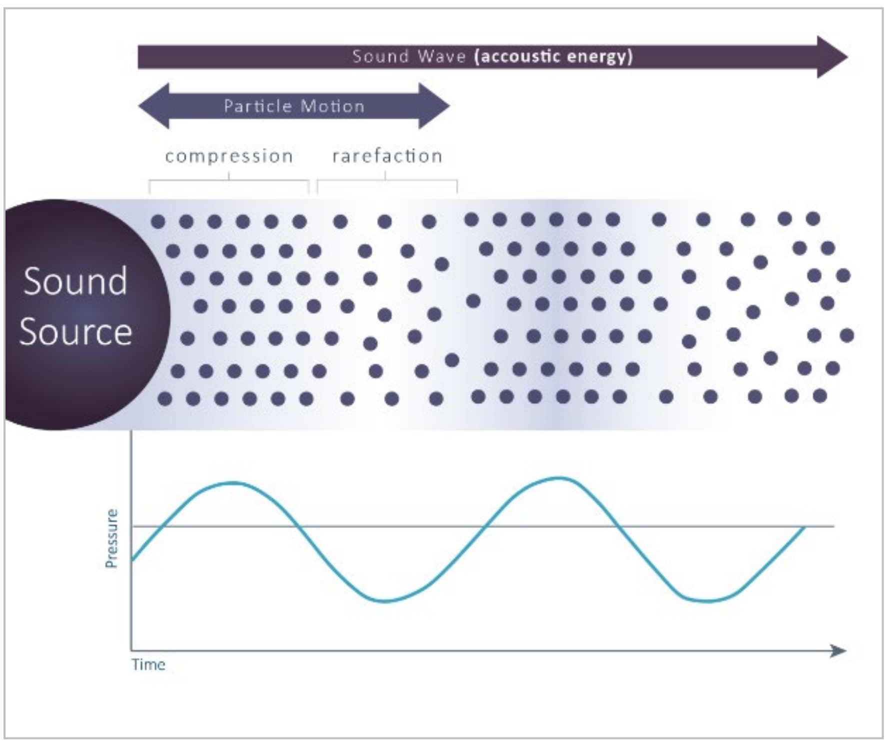
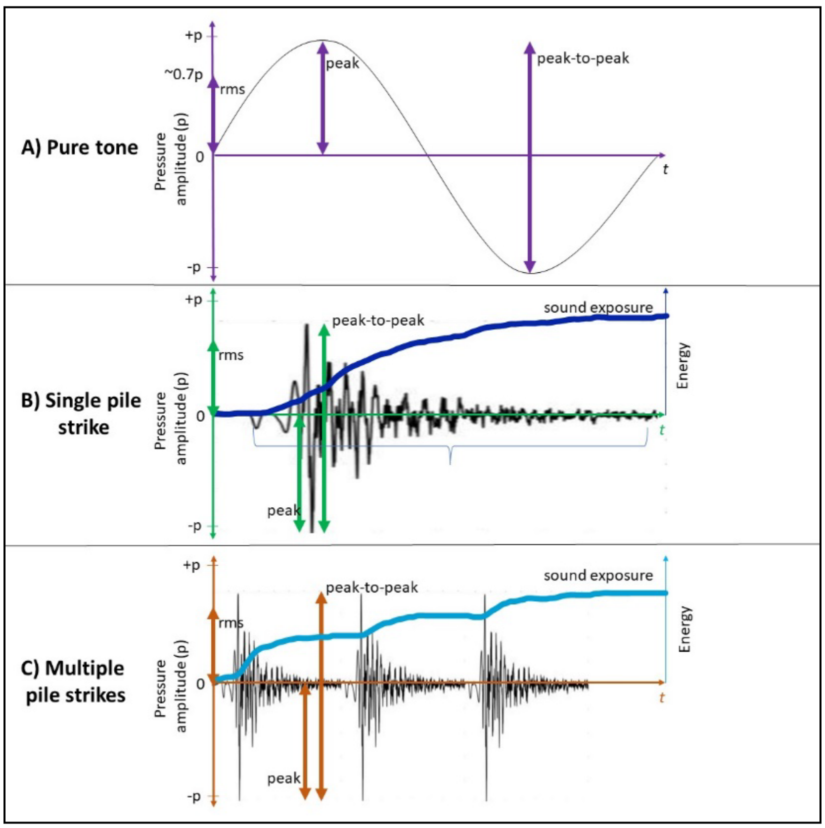


Figure B-20: Basic Mechanics of a Sound Wave

B.4.3 Units of Measurement

Sound can be quantified and characterized based on a number of physical parameters. A complete description of the units can be found in ISO 18405:2017. Some of the major parameters and their International System of Units (in parentheses) are:

Acoustic pressure (pascal [Pa]): The values used to describe the acoustic (or sound) pressure are peak pressure, peak-to-peak pressure and root-mean-square (rms) pressure deviation. The peak sound pressure is defined as the maximum absolute sound pressure deviation within a defined time period and is considered an instantaneous value. The peak-to-peak pressure is the range of pressure change from the most negative to the most positive pressure amplitude of a signal (Figure B-21). Whereas the rms sound pressure represents a time-averaged pressure and is calculated as the square root of the mean (average) of the time-varying sound pressure squared over a given period (Figure B-21). The peak level (Lpk), peak-to-peak level (Lpk-pk), and sound pressure level (SPL) are computed by multiplying the logarithm of the ratio of the peak or rms pressures to a reference pressure (1 μPa in water) by a factor of 20 and are reported in decibels (dB).



A) A sine wave of a pure tonal signal with equal positive and negative peaks, so peak-to-peak is exactly twice the peak and rms (root-mean-square) is approximately 0.7 x peak. B) A single pile-driving strike with one large positive pulse and a large negative pulse that is not necessarily the same magnitude. In this example, the negative pulse is more extreme so is the reported peak value and peak-to-peak is less than double that. Sound exposure is shown as it accumulates across the time window. The final sound exposure would be considered the “single-shot” exposure and the rms value is that value divided by the duration of the pulse. C) Three consecutive pile-driving strikes with peak and peak-to-peak assessed the same way as in panel B). Sound exposure is shown accumulating across all three strikes and rms is the total sound exposure divided by the entire time window shown. The cumulative sound exposure for this series of signals would be considered the total energy from all three pile strikes.

Figure B-21: Sound Pressure Wave Representations of Four Metrics: Root-mean-square (rms), Peak (Lpk), Peak-to-peak (Lpk-pk), and Sound Exposure (SEL)

Particle velocity (m/s): Particle velocity describes the rate of change in position of an oscillating particle about its origin with respect to time. Similar to sound pressure, particle velocity is dynamic and changes as the particles move back and forth. Therefore, peak particle velocity and rms particle velocity can be used to describe this physical quantity. One major difference between sound pressure and particle velocity is that the former is a scalar (i.e., without a directional component) and the latter is a vector (i.e., includes both magnitude and direction). Particle acceleration can also be used to describe particle motion and is defined as the rate of change of velocity of a particle with respect to time. It is measured in units of meters per second squared, or m/s^2.

Sound exposure (pascal squared second): Sound exposure is proportional to the acoustic energy of a sound. It is the time-integrated squared sound pressure over a stated period or acoustic event (Figure B-21). Unlike sound pressure, which provides an instantaneous or time-averaged value of acoustic pressure, sound exposure is cumulative over a period of time.

Acoustic intensity (watts per square meter): Acoustic or sound intensity is the amount of acoustic energy that passes through a unit area normal to the direction of propagation per second. It is the product of the sound pressure and the sound velocity. With an idealized constant source, the pressure and particle velocity will vary in proportion to each other at a given location, but the intensity will remain constant.

Sound levels: There is an extremely wide dynamic range of values when measuring acoustic pressure in pascals, so it is customary to use a logarithmic scale to compress the range of values. Aside from the ease it creates for comparing a wide range of values, animals (including humans) perceive sound on a logarithmic scale. These logarithmic acoustic quantities are known as **sound levels** and are expressed in dB, which is the logarithm of the ratio of the measurement in question to a fixed reference value. Underwater acoustic sound pressure levels are referenced to a pressure of 1 micropascal (μPa) (equal to 10^{-6} Pa or 10^{-11} bar). Note: airborne sound pressure levels have a different reference pressure: 20 μPa.

The metrics previously described (sound pressure, particle velocity, sound exposure, and intensity) can also be expressed as levels, and are commonly used in this way:

- Root-mean-square SPL (in dB re 1 μPa)
- Peak pressure level (Lpk, in dB re 1 μPa)
- Peak-to-peak pressure level (Lpk-pk, in dB re 1 μPa)
- Sound exposure level (SEL, in dB re 1 $\mu Pa^2 s$)
- Particle velocity level (sound velocity level in dB re 1 nm/s)

As a note, there are a few commonly used time periods used for SEL, including a 24-hour period (SEL_{24h}; used in the United States for the regulation of noise impacts to marine mammals), or the duration of a single event, such as a single pile-driving strike or an airgun pulse, called the single strike SEL (SEL_{ss}). A sound exposure for some other period of time, such as the entire installation of a pile, may be written without a subscript (SEL), but to be meaningful, should always denote the duration of the event.

Source level*:* Another commonly discussed concept is source level. Source level is a representation of the amount of acoustic power radiated from the sound source being described. It describes how loud a particular source is in a way that can inform expected received levels at various ranges. It can be conceptualized as the product of the pressure at a particular location and the range from that location to a spherical (omnidirectional) source in an idealized infinite lossless medium. The source level is the sum of the received level and the propagation loss to that receiver. It is often discussed as what the received level would be 1 meter from the source, but this can lead to confusion as an actual measurement at 1 meter is likely to be impossible for large and/or non-spherical sources. The most common type is an SPL source level in units of dB re 1 μPa m, though in some circumstances an SEL source level (in dB re 1 $\mu Pa^2 m^2 s$) may be expressed; peak source level (in units of dB re 1 μPa m) may also be appropriate for some sources.

B.4.4 Propagation of Sound in the Ocean

Underwater sound can be described through a source-path-receiver model. An acoustic source emits sound energy that radiates outward and travels through the water and the seafloor. The sound level decreases with increasing distance from the acoustic source as the sound travels through the environment. The amount by which the sound levels decrease between the theoretical source level and a receiver is called propagation loss. Among other things, the amount of propagation loss that occurs depends on the source-receiver separation, the geometry of the environment the sound is propagating through, the frequency of the sound, the properties of the water column, and the properties of the seafloor and sea surface.

When sound waves travel through the ocean, they may encounter areas with different physical properties that will likely alter the propagation pathway of the sound, compared to a homogenous and boundary free environment. For example, near the ocean's surface, water temperature is usually higher, resulting in relatively fast sound speeds. As temperature decreases with increasing depth, the sound speed decreases. Sounds bend toward areas with lower speeds (Urick 1983). Ocean sound speeds are often slowest at mid-latitude depths of about 1,000 meters, and because of sound's preference for lower speeds, sound waves above and below this "deep sound channel" often bend toward it. Sounds originating in this layer can travel great distances. Sounds can also be trapped in the mixed layer near the ocean's surface (Urick 1983). Latitude, weather, and local circulation patterns influence the depth of the mixed layer, and the propagation of sounds near the surface is highly variable and difficult to predict.

At the boundaries near the sea surface and the seafloor, acoustic energy can be scattered, reflected, or attenuated depending on the properties at the surface (e.g., roughness, presence of wave activity, or bubbles) or seafloor (e.g., bathymetric features, substrate heterogeneity) (Urick 1983). For example, fine-grain sediments tend to absorb sounds well, while hard-bottom substrates reflect much of the acoustic energy back into the water column. The presence of ice on the ocean's surface can also affect sound propagation. For example, the presence of solid ice may dampen sound levels by scattering incident sounds. The effect will also depend on the thickness and roughness of the ice, among many other factors related to the ambient conditions. As a sound wave moves from a source to a receiver (i.e., an animal), it may travel on multiple pathways that may be direct, reflected, refracted, or a combination of these mechanisms, creating a complex pattern of transmission across range and depth. The patterns may become even more complicated in shallow waters due to repeated interactions with the surface and the bottom, frequency-specific propagation, and more heterogenous seafloor properties. All of these variables contribute to the difficulty in reliably predicting the sound field in a given marine environment at any particular time.

B.4.5 Sound Source Classification

In the current regulatory context, anthropogenic sound sources are categorized as either impulsive or non-impulsive, and either continuous or intermittent, based on their differing potential to affect marine species (NMFS 2018b). Specifically, when it comes to potential damage to marine mammal hearing, sounds are classified as either impulsive or non-impulsive, and when considering the potential to affect behavior or acoustic masking, sounds are classified as either continuous or intermittent.

Impulsive noises are characterized as having (ANSI S1.13-2005):

- Broadband frequency content;
- Fast rise-times and rapid decay times;
- Short durations (i.e., <1 second); and
- High peak sound pressures.

Whereas the characteristics of non-impulsive sound sources are less clear but may be:

- Variable in spectral composition, i.e., broadband, narrowband, or tonal;
- Longer rise-time/decay times, and longer total durations compared to an impulsive sound; or
- Continuous (e.g., vessel engine radiated noise), or intermittent (e.g., echosounder pulses).

It is generally accepted that sources like explosions, airguns, sparkers, boomers, and impact pile driving are impulsive and have a greater likelihood of causing hearing damage than non-impulsive sources (note: explosions are further considered for non-auditory injury. Impulsive sounds are more likely to induce physiological effects, including temporary threshold shift (TTS) and permanent threshold shift (PTS), than non-impulsive sounds with the same energy. This binary at-the-source classification of sound types, therefore, provides a conservative framework upon which to predict potential adverse hearing impacts to marine mammals.

For behavioral effects of anthropogenic sound on marine mammals, NMFS classifies sound sources as either intermittent or continuous (NMFS 2018). Continuous sounds, such as drilling or vibratory pile driving, remain "on," i.e., producing sound, for a given period of time, though this is not well defined. An intermittent sound typically consists of bursts or pulses of sound on a regular on-off pattern, also called the duty cycle. Examples of intermittent sounds are those from scientific echosounders, sub-bottom profilers, and impact pile driving. It is important to recognize that these delineations are not always practical in application, as a continuous yet moving sound source (such as a vessel passing over a fixed receiver) could be considered intermittent from the perspective of the receiver.

In reality, animals will encounter many signals in their environment, which may contain many or all of these sound types, called complex sounds. Even for sounds that are impulsive at the source, as the signal propagates through the water, the degree of impulsiveness decreases (Martin et al. 2020). While there is evidence, at least in terrestrial mammals (Hamernik and Hsueh 1991), that complex sounds can be more damaging than continuous sounds of the same energy, there is not currently a regulatory category for this type of sound. One approach for assessing the impulsiveness of a sound that has gained attention is to compute the kurtosis of that signal. Kurtosis is a statistical measure that describes the prevalence of extreme values within a distribution of observations, in other words the "spikiness" of the data. By definition, a sound with a kurtosis value of 3 or less has very few extreme values and is generally considered Gaussian (i.e., normally distributed) noise. Martin et al. (2020) showed that a kurtosis value greater than 40 represents a distribution of observations with many extreme values and is very spiky. This generally describes an impulsive noise. A distribution of sound level observations from a time series with a kurtosis value somewhere in between these two values would be considered a complex sound.

B.4.6 Sound Sources Related to Offshore Wind

B.4.6.1 Geophysical and Geotechnical Surveys

Geophysical and geotechnical surveys are conducted to characterize the bathymetry, sediment type, and benthic habitat characteristics of the marine environment. They may also be used to identify archaeological resources or obstacles on the seafloor. These types of surveys occur in the site assessment phase in order to inform the placement of offshore wind foundations, but may also occur intermittently during and after turbine construction to identify, guide, and confirm the locations of turbine foundations. The suite of HRG sources that may be used in geophysical surveys includes side-scan sonars, multibeam echosounders (MBES), magnetometers and gradiometers, parametric sub-bottom profilers, compressed high-intensity radiated pulses sub-bottom profilers, boomers, and/or sparkers. Seismic airguns are not expected to be used for offshore wind applications. These HRG sources may be towed behind a ship, mounted on a ship's hull, or deployed from remotely operated vehicles or automated underwater vehicles.

Many HRG sources are active acoustic sources, meaning they produce sound deliberately to obtain information about the environment. With the exception of some MBES and side-scan sonars, they produce sounds below 180 kilohertz (kHz) and thus may be audible to marine species. Source levels vary widely depending on source type and operational power level used, from approximately 145 dB re 1 µPa m for towed sub-bottom profilers up to 245 dB re 1 µPa m for some MBES (Crocker and Fratantonio 2016). Generally speaking, sources that emit sound in narrow beams directed at the seafloor are less likely to affect marine species because they ensonify a smaller portion of the water column, thus reducing the likelihood that an animal encounters the sound (Ruppel et al. 2022). While sparkers are omnidirectional, most other HRG sources have narrower beamwidths (e.g., MBES: up to 6 degrees, parametric sub-bottom profilers: 30 degrees, boomers: 30 degrees to 90 degrees) (Crocker and Fratantonio 2016). Most HRG sources emit short pulses of sound, with periods of silence in between. This means that only several "pings" emitted from a vessel towing an active acoustic source would reach an animal below, even if the animal was stationary (Ruppel et al. 2022). HRG surveys may occur throughout the construction area with the potential for greater effort in some areas.

Geotechnical surveys may use vibracores, jet probes, bottom-grab samplers, deep borings, or other methods to obtain samples of sediments at each potential turbine location and along the cable route. For many of these methods, source levels have not been measured, but it is generally assumed that low-frequency, low-level noise will be introduced as a byproduct of these actions. It is likely that the sound of the vessel will exceed that generated by the geotechnical method itself.

B.4.6.2 Unexploded Ordnance Detonations

UXOs may be discovered on the seabed in offshore wind lease areas or along export cable routes. While non-explosive methods may be employed to lift and move these objects, some may need to be detonated. Underwater explosions of this type create shock waves characterized by extreme changes in pressure, both positive and negative. Shock waves are supersonic, so they travel faster than the speed of sound. The explosive sound field extremely is complex, especially in shallow waters. In 2015, von Benda-Beckmann et al. 2015 measured received levels of explosions in shallow waters at distances ranging from 100 to 2,000 meters from the source, in water depths ranging from 6 to 22 meters. The measured SEL from the explosive removal of a 263-kilogram charge was 216 dB re 1 μPa^2s at a distance of 100 meters and 196 dB re 1 μPa^2s at 2,000 meters. They found that SELs were lower near the surface than near the seafloor or in the middle of the water column, suggesting that if an animal is near the surface, the effects may be less damaging. Most of the acoustic energy for underwater explosions is below 1,000 Hz.

As an alternative to traditional detonation, a newer method called deflagration allows for the controlled burning of underwater ammunition. Typically, a remotely operated vehicle uses a small, targeted charge to initiate rapid burning of the ordnance; once this process is complete, the remaining debris can be cleared away. Recent work has demonstrated that both Lpk and SEL measured from deflagration events may be as much as 20 dB lower than equivalently sized high-order detonations (Robinson et al. 2020).

B.4.6.3 Impact and Vibratory Pile Driving

At present, the installation of turbine foundations is largely done using pile driving. There are several techniques, including impact and vibratory driving, and many pile designs and sizes, including monopile and jacket foundations. Impact pile driving employs a hammer to strike the pile head and force the pile into the sediment with a typical hammer strike rate of approximately 30 to 50 strikes/minute. Typically, force is applied over a period of less than 20 milliseconds, but the pile can generate sound for upwards of 0.5 seconds. Pile-driving noise is characterized as impulsive because of its high peak pressure, short duration, and rapid onset time. Underwater sound levels generated during pile driving depend on many factors including the pile material and size, characteristics of the substrate, penetration of the pile in the seabed, hammer energy and size, and water depth. Currently the design envelope for most offshore wind turbine installations anticipates hammer energy between 2,500 and 4,000 kilojoule (kJ), but generally speaking, with increasing pile diameter, greater hammer energy is used. The propagation of pile-driving sounds depends on factors such as the sound speed in the water column (influenced by temperature, salinity, and depth), the bathymetry, and the composition of sediments in the seabed and will therefore vary among sites. Due to variation in these features, sounds may not radiate symmetrically outward from a pile.

Thus far, there are only a few measurements from construction of offshore wind turbines in U.S. waters. Two monopiles (7.8 meters in diameter) were installed off the coast of Virginia (27-meter water depth) in 2020. Dominion Energy (2020) recorded sounds during this process; without noise mitigation, Lpk source levels were back-calculated to be 221 dB re 1 µPa m, but with a double bubble curtain, Lpk source levels were around 212 dB re 1 µPa m. The unmitigated SPL source level was 213 dB re 1 µPa m; the mitigated SPL source level was 204 dB re 1 µPa m.

Jacket foundations are also common, if not for the main turbine structures, for other structures associated with the wind farm such as the offshore substations. Jacket foundations are installed using pin piles which are generally significantly smaller than monopiles, on the order of 2 to 5 meters in diameter, but more pin piles are needed per foundation. The sound levels generated will vary depending on the pile material, size, whether the piles are installed with the jacket in place, substrate, hammer energy, and water depth. At the Block Island Wind Farm, Amaral et al. (2018a) measured sound levels at various distances during pile driving of jacket foundations (50-inch pile diameter, 30-meter water depth). It should be noted that the piles were installed at an angle (from vertical), which influenced the directionality of the noise produced, so caution is encouraged with interpretation. Nonetheless, the authors reported SPL received levels between 150 to 160 dB re 1 µPa at approximately 750 meters from the piles. The maximum SEL_{SS} measured at 750 meters from the jacket foundations at Block Island Wind Farm ranged from 160 to 168 dB re 1 $\mu Pa^2 s$, nearly 10 dB lower than Coastal Virginia Offshore Wind. Using measurements combined with acoustic modeling, the peak-peak source levels for pile driving at Block Island Wind Farm were estimated to be between 233 and 245 dB re 1 µPa m (Amaral et al. 2018b).

Vibratory hammers may be used as an alternative to impact pile driving. The vibratory hammer continuously exerts vertical vibrations into the pile, which causes the sediment surrounding the pile to liquefy, allowing the pile to penetrate the substrate. The vibratory hammer typically oscillates at a frequency of 20 to 40 Hz (Matuschek and Betke 2009) and produces most of its acoustic energy below 2 kHz. Buehler et al. (2015) measured sound levels at 10 meters distance from a 72-inch steel pile, and found them to be 185 dB re 1 µPa, but this is significantly smaller than the sizes expected for offshore wind. While no measurements of vibratory piling for large monopiles have been conducted, modeling predictions from South Coast Wind, for example, estimate that SPL received levels could exceed the behavioral harassment threshold for marine mammals (120 dB re 1 μPa) at distances >40 kilometers for a 16-meter-diameter monopile (LGL Ecological Research Associates 2022). Vibratory pile driving is a non-impulsive sound source and the hammer produces sound continuously, so different criteria are used for assessing behavioral and physiological effects on marine mammals (Section B.5.4).

A technique that is quickly gaining use for installation in hard rock substrates is down-the-hole (DTH) pile driving, which uses a combination of percussive and drilling mechanisms, with a hammer acting directly on the rock to advance a hole into the rock, and also advance the pile into that hole (Guan et al. 2022). Noise characteristics for DTH pile driving include both impulsive and non-impulsive components. The impulsive component of the DTH pile driving is the result of a percussive hammer striking the bedrock, while the non-impulsive component is from drilling and air-lifting of cuttings and debris from the pile. While only limited studies have been conducted on DTH pile-driving noise, its characteristics strongly resemble those of impact pile driving, but with a higher hammer striking rate (approximately 10 to 15 Hz). The dominant frequencies from DTH pile driving are below 2 kHz, similar to conventional impact pile driving. Due to the high rate of hammer striking, along with the sounds of drilling and debris clearing out, sound levels in between the pulses are much higher than conventional impact pile driving (Guan et al. 2022).

Various noise abatement technologies, such as bubble curtains, arrays of enclosed air resonators, or segmented nets of rubber or foam, may be employed to reduce noise from impact pile driving. Measurements from European wind farms have shown that a single noise abatement system can reduce broadband sound levels by 10 to 15 dB, while using two systems together can reduce sound levels as much as 20 dB (Bellmann et al. 2020). Based on Realtime Opportunity for Development Environmental Observations measurements from Coastal Virginia Offshore Wind, double Big Bubble Curtains are shown to be most effective for frequencies above 200 Hz, and greater noise reduction was seen in measurements taken in the middle of the water column compared to those near the seabed. Approximate sound level reduction is 3 to 5 dB below 200 Hz, and 8 to 20 dB above 200 Hz, depending on the characteristics of the bubble curtain (Amaral et al. 2020).

B.4.6.4 Drilling

Drilling associated with offshore wind activities may include geotechnical surveys, horizontal directional drilling (HDD) at the export cable landfalls, and, if necessary, to remove large boulders at the site of foundation installation or during foundation installation to reduce the risk of pile run. Sounds from drilling are generally considered to be non-impulsive and are nearly continuous in nature, though they may be highly variable depending on the type of substrate that is encountered (Richardson et al. 1995). There could be tonal sound generated by the drill bit, mechanical noise transferred through the ship's hull, and noise from the vessels and dynamic positioning (DP) systems. HDD uses equipment that is generally located on shore, and the sound that propagates into the water is expected to be negligible. Geotechnical drilling SPLs (in the 30 to 2,000 Hz band) have been measured up to 145 dB re 1 μPa m from a jack-up platform (Erbe and McPherson 2017), and up to 162 dB re 1 μPa m from an anchored drilling vessel (Huang et al. 2023). If drilling is required for foundation installation, a large drill bit at the bottom of the pile would slowly rotate to break up the material inside the pile, and the liquefied material would be pumped out. While measurements of these operations specifically for offshore wind installation have not been conducted, the closest proxy is from oil and gas-related operations, where a 6-meter-diameter drill bit was used for the excavation of mudline cellars (Austin et al. 2018). Austin et al. (2018) measured received levels at 1,000 meters from the operations and back-calculated the SPL source levels to be between 191 to 193 dB re 1 μPa m.

B.4.6.5 Vessels

During construction, small vessels and aircraft may be used to transport crew and equipment, and large vessels will be used to conduct pile driving, using DP systems. DP is the process by which a vessel holds station over a specific seafloor location for some time period using input from gyrocompasses, motion sensors, Global Positioning System, active acoustic positioning systems, and wind sensors to determine relative movement and environmental forces at work. Generally speaking, most acoustic energy from DP is below 1,000 Hz, often below 50 Hz, with tones related to engine and propeller size and type. The sound can also vary directionally, and this directionality is much more pronounced at higher frequencies. Because this is a dynamic operation, the sound levels produced will vary based on the specific operation, DP system used (e.g., jet or propeller rotation, versus a rudder or steering mechanism), and factors such as the blade rate and cavitation, in some cases. Representative sound field measurements from the use of DP are difficult to obtain because the sound transmitted is often highly directional and context specific. The direction of sound propagation may change as different DP needs requiring different configurations are applied.

Several studies have found that the measured sound levels of DP alone are, counterintuitively, higher than those of DP combined with the intended activities such as drilling (Jiménez-Arranz et al. 2020; Kyhn et al. 2011; Nedwell and Edwards 2004) and coring (Warner and McCrodan 2011). Nedwell and Edwards (2004) reported that DP thrusters of the semi-submersible drill rig Jack Bates produced periodic noise (corresponding to the rate of the thruster blades) with most energy between 3 to 30 Hz. The received SPL measured at 100 meters from the vessel was 188 dB re 1 µPa. Warner and McCrodan (2011) found that most DP-related sounds from the self-propelled drill ship, R/V Fugro Synergy, were in the 110 to 140 Hz range, with an estimated source level of 169 dB re 1 µPa·m. Sounds in this frequency range varied by 12 dB during DP, while the broadband levels, which also included diesel generators and other equipment sounds, varied by only 5 dB over the same time period (Warner and McCrodan 2011). All of the above sources report high variability in levels with time. This is due in part to the intermittent usage and relatively slow rotation rates of thrusters used in DP. It is also difficult to provide a realistic range of source levels from the data thus far because most reports do not identify the direction from which sound was measured relative to the vessel, and DP thrusters are highly directional systems.

The active acoustic positioning systems used in DP can be additional sources of high-frequency sound. These systems usually consist of a transducer mounted through the vessel's hull and one or more transponders affixed to the seabed. Kongsberg High Precision Acoustic Positioning systems produce pings in the 10 to 32 kHz frequency range. The hull-mounted transducers have source levels of 188 to 206 dB re 1 µPa·m depending on adjustable power settings (Kongsberg Maritime AS 2013). The fixed transponders have maximum source levels of 186 to 206 dB re 1 µPa m depending on model and beam width settings from 15 to 90 degrees (Jiminez-Arranz et al. 2020). These systems have high source levels, but beyond 2 kilometers, they are generally quieter than other components of the sound from DP vessels for various reasons including: their pulses are produced in narrowly directed beams, each individual pulse is very short and their high-frequency content leads to faster attenuation.

Noise from vessel transit is different from that of DP systems, but is also considered to be continuous, with a combination of broadband and tonal sounds (Richardson et al. 1995; Ross 1976). Transiting vessels generate continuous sound from their engines, propeller cavitation, onboard machinery, and hydrodynamics of water flow (Ross 1976). The actual radiated sound depends on several factors, including the type of machinery on the ship, the material conditions of the hull, how recently the hull has been cleaned, interactions with the sea surface, and shielding from the hull, which reduces sound levels in front of the ship.

In general, vessel noise increases with ship size, power, speed, propeller blade size, number of blades, and rotations per minute. Source levels for large container ships can range from 177 to 188 dB re 1 µPa m

(McKenna et al. 2013) with most energy below 1 kHz. Smaller vessels typically produce higher-frequency sound concentrated in the 1 to 5 kHz range. Kipple and Gabriele (2003) measured underwater sound from vessels ranging from 14 to 65 feet long (25 to 420 horsepower) and back-calculated source levels to be 157 to 181 dB re 1 µPa m. Similar levels are reported by Jiménez-Arranz et al. (2020), who provide a review of measurements for support and crew vessels, tugs, rigid hull inflatable boats, icebreakers, cargo ships, oil tankers, and more.

During transit to and from shore bases, survey vessels typically travel at speeds that optimize efficiency, except in areas where transit speed is restricted. The vessel strike speed restrictions that are in place along the Atlantic OCS are expected to offer a secondary benefit of underwater noise reduction. For example, recordings from a speed reduction program in the Port of Vancouver (210- to 250-meter water depths) showed that reducing speeds to 11 knots reduced vessel source levels by 5.9 to 11.5 dB, depending on the vessel type (MacGillivray et al. 2019). Vessel noise is also expected to be lower during geological and geophysical surveys, as they typically travel around 5 knots when towing instruments.

B.4.6.6 Site Preparation

Prior to offshore wind project foundation and export cable installation, boulder clearance and pre-lay grapnel runs may be conducted to clear the area of obstructions. This may involve the use of a displacement plow, a subsea grab or, in shallower waters, a backhoe dredger. Sandwave clearance may also be conducted in advance of export cable installation to remove mobile sediments using a suction hopper dredger, controlled flow excavation, or plow. At landfall locations, export cables may be installed using HDD, which may require mechanical dredging of the HDD exit pit.

Sounds from site preparation activities are considered non-impulsive and are nearly continuous in nature. Dredging produces distinct sounds during each specific phase of operation: excavation, transport, and placement of dredged material (Central Dredging Association 2011; Jiminez-Arranz et al. 2020). Engines, pumps, and support vessels used throughout all phases may introduce low-level, continuous noise into the marine environment. The sounds produced during excavation vary depending on the sediment type—the denser and more consolidated the sediment is, the more force the dredger needs to impart, and the higher sound levels that are produced (Robinson et al. 2011). Sounds from mechanical dredges occur in intervals as the dredge lowers a bucket, digs, and raises the bucket with a winch. During the sediment transport phase, many factors—including the load capacity, draft, and speed of the vessel—influence the sound levels that are produced (Reine et al. 2014). SPL source levels during backhoe dredge operations range from 163 to 179 dB re 1 µPa m (Nedwell et al. 2008; Reine et al. 2012). As a whole, dredging activities generally produce low-frequency sounds; with most energy below 1,000 Hz and frequency peaks typically occurring between 150 to 300 Hz (McQueen et al. 2018). Additional detail and measurements of dredging sounds can be found in (Jiminez-Arranz et al. 2020; McQueen et al. 2018; Robinson et al. 2011a).

B.4.6.7 Cable Laying and Trenching

The installation of cables can be done by towing a tool behind the installation vessel to simultaneously open the seabed and lay the cable, or by laying the cable and following with a tool to embed the cable. Possible installation methods for these options include jetting, vertical injection, control flow excavation, trenching, and plowing. Burial depth of the cables is typically 1 to 2 meters. Cable installation vessels may use DP to lay the cables which can introduce considerable levels of noise into the marine environment (Section B.4.6.5).

Nedwell and Edwards (2004) measured sounds from a 130-meter-long trenching vessel and found that sound levels were similar to those produced during pipeline-laying in the same area, with the exception of a 20 kHz tonal sound, which they attributed to the vessel’s DP thrusters. Nedwell et al. (2003) recorded underwater sound 160 meters away from trenching activity (water depth 7 to 11 meters) and back-calculated the SPL source level of trenching to be 178 dB re 1 µPa m (assuming propagation loss of 22logR). They described the sound as generally spanning a wide range of frequencies, variable over time, and accompanied by some tonal machinery noise and transient noises associated with rock breakage.

Johansson and Andersson (2012) recorded underwater noise levels during both pipelaying and trenching. The mean SPL measured (at 1,500 meters from the pipeline) during pipelay operations was 130.5 dB re 1 µPa, nearly 20 dB higher than average background noise at the same location. There were eight support vessels in the vicinity during pipelaying operations. During trenching, with only one vessel in the vicinity, received levels were 126 dB re 1 µPa, and the authors back-calculated the SPL source level to be 183.5 dB re 1 µPa, similar to that of commercial vessels in the region.

B.4.6.8 Aircraft

Manned aircraft consist of propeller and jet engines, fixed-wing craft, as well as helicopters. Unmanned systems also exist. For jet engine aircraft, the engine is the primary source of sound. For propeller driven aircraft and helicopters, the propellors and rotors also produce noise. Aircraft generally produce low-frequency sound below 500 Hz (Richardson et al. 1995). While aircraft noise can be substantial in air, penetration of aircraft noise into the water is limited because much of the noise is reflected off the water’s surface (Richardson et al. 1995). The noise that penetrates into the water column does so via a critical incident angle or cone. With an idealized flat sea surface, the maximum critical incident angle is approximately 13 degrees (Urick 1983); beyond this, sound is reflected off the surface. When the sea surface is not flat, there may be some additional penetration into the water column in areas outside of this 13-degree cone. Nonetheless, the extent of noise from passing aircraft is more localized in water than it is in air.

Jiménez-Arranz et al. (2020) and Richardson et al. (1995) reviewed sound measurements recorded below passing aircraft of various models. These SPL measurements included 124 dB re 1 µPa (dominant frequencies between 56 to 80 Hz) from a maritime patrol aircraft with an altitude of 76 meters, 109 dB re 1 µPa (dominant frequency content below 22 Hz) from a utility helicopter with an altitude of 152 meters, and 107 dB re 1 µPa (tonal, 82 Hz) from a turbo propeller with an altitude of 457 meters. Recent published levels associated with unmanned aircraft (Christiansen et al. 2016; Erbe et al. 2017) indicate source levels are around or below 100 dB re 1 µPa m.

B.4.6.9 WTG Operations

Once windfarms are operational, low-level sounds are generated by each WTG, but sound levels are much lower than during construction. This type of sound is considered to be continuous, omnidirectional radially from the pile, and non-impulsive. Most of the energy associated with operations is below 120 Hz. Sound levels from wind turbine operations are likely to increase somewhat with increasing generator size and power ratings, as well as with wind speeds. Recordings from Block Island Wind Farm indicated that there was a correlation between underwater sound levels and increasing wind speed, but this was not clearly influenced by turbine machinery; rather it may have been explained by the natural effects that wind and sea state have on underwater sound levels (Elliott et al. 2019; Urick 1983).

A recent compilation (Tougaard et al. 2020) of operational noise from several wind farms, with turbines up to 6.15 MW in size, showed that operational noise generally attenuates rapidly with distance from the turbines (falling to near ambient sound levels within approximately 1 kilometer from the source), and the combined noise levels from multiple turbines is lower or comparable to that generated by a small cargo ship. Tougaard et al. (2020) developed a formula predicting a 13.6 dB increase for every 10-fold increase in WTG power rating. This means that operational noise could be expected to increase by 13.6 dB when increasing in size from a 0.5 MW turbine to a 5 MW one, or from 1 MW to 10 MW. The least squares fit of that dataset would predict that the SPL measured 100 meters from a hypothetical 15 MW turbine in operation in 10 meters per second (m/s) (19 knots or 22 miles per hour) wind would be 125 dB re 1 µPa. However, all of the 46 data points in that dataset, with the exception of the two from Block Island Wind Farm, were from WTGs operated with gear boxes of various designs rather than the newer use of direct drive technology, which is expected to lower underwater noise levels significantly. Stöber and Thomsen (2021) make predictions for source levels of 10 MW turbines based on a linear extrapolation of maximum received levels from WTGs with ratings up to 6.15 MW. The linear fit is likely inappropriate, and the resulting predictions may be exaggerated. Tougaard et al. (2020) point out that received level differences among different pile types could be confounded by differences in water depth and turbine size. In any case, additional data is needed to fully understand the effects of size, foundation type properties (e.g., structural rigidity and strength), and drive type on the amount of sound produced during turbine operation.

B.4.6.10 Decommissioning

The methods that may be used for decommissioning are not well understood at this time. It is possible that explosives may be used for some offshore wind projects (Section B.4.6.2), but are not being considered under Alternative B of this Final EIS. However, given the general trend of reducing the use of underwater explosives that has been observed in the oil and gas industry, it is likely that offshore wind structures will instead be removed by cutting. While it is difficult to extrapolate directly, we can glean some insights from a recent study which measured received sound levels during the mechanical cutting of well conductor casings on oil and gas platforms in California. The cutters operated at 60 to 72 revolutions per minute, and the cutting time varied widely between cuts (on the order of minutes to hours). At distances of 106 to 117 meters from the cutting, received SPLs were 120 to 130 dB re 1 µPa, with most acoustic energy falling between 20 and 2,000 Hz (Fowler et al. 2022). This type of sound is considered to be non-impulsive and could be continuous while cuts are actually being made, with quieter periods between cuts. Additional noise from vessels (Section B.4.6.5) and other machinery may also be introduced throughout the decommissioning process.

B.5 Marine Mammals and Underwater Sound

B.5.1 The Importance of Sound to Marine Mammals

Marine mammals rely heavily on acoustic cues for extracting information from their environment. Sound travels faster and farther in water (approximately 1,500 m/s) than it does in air (approximately 350 m/s), making this a reliable mode of information transfer across large distances and in dark environments where visual cues are limited. Acoustic communication is used in a variety of contexts, such as attracting mates, communicating to young, or conveying other relevant information (Bradbury and Vehrencamp 2011). Marine mammals can also glean information about their environment by listening to acoustic cues, like ambient sounds from a reef, the sound of an approaching storm, or a call from a nearby predator. Finally, toothed whales produce and listen to echolocation clicks to locate food and to navigate (Madsen and Surlykke 2013).

B.5.2 Hearing Anatomy

Like terrestrial mammals, the auditory anatomy of marine mammals generally includes the inner, middle, and outer ear (Ketten 1994). Not all marine mammals have an outer ear, but if it is present, it funnels sound into the auditory pathway. The middle ear acts as a transformer, filtering and amplifying the sound. The inner ear is where auditory reception takes place. The key structure in the inner ear responsible for auditory perception is the cochlea, a spiral-shaped structure containing the basilar membrane, which is lined with auditory hair cells. Specific areas of the basilar membrane vibrate in response to the frequency content of the acoustic stimulus, causing hair cells mapped to specific frequencies to be differentially stimulated and send signals to the brain (Ketten 1994). While the cochlea and basiliar membrane are well conserved structures across all mammalian taxa, there are some key differences in the auditory anatomy of terrestrial versus marine mammals that require explanation. Marine mammals have the unique need to hear in aqueous environments. Amphibious marine mammals (including seals, sea otters, and sea lions) have evolved to hear both in air and under water, and all except phocid pinnipeds have external ear appendages. Cetaceans do not have external ears, do not have air-filled external canals, and the bony portions of the ear are much denser than those of terrestrial mammals (Ketten 1994).

All marine mammals have binaural hearing and can extract directional information from sound, but the pathway that sound takes into the inner ear is not well understood for all cetaceans and may not be the same for all species. For example, in baleen whales, bone conduction through the lower jaw may play a role in hearing (Cranford and Krysl 2015), while odontocetes have a fat-filled portion of the lower jaw which is thought to funnel sound toward the ear (Mooney et al. 2012). Hearing tests have been conducted on several species of odontocetes, but there has yet to be a hearing test on a baleen whale, so most understanding comes from examining the ears from deceased whales (Erbe et al. 2016; Houser et al. 2017). However, work is currently being undertaken to collect measures of minke whale hearing in Norway, though results have not yet been published (NMMF 2023).

Many marine mammal species produce sounds through vibrations in their larynx (Frankel 2002). In baleen whales, for example, air in the lungs and laryngeal sac expands and contracts, producing vibrations and sounds within the larynx (Frankel 2002). Baleen whales produce low-frequency sounds that can be used to communicate with other animals over great distances (Clark and Gagnon 2002). Differences in sound production among marine mammals varies, in part, with their use of the marine acoustic environment. Toothed whales hunt for their prey using relatively high-frequency (10s of kHz) echolocation signals. To produce these signals, they have a specialized structure called the “melon” in the top of their head that is used for sound production. When air passes through the phonic lips, a vibration is produced, and the melon helps transmit the vibration from the phonic lips to the environment as a directed beam of sound (Frankel 2002). It is generally believed that if an animal produces and uses a sound at a certain frequency, its hearing sensitivity will at least overlap those particular frequencies. An animal’s hearing range is likely much broader than this, as they rely heavily on acoustic information, beyond the signals they produce themselves, to understand their environment.

B.5.3 Potential Impacts of Underwater Sound

Depending on the level of exposure, the context, and the type of sound, potential impacts of underwater sound on marine mammals may include non-auditory injury, permanent or temporary hearing loss, behavioral changes, acoustic masking, or increases in physiological stress (OSPAR Commission 2009). Each of these impacts is discussed below.

Non-auditory Injury: Non-auditory physiological impacts are possible for very intense sounds or blasts, such as explosions. This kind of impact is not expected for most of the activities associated with offshore wind development; it is only possible during detonation of unexploded ordnances or if explosives are used in decommissioning. Although many marine mammals can adapt to changes in pressure during their deep foraging dives, the shock waves produced by explosives expose the animal to rapid changes in pressure, which in turn cause a rapid expansion of air-filled cavities (e.g., the lungs). This forces the surrounding tissue or bone to move beyond its limits, which may lead to tears, breaks, or hemorrhaging. The extent and severity to which such injury will occur depends on several factors, including the size of these air-filled cavities, ambient pressure, how close an animal is to the blast, how large the blast is, and the animal’s mass (U.S. Navy 2017). In extreme cases, this can lead to severe lung damage, which can directly kill the animal. A less severe lung injury may indirectly lead to death due to an increased vulnerability to predation or the inability to complete foraging dives.

Permanent or Temporary Hearing Loss: An animal's auditory sensitivity to a sound depends on the spectral, temporal, and amplitude characteristics of the sound (Richardson et al. 1995). When exposed to sounds of significant duration and amplitude (typically within close range of a source), marine mammals may experience noise-induced threshold shifts. PTS is an irreversible loss of hearing due to hair cell loss or other structural damage to auditory tissues (Henderson et al. 2008; Saunders et al. 1985). TTS is a relatively short-term (e.g., within several hours or days), reversible loss of hearing following noise exposure (Finneran 2015; Southall et al. 2007), often resulting from hair cell fatigue (Saunders et al. 1985; Yost 2000). While experiencing TTS, the hearing threshold rises, meaning that a sound must be louder in order to be detected. Prolonged or repeated exposure to sounds at levels that are sufficient to induce TTS—without adequate recovery time—can lead to PTS (Finneran 2015b; Southall et al. 2007). Research suggests that some odontocete species may have mechanisms to reduce their hearing sensitivity, which may help to protect them from PTS or TTS when provided with a warning signal that an intense sound is just about to arrive (Nachtigall and Supin 2013).

Behavioral Impacts: Farther away from a source and at lower received levels, marine mammals may show varying levels of behavioral disturbance to noise beginning at distances farther from a sound source at lower received levels than those associated with hearing loss. Behavioral effects may range from no observable response to overt behavioral changes. They may flee from an area to avoid the noise source, may exhibit changes in vocal activity, stop foraging, or change their typical dive behavior, among other responses (National Research Council 2003). When exposed to the same sound repeatedly, it is possible that marine mammals may become either habituated (show a reduced response) or sensitized (show an increased response) (Bejder et al. 2009). A number of contextual factors play a role in whether an animal exhibits a response to a sound source, including those intrinsic to the animal and those related to the sound source. Some of these factors include: (1) the exposure context, e.g., behavioral state of the animal, habitat characteristics; (2) the biological relevance of the signal, e.g., whether the signal is audible, whether the signal sounds like a predator; (3) the life stage of the animal, e.g., juvenile, mother and calf; (4) prior experience of the animal, e.g., is it a novel sound source; (5) sound properties, e.g., duration of sound exposure, SPL, sound type, mobility/directionality of the source; and (5) physical properties of the medium that may affect how the sound propagates, e.g., bathymetry, temperature, salinity (Southall et al. 2021). Because of these many factors, behavioral impacts are challenging to both predict and measure, and this remains an ongoing field of study within the field of marine mammal bioacoustics. Furthermore, the implications of behavioral disturbance can range from, as an example, temporary displacement of an individual to long-term consequences on a population, such as a reduction in fitness related to decreased foraging success.

Auditory Masking: Auditory masking may occur over larger spatial scales than noise-induced threshold shift or behavioral disturbance. Masking occurs when a noise source overlaps in time, space, and frequency as a signal that the animal is either producing or trying to detect in its environment (Clark et al. 2009; Richardson et al. 1995). Masking can reduce an individual's "communication space" (the range at which it can effectively transmit and receive acoustic cues from conspecifics) or "listening space" (the range at which it can detect relevant acoustic cues from the environment). A growing body of research is focused on the risk of masking from anthropogenic sources, the ecological significance of masking, and what anti-masking strategies may be used by marine animals. This understanding is essential to fully address masking in regulation or mitigation approaches (Erbe et al. 2016). In the interim, most assessments only consider the overlap in frequency between the sound source and the hearing range of marine mammals.

Physiological stress: The presence of anthropogenic noise, even at low levels, can increase physiological stress in a range of taxa, including humans (Kight and Swaddle 2011; Wright et al. 2007). This is difficult to measure in wild animals, but several methods have recently emerged that allow for reliable measurements in marine mammals (Hunt et al. 2014). For example, animals tagged with heart rate monitors and the collection of fecal and blubber samples can be used to address questions about near real-time stressors (Rolland et al. 2005). For NARWs, vessel noise is known to increase stress hormone levels, which may contribute to suppressed immunity and reduced reproductive rates and fecundity (Rolland et al. 2012). For narwhal (*Monodon monoceros*), increased vessel traffic contributed to increased stress hormone levels (Watt et al. 2021). Furthermore, a paradoxical physiological response to vessel and seismic airgun noise was reported in tagged narwhal displaying simultaneous bradycardia with increased fluke stroke and respiration rates (Williams et al. 2022). The reactions to anthropogenic noise by this deep-diving cetacean demonstrated how a cascade of effects along the entire oxygen pathway could challenge physiological homeostasis especially if disturbance is prolonged (Williams et al. 2022).

The effects of anthropogenic sound on marine life have been studied for more than half a century. In that time, it has become clear that this is a complex subject with many interacting factors and extreme variability in response from one sound source to another and from species to species, and even within species, i.e., individuals may have markedly different responses to a similar exposure. But some general trends have emerged from this body of work. First, the louder and more the received sound is, the higher the likelihood that there will be an adverse physiological effect, such as PTS or TTS. These impacts generally occur at relatively close distances to a source, in comparison to behavioral effects, masking, or increases in stress, which can occur wherever the sound can be heard. Secondly, the hearing sensitivity of an animal plays a major role in whether it will be affected by a sound or not, and there is a wide range of hearing sensitivities among marine mammal species. Regulation to protect marine life from anthropogenic sound has formed around these general concepts.

B.5.4 Marine Mammal Acoustic Thresholds

The applicant submitted comprehensive underwater acoustic propagation and animal exposure modeling for underwater sound and its potential impacts on marine species during piling installation for up to 132 WTG and/or ESP foundations (the proposed Project).[3] The applicant submitted the modeling results as a part of the COP (Appendix III-M; Epsilon 2023) and Letter of Authorization (LOA) application (JASCO 2023). Table B-26 summarizes the NMFS threshold criteria for PTS and Level A harassment used in the model.

[3] Modeling used 132 foundations, although the current proposed Project design envelope only includes 130 positions. As a result, the model provides a conservative overestimate of potential impacts.

Table B-26: Permanent Threshold Shift Onset Acoustic Threshold Levels

Hearing Group	PTS Onset Thresholds to Evaluate Level A Harassment[a] (Received Level)	
	Impulsive	Non-impulsive
LFC	PK 219; SEL_{24h} 183	SEL_{24h} 199
MFC	PK 230; SEL_{24h} 185	SEL_{24h} 198
HFC	PK 202; SEL_{24h} 155	SEL_{24h} 173
PPW	PK 218; SEL_{24h} 185	SEL_{24h} 201

Sources: NMFS 2018b; COP Appendix III-M; Epsilon 2023

μPa = micropascal; μPa^2s = micropascal squared second; dB = decibel; HFC = high-frequency cetacean (harbor porpoise [*Phocoena phocoena*]); PK = peak sound pressure level; SEL_{24h} = sound exposure level over 24 hours [weighted by hearing group, in units of dB referenced to 1 μPa^2s]; LFC = low-frequency cetacean (all the large whales except sperm whales [*Physeter macrocephalus*]); MFC = mid-frequency cetacean (all dolphins, pilot whales, and sperm whales); PPW = pinnipeds in the water (all seals); PTS = permanent threshold shift

[a] NMFS (2018a) uses a dual-metric acoustic thresholds for impulsive sounds, in which the largest isopleth (mapped distance) from either method is used for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the PK level thresholds associated with impulsive sounds, these thresholds should also be considered.

Because of the complexity and variability of marine mammal behavioral responses to acoustic exposure, NMFS has not yet released updated technical guidance on behavioral threshold criteria (Level B harassment; NMFS 2018b). NMFS currently recommends an SPL threshold for behavioral disturbance of 160 dB re 1 μPa for non-explosive impulsive sounds (e.g., airguns and impact pile driving) and intermittent sound sources (e.g., scientific and non-tactical sonar), and 120 dB re 1 μPa for continuous sounds (e.g., vibratory pile driving, drilling, etc.) (NMFS 2023b). This is an “unweighted” criterion that is applicable for all marine mammal species. In-air behavioral thresholds exist for harbor seals and non-harbor seal pinnipeds at 90 dB re 20 μPa SPL and 100 dB re 20 μPa SPL, respectively (NMFS 2023b). Unlike with sound exposure level-based thresholds, the accumulation of acoustic energy over time is not relevant for this criterion—meaning that exposures to noise above the behavioral disturbance threshold can occur even if an animal experiences a received SPL of 160 dB re 1 μPa very briefly in one instance.

While the behavioral disturbance threshold is generally applied in a binary fashion, as alluded to previously, there are numerous factors that determine whether an individual will be affected by a sound, resulting in substantial variability even in similar exposure scenarios. In particular, it is recognized that the context in which a sound is received affects the nature and extent of responses to a stimulus (Ellison et al. 2012; Southall et al. 2007). Therefore, a “step function” concept for behavioral disturbances was introduced by Wood et al. (2012) whereby proportions of exposed individuals experience behavioral disturbance at different received levels, centered at an SPL of 160 dB re 1 μPa. These probabilistic thresholds reflect the higher sensitivity that has been observed in beaked whales and migrating mysticete whales (Table B-27). At the moment, this step function provides additional insight to calculating level B takes for certain species groups. The M-weighting functions, described by Southall et al. (2007) and used for the Wood et al. (2012) probabilistic disturbance step thresholds, are different from the weighting functions by Finneran (2016), previously mentioned. The M-weighting was specifically developed for interpreting the likelihood of audibility, whereas the Finneran weighting functions were developed to predict the likelihood of auditory injury.

The COP (Appendix III-M; Epsilon 2023) applied both the NMFS-recommended unweighted and the frequency-weighted criteria (Wood et al. 2012) to estimate behavioral response to impulsive pile-driving sound (COP Appendix III-M, Table 8; Epsilon 2023). However, this impacts assessment relies on the ranges to the single step function threshold of SPL 160 dB referenced to 1 μPa (dB re 1 μPa) following the most current recommendations from NMFS (87 Fed. Reg. 126 [July 1, 2022]) and most applicable to marine mammals as an overall faunal group (Table B-27).

Table B-27: Behavioral Exposure Criteria

Marine Mammal Group	Probability of Response to Frequency-Weighted SPL[a] Impulsive Sources (dB re 1 µPa)				Unweighted SPL[b] Impulsive and Non-impulsive, Intermittent Sources (dB re 1 µPa)	Unweighted SPL[b] Non-impulsive, Continuous Sources (dB re 1 µPa)
	120	140	160	180	160	120
Harbor porpoise (*Phocoena phocoena*)	50%	90%	—	—	100%	100%
Migrating mysticete whales	10%	50%	90%	-	100%	100%
All other species (and behaviors)	—	10%	50%	90%	100%	100%

Sources: COP Appendix III-M; Epsilon 2023

µPa = micropascal; dB = decibel; SPL = root-mean-square sound pressure level; re = referenced to
Probability of behavioral response frequency-weighted SPL (dB re 1 µPa); probabilities are not additive
[a] Source: Wood et al. 2012
[b] Source: NMFS-recommended threshold (87 Fed. Reg. 126 [July 1, 2022])

For UXO detonations, the exposure assessment conducted by JASCO (2022) used the SEL-based PTS thresholds from Table B-26, but Level B exposures were estimated using SEL-based TTS thresholds as shown in Table B-28 because these are applicable for single detonation events that are proposed for Alternative B. Additionally, given the nature of underwater explosions, potential mortality and non-auditory injury were considered in the modeling study using peak pressure and acoustic impulse thresholds from the U.S. Navy (Table B-29) following the methodology of Hannay and Zykov (2022).

Table B-28: Temporary Threshold Shift Onset Acoustic Threshold Levels for Assessing Behavioral Disturbances from a Single Unexploded Ordnance Detonation

Hearing Group	TTS Onset Thresholds for Behavioral Disturbances (SEL_{24h})
LFC	168 dB re 1 µPa^2s
MFC	170 dB re 1 µPa^2s
HFC	140 dB re 1 µPa^2s
PPW	170 dB re 1 µPa^2s

Sources: JASCO 2023; NMFS 2018b

µPa^2s = micropascal squared second; dB re 1 µPa = decibels referenced to 1 micropascal; HFC = high-frequency cetacean (harbor porpoise [*Phocoena phocoena*]); SEL_{24h} = sound exposure level over 24 hours; LFC = low-frequency cetacean (all the large whales except sperm whales [*Physeter macrocephalus*]); MFC = mid-frequency cetacean (all dolphins, pilot whales, and sperm whales); PPW = pinnipeds in the water (all seals); TTS = temporary threshold shift

Table B-29: Threshold Criteria for Non-Auditory Injury During Potential Detonation of Unexploded Ordnances

Impact Criterion	Threshold
Onset Mortality—Impulse	$103M^{1/3}(1+\frac{D}{10.1})^{1/6}\ Pa-s$
Onset Injury—Impulse (non-auditory)	$47.5M^{1/3}(1+\frac{D}{10.1})^{1/6}\ Pa-s$
Onset Injury—Peak Pressure (non-auditory) for marine mammals	PK 237 dB re 1 µPa

Sources: COP Appendix III-M; Epsilon 2023; U.S. Navy 2017

D = animal depth; dB re 1 µPa = decibels referenced to 1 micropascal; M = animal mass in kilograms; Pa = pascal; PK = peak sound pressure level

JASCO modeled three levels of attenuation for impact pile driving: 0 dB (no attenuation), 10 dB, and 12 dB; and two levels of attenuation for potential UXO detonations: 0 dB and 10 dB (COP Appendix III-M; Epsilon 2023). The 0 dB level was modeled as a reference point to evaluate the effectiveness of the sound reduction technology capable of reducing the produced pressures by at least 10 dB as proposed under Alternative B. When comparing the two potential levels of attenuation for impact pile driving (10 dB and 12 dB), 10 dB represents the lowest level of noise attenuation which would result in the greatest risk of impact on marine mammals aside from no attenuation. Although the applicant has proposed to achieve 12 dB attenuation, the EIS assesses an attenuation level of only 10 dB as a maximum-case scenario for all applicable activities.

B.5.5 Marine Mammal Sound Exposure Estimates under the Proposed Action

As discussed in EIS Section 3.7, marine mammals occur in the RI/MA Lease Areas. Noise from proposed Project-related impact pile driving, vibratory setting, drilling, potential detonations of UXO, and HRG surveys has the potential to cause auditory impacts (i.e., PTS/Level A harassment) and behavioral impacts (i.e., Level B harassment) to marine mammals. As defined by the Marine Mammal Protection Act (U.S. Code Title 16, Section 1362[18][C][i]), Level A harassment "has the potential to injure a marine mammal or marine mammal stock in the wild," while Level B harassment "has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

Each activity has varying degrees of risk for auditory and behavioral impacts and are therefore discussed separately. The COP (Appendix III-M; Epsilon 2023) and the applicant's LOA application (JASCO 2023) modeled sound propagation for each activity.

The Project includes two potential construction schedules, which incorporate the maximum Project design envelope and allows for some flexibility in the final construction plan. The first construction schedule (Construction Schedule A) assumes a 2-year construction scenario where 54 Phase 1 WTGs are installed on monopiles, 53 Phase 2 WTGs are installed on monopiles, 23 Phase 2 WTGs are installed on jackets, and 2 ESPs are installed on jackets (one during each phase). Construction Schedule A assumes that foundations for all of Phase 1 and a portion of Phase 2 are installed in Year 1 and that the remaining Phase 2 foundations are installed in Year 2. Construction Schedule B assumes a 3-year construction scenario where 55 Phase 1 WTGs are installed on monopiles, 75 Phase 2 WTGs are installed on jackets, and 2 ESPs are installed on jackets (one during each phase). Construction Schedule B assumes that all ESP foundations and Phase 1 12-meter monopile WTG foundations are installed in Year 1 and that the Phase 2 jacket WTG foundations are installed in Years 2 and 3. However, under both construction schedules, two positions may potentially have co-located ESPs (i.e., two foundations installed at one grid position), resulting in 132 foundations, so although Table B-30 includes 133 foundations installed in this schedule, only 132 would be installed under the Proposed Action (JASCO 2023).

Construction Schedule B has the longest duration (3 years) and the greatest number of piling days. Therefore, Construction Schedule B is carried forward in the effects analysis for the Proposed Action. A summary of the number of piling days under Construction Schedule B is provided in Table B-30.

Table B-30: Maximum Monthly Pile-Driving Days, Construction Schedule B (All Years Summed)[a]

Month	Total Days of Impact Pile Driving	Total Days with Vibratory Setting Followed by Impact Pile Driving[b]	Total Days with Drilling[c]	Total Days of Foundation Installation
May	6	0	4	6
June	17	6	10	23
July	15	11	9	26
August	10	16	9	26
September	7	10	9	17
October	0	8	4	8
November	2	3	3	5
December	2	0	0	2
Total	59	54	48	113
Total days	113 days			
Total foundations	133 foundations			
Total piles	367 piles			

Source: JASCO 2023

[a] This schedule covers the 5-year period 2025–2029, during which pile installation is scheduled to begin in 2026. These dates reflect the currently projected construction start year and are subject to change because exact start dates and construction schedules are not currently available. No concurrent/simultaneous pile driving of foundations is planned.

[b] The number of days with vibratory pile setting is based on a percentage of the number of days of pile installation and includes installation of a mix of monopiles at a rate of both one per day and two per day, as well as installation of jacket foundations at a rate of four pin piles per day.

[c] As a conservative measure, it was assumed that vibratory pile setting and drilling would not occur on the same day, when possible. However, for months when the number of days with vibratory pile setting plus the number of days with drilling exceeded the total number of impact piling days that month, the minimum number of days of overlap possible for these two activities was assumed.

For each pile type, the modeling included a piling schedule that accounted for soft-start procedures (Tables B-31 through B-33), as well as noise attenuation of at least 10 decibels (dB). Noise attenuation may be achieved with a variety of systems such as HydroSound Damper, bubble curtains, IHC Hydrohammer noise mitigation systems, or similar. For this analysis, BOEM identified 10 dB as the most appropriate because the type and manufacturer of a sound attenuation system has not yet been identified (Bellmann et al. 2020).

Table B-31: Soft-Start Procedure for Each Modeled Foundation Under the Proposed Action Installed using Only Impact Pile Driving

12-Meter Monopile, 5,000 kJ Hammer			13-Meter Monopile, 5,000 kJ Hammer			12-Meter Monopile, 6,000 kJ Hammer			4-Meter Pin Pile, 3,500 kJ Hammer			13-Meter Monopile, 6,000 kJ Hammer[a]		
Energy Level (kJ)	Strike Count	Pile Penetration (%)	Energy Level (kJ)	Strike Count	Pile Penetration (%)	Energy Level (kJ)	Strike Count	Pile Penetration (%)	Energy Level (kJ)	Strike Count	Pile Penetration (%)	Energy Level (kJ)	Strike Count	Pile Penetration (%)
1,000	690	25	1,000	745	25	1,000	750	25	525	875	25	1,000	850	25
1,000	1,930	25	1,000	2,095	25	2,000	1,250	25	525	1,925	25	2,000	1,375	25
2,000	1,910	20	2,000	2,100	20	3,000	1,000	20	1,000	2,165	14	3,000	1,100	20
3,000	1,502	20	3,000	1,475	20	4,500	1,000	20	3,500	3,445	26	4,500	1,100	20
5,000	398	10	5,000	555	10	6,000	500	10	3,500	1,395	10	6,000	550	10
Total	6,430	100	Total	6,970	100	Total	4,500	100	Total	9,805	100	Total	4,975	100
Strike rate	30.0 blows per minute		Strike rate	30.0 blows per minute		Strike rate	25.0 blows per minute		Strike rate	30.0 blows per minute		Strike rate	27.6 blows per minute	

Source: COP Appendix III-M; Epsilon 2023
kJ = kilojoule
[a] Although the Proposed Action may install the 13-meter monopile foundations at a maximum of 6,000 kJ, this is not modeled beyond acoustic source modeling in JASCO (2023) and is not considered in the proposed construction schedule.

Table B-32: Soft-Start Procedure for Monopile Foundations Under the Proposed Action Installed using Vibratory Pile Setting Followed by Impact Pile Driving

12-Meter Monopile			13-Meter Monopile			12-Meter Monopile			13-Meter Monopile			All Monopiles
Vibratory Hammer	5,000 kJ Impact Hammer		Vibratory Hammer	5,000 kJ Impact Hammer		Vibratory Hammer	6,000 kJ Impact Hammer		Vibratory Hammer	6,000 kJ Impact Hammer		
Duration (minute)	Energy Level (kJ)	Strike Count	Duration (minute)	Energy Level (kJ)	Strike Count	Duration (minute)	Energy Level (kJ)	Strike Count	Duration (minute)	Energy Level (kJ)	Strike Count	Pile Penetration (%)
60	—	—	60	—	—	60	—	—	60	—	—	25
—	1,000	1,930	—	1,000	2,095	—	2,000	1,250	—	2,000	1,375	25
—	2,000	1,910	—	2,000	2,100	—	3,000	1,000	—	3,000	1,100	20
—	3,000	1,502	—	3,000	1,475	—	4,500	1,000	—	4,500	1,100	20
—	5,000	398	—	5,000	555	—	6,000	500	—	6,000	550	10
—	Total	5,740	—	Total	6,225	—	Total	3,750	—	Total	4,125	100
Frequency: 20 Hz	Strike rate: 30.0 blows per minute		Frequency: 20 Hz	Strike rate: 30.0 blows per minute		Frequency: 20 Hz	Strike rate: 30.0 blows per minute		Frequency: 20 Hz	Strike rate: 30.0 blows per minute		—

Source: COP Appendix III-M; Epsilon 2023
Hz = hertz; kJ = kilojoule

Table B-33: Soft-Start Procedure for Jacket Foundations Under the Proposed Action Installed using Vibratory Pile Setting Followed by Impact Pile Driving

4-Meter Pin Pile			
Vibratory Hammer	3,500 kJ Impact Hammer		
Duration (minute)	Energy Level (kJ)	Strike Count	Pile Penetration (%)
60	—	—	25
—	525	1,925	25
—	1,000	2,165	14
—	3,500	3,445	26
—	3,500	1,395	10
—	Total	8,930	100
Frequency: 20 Hz	Strike rate: 30.0 blows per minute		

Source: COP Appendix III-M; Epsilon 2023
Hz = Hertz; kJ = kilojoule

The proposed Project also includes potential detonations of UXO. Initial geophysical survey results suggest there is a moderate risk of encountering UXOs within the SWDA and OECC. The preferred approach if UXOs are encountered is avoidance in which the WTG and ESP foundations and associated cables would be relocated to avoid the UXOs. There may be instances where avoidance of the UXOs are not feasible, so in-situ detonation would be required to continue construction activities such as foundation installation and cable-laying activities. The selection of the disposal method would be determined by the size, location, and condition of each individual UXO that the proposed Project may encounter (JASCO 2023). If detonation of UXOs is necessary, detonation noise has the potential to cause non-auditory injuries, potential mortal injuries, PTS or TTS in marine mammals, sea turtles, and marine fish. Therefore, this activity is assessed in the EIS. It is currently assumed up to 10 UXOs may require in-situ detonation over 2 years of construction (i.e., 6 in Year 1 and 4 in Year 2).

To estimate marine mammal densities (animals per square kilometer) for the modeling, JASCO (2023) used the most recent models available for each species from the Duke University Marine Geospatial Ecological Laboratory (Roberts et al. 2022). This is considered the best available information to be used for modeling in this assessment. The mean density for each month was calculated using the mean of all (5 × 5 kilometers [3.1 × 3.1 miles]) grid cells partially or fully within a 10-kilometer (6-mile) buffer around the SWDA for vibratory pile setting followed by impact pile driving and impact pile driving only; these were determined based on the longest 95th percentile exposure-based range ($ER_{95\%}$) estimated by JASCO (2023) for impact pile driving only and the smallest acoustic range from the COP (Appendix III-M; Epsilon 2023). Density values from the data are given in units of animals per 100 square kilometers (km^2; 38.6 square miles). The mean density between May to December were also calculated to coincide with planned impact pile-driving activities. Table B-34 provides the mean monthly and May to December averages for marine mammals included in the modeling. Blue whale densities from Roberts et al. (2022) were not applied to the modeling as they are considered a rare species within the proposed Project area (JASCO 2023).

Table B-34: Mean Density Estimates for Marine Mammal Species Modeled in a 10-Kilometer (6-Mile) Perimeter[a] around the Southern Wind Development Area for all Months

Common Name (Scientific Name)	Monthly Density (animals per 100 km²)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	May to December Mean[b]
Fin whale (*Balaenoptera physalus*)	0.215	0.166	0.107	0.164	0.272	0.256	0.438	0.366	0.227	0.057	0.051	0.141	0.226
Minke whale (*Balaenoptera acutorostrata*)	0.113	0.137	0.136	0.806	1.728	1.637	0.700	0.471	0.516	0.465	0.052	0.077	0.706
Humpback whale (*Megaptera novaeangliae)*	0.031	0.023	0.043	0.149	0.294	0.307	0.172	0.120	0.167	0.236	0.190	0.030	0.189
NARW (*Eubalaena glacialis*)	0.387	0.461	0.456	0.478	0.295	0.050	0.022	0.018	0.028	0.052	0.068	0.197	0.091
Sei whale *(Balaenoptera borealis*)	0.039	0.021	0.044	0.112	0.192	0.052	0.013	0.011	0.019	0.036	0.079	0.065	0.058
Sperm whale (*Physeter macrocephalus*)	0.031	0.011	0.013	0.003	0.014	0.028	0.038	0.107	0.070	0.057	0.031	0.020	0.046
Atlantic white-sided dolphin (*Lagenorhynchus acutus)*	2.049	1.230	0.850	1.313	3.322	3.003	1.392	0.730	1.654	2.431	1.791	2.440	2.095
Atlantic spotted dolphin (*Stenella frontalis)*	0.001	<0.001	<0.001	0.003	0.018	0.025	0.031	0.054	0.273	0.431	0.179	0.018	0.128
Short-beaked common dolphin (*Delphinus delphis)*	7.130	2.455	1.884	3.258	6.254	13.905	10.533	14.446	25.703	22.676	11.103	10.774	14.424
Common bottlenose dolphin (*Tursiops truncates)*	0.495	0.111	0.059	0.156	0.814	1.358	1.479	1.659	1.483	1.337	1.255	1.101	1.311
Risso's dolphin (*Grampus griseus)*	0.043	0.004	0.002	0.018	0.096	0.048	0.068	0.128	0.158	0.087	0.120	0.179	0.111
Long-finned pilot whale (*Globicephala melas)*	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189
Short-finned pilot whale (*Globicephala macrorhynchus)*	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
Harbor porpoise (*Phocoena phocoena)*	10.007	10.784	10.277	8.914	6.741	0.960	0.880	0.848	0.988	1.271	1.418	5.812	2.365
Gray seal (*Halichoerus grypus)*	5.395	5.603	4.176	3.203	4.716	0.806	0.088	0.094	0.226	0.500	1.768	4.534	1.591
Harbor seal (*Phoca vitulina)*	8.093	8.404	6.265	4.804	7.074	1.209	0.132	0.140	0.339	0.750	2.652	6.802	2.387
Harp seal (*Pagophilus groenlandicus)*	5.781	6.003	4.475	3.432	5.053	0.864	0.094	0.100	0.242	0.535	1.894	4.858	1.705

Source: JASCO 2023
km² = square kilometer; SWDA = Southern Wind Development Area
[a] The perimeter around the SWDA was determined based on the longest exposure range to the thresholds for vibratory pile setting from the modeling (JASCO 2023).
[b] Pile-driving activities would only occur from May to December.

The following subsections summarize the results of the animal exposure modeling conducted for the Project's Incidental Take Regulation application (JASCO 2023) and COP (Appendix III-M; Epsilon 2023), which incorporate the schedules and densities provided above.

B.5.5.1 Noise Exposure from Foundation Installation Activities

The WTG and ESP foundations would be installed using a combination of vibratory pile setting and impact pile driving. Sixty-three of the 132 foundations, which includes all pile types (i.e., 12-meter monopile, 13-meter monopile, and 4-meter pin pile for the jacket foundations), would be installed using impact pile driving; the remaining foundations would be installed first using vibratory pile setting followed by impact pile driving. The applicant has determined it may be necessary to start pile installation using a vibratory hammer rather than using an impact hammer, a technique known as vibratory setting of piles. The vibratory method is particularly useful when seabed sediments are not sufficiently stiff to support the weight of the pile during the initial installation, increasing the risk of 'pile run' where a pile sinks rapidly through seabed sediments. A seabed drivability analysis conducted by the applicant estimated the number of foundation positions that could potentially require vibratory setting of piles. The analysis suggested that up to 50 percent of foundations (approximately 66 foundations) could require vibratory setting. An additional 6 percent conservatism is assumed (6 percent of 66 is approximately 4 additional foundations), resulting in approximately 70 total foundations (53 percent of all proposed foundations) that may require vibratory setting (JASCO 2023; COP Appendix III-M; Epsilon 2023).

The piling soft-start schedule for impact pile driving only and vibratory pile setting followed by impact pile driving are provided in Tables B-31 through B-33 for all foundation types. These piling schedules were used in the acoustic propagation and exposure modeling to estimate the threshold ranges and exposure estimates. The piling schedules determine the overall duration of piling activities for each foundation. For consecutive piles, a delay in the pile schedule is included between foundation installation event; for foundations requiring vibratory pile setting, 15 minutes were also included in between the vibratory and impact hammering to account for the time needed to switch equipment (JASCO 2023; COP Appendix III-M; Epsilon 2023).

The JASCO Applied Sciences Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the probability of exposure of animals to sound above thresholds arising from the proposed Project's impact pile-driving activities. Sound exposure models like JASMINE use simulated animals (animats) to sample the predicted 3D sound fields with movement rules derived from animal observations (JASCO 2023). Modeled sound fields are generated from representative pile locations, and animats are programmed to behave like the marine animals that may be present in the proposed Project area. The parameters used for forecasting realistic behaviors (e.g., diving, foraging, aversion, surface times) are determined and interpreted from marine species studies (e.g., tagging studies), where available or reasonably extrapolated from related species as referenced in the model (JASCO 2023; COP Appendix III-M; Epsilon 2023).

The acoustic modeling to SEL thresholds, without considering animal movement, produces the 95th percentile acoustic ranges at which a marine mammal would have to remain stationary for the entire duration of the activity to be exposed to levels above the stated threshold. To provide a realistic estimate of distances at which acoustic thresholds for marine mammals may be met, the COP (Appendix III-M; Epsilon 2023) modeled exposure ranges to PTS and behavioral thresholds for impulsive sources. To determine exposure ranges, pile strikes are propagated to create an ensonified environment while simulated animals (i.e., animats) are moved about the ensonified area following expected species-specific behaviors. Modeled animats that have received sound energy that exceeds the acoustic threshold criteria are registered, and the closest point of approach recorded at any point in that animal's movement is then reported as its exposure range. This process is repeated multiple times for each animat. The exposure-based ranges represent the range over which 95 percent of the closest points of approaches for animats that exceeded the threshold (i.e., $ER_{95\%}$). The potential for noise from vibratory pile setting to induce PTS is low relative to impact pile driving; however, due to the relatively short (15-minute) period between vibratory and impact piling for each foundation, vibratory setting and impact pile driving must be considered together as part of the total received acoustic energy for the entire pile installation (JASCO 2023; COP Appendix III-M; Epsilon 2023).

The Project design envelope described in EIS Section 2.1.2, Alternative B – Proposed Action, includes installation of both one and two monopile foundations installed per day. However, the modeled $ER_{95\%}$ with 10 dB noise attenuation for all pile types installed using impact pile driving only summarized in Table 3.7-9 and piles installed using vibratory pile setting followed by impact pile driving summarized in Table 3.7-10 in EIS Section 3.7 represent the results for only installation of up to two monopiles per day, as these were the largest ranges for these foundation types, which enabled a conservative assessment of impacts in the EIS. As discussed further in this section, the exposure estimates account for the full construction schedule in Table B-30, which accounts for both scenarios (i.e., days where one pile is driven and days where two piles are driven). All pin piles would be installed at a rate of four piles per day.

The applicant's requested take numbers for Level A harassment authorization were based on an expectation that 10 dB sound attenuation would be the minimal attenuation level achieved during the proposed activity. Information on sound reduction effectiveness reviewed in the COP (Appendix III-M; Epsilon 2023) and LOA application (JASCO 2023) included sources such as the California Department of Transportation bubble curtain "on and off" studies conducted in San Francisco Bay in 2003 and 2004 (Caltrans 2015). A review of performance measured during impact driving for wind energy facility foundation installation (Bellmann et al. 2020) provides expected performance for common noise reduction system configurations. Measurements with a single bubble curtain and an air supply of 0.3 cubic meters per minute resulted in 7 to 11 dB of broadband attenuation for optimized systems in up to 131-foot water depth. Increased air flow (0.5 cubic meters per minute meter) may improve the attenuation levels up to 11 to 13 dB (JASCO 2023). Double bubble curtains add sound impedance and, for optimized systems, can achieve 15 to 16 dB of broadband attenuation (measured in up to 131-foot water depth). An IHC Hydrohammer noise mitigation system can provide 15 to 17 dB of attenuation but is currently limited to piles under 8 meters in diameter. Other attenuation systems such as the AdBm noise mitigation system achieved 6 to 8 dB (JASCO 2023), while Hydro Sound Dampers were measured at 10 to 12 dB attenuation and are independent of depth (Bellmann et al. 2020). Systems may be deployed in series to achieve higher levels of attenuation).

Based on the best available information (Bellmann et al. 2020; Caltrans 2015; JASCO 2023), it is reasonable to assume the applicant may achieve up to 12 dB noise attenuation due to implementation of noise attenuation during foundation installation activities. The applicant has not identified the specific attenuation system that would ultimately be used during the proposed activity (e.g., what size bubbles and in what configuration a bubble curtain would be used; whether a double curtain would be employed; whether Hydro Sound Dampers, noise abatement system, or some other alternate attenuation device would be used). In the absence of specific information regarding the attenuation system that would be ultimately used, and in consideration of the available information on attenuation that has been achieved during impact pile driving, the EIS conservatively assumes that the lower-level effectiveness of 10 dB sound attenuation would be achieved (although greater noise attenuation may be achieved).

Modeled $ER_{95\%}$ to Level B harassment with 10 dB attenuation during impact pile driving is lower for jacket piles (2.5 to 3.0 miles depending on the hearing group) compared to the monopiles (2.6 to 3.4 miles depending on the hearing group) for all marine mammals (Tables 3.7-9 and 3.7-10 in EIS Section 3.7) (COP Appendix III-M; Epsilon 2023). Even with a minimum of 10 dB attenuation, Level B harassment to marine mammals during foundation installation activities are likely to occur due to the large radial distance to this threshold and the number of days that pile driving may occur.

Modeled $ER_{95\%}$ to thresholds for Level A harassment were the largest for low-frequency cetaceans (LFC) (mysticetes) (Tables 3.7-9 and 3.7-10 in EIS Section 3.7). The isopleths for Level A harassment during foundation installation with 10 dB noise attenuation for NARW, fin whale, sei whale, humpback whales (*Megaptera novaeangliae*), and minke whales (*Balaenoptera acutorostrata*) averaged 1.6 miles for jacket foundations (pin piles) and 1.1 miles for monopiles. These ranges can be effectively monitored using a combination of visual and acoustic monitoring as is proposed for this Project (EIS Appendix H).

Modeled $ER_{95\%}$ to thresholds for Level A harassment during foundation installation were a maximum of 2,592 feet for seals (pinnipeds in water hearing group) and 755 feet for harbor porpoise (*Phocoena phocoena*; high-frequency cetacean [HFC] hearing group) and 0 feet for small for dolphins, pilot whales, and sperm whales (mid-frequency cetacean [MFC] hearing group) (Tables 3.7-9 and 3.7-10 in EIS Section 3.7).

Table B-35 summarizes the numbers of marine mammals estimated to experience sound levels above threshold criteria for Level A and B harassment for the construction schedule in Table B-30 with 10 dB noise attenuation during impact pile driving (JASCO 2023). The exposure estimates incorporate a construction schedule that includes a combination of foundations installed with vibratory setting of piles followed by impact pile driving and foundations installed with impact pile driving alone for all foundation types (JASCO 2023).

Table B-35: Number of Animals Exposed to Noise at or Above Thresholds for All Foundation Types[a] over All 3 Years of Construction under the Proposed Action with 10 Decibel Noise Attenuation

Species	Level A Harassment	Level B Harassment
Fin whale (*Balaenoptera physalus*)[b]	33	349
Humpback whale (*Megaptera novaeangliae*)	29	247
Minke whale (*Balaenoptera acutorostrata*)	140	1,009
NARW (*Eubalaena glacialis*)[b]	0[c]	74
Sei whale (*Balaenoptera borealis*)[b]	6	50
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	0	3,427
Atlantic spotted dolphin (*Stenella frontalis*)	0	227
Common bottlenose dolphin (*Tursiops truncatus*)	0	3,622
Long-finned pilot whale (*Globicephala melas*)	0	3,622
Short-finned pilot whale (*Globicephala macrorhynchus*)	0	370
Risso’s dolphin (*Grampus griseus*)	0	698
Common dolphin (*Delphinus delphis)*	0	48,808
Sperm whale (*Physeter macrocephalus*)[b]	0	97
Harbor porpoise (*Phocoena phocoena*)	18	1,594
Gray seal (*Halichoerus grypus*)	3	2,036
Harbor seal (*Phoca vitulina*)	3	1,072
Harp seal (*Pagophilus groenlandicus*)	3	2,841

Source: JASCO 2023

NARW = North Atlantic right whale

[a] The exposure estimates in this table include all foundations under the Proposed Action as a combination of foundations installed with vibratory setting of piles followed by impact pile driving and foundations installed with impact pile driving alone using the construction schedule in Table 1-3 of the BA (BOEM 2023a).

[b] This is an ESA-listed species.

[c] Five PTS exposures were estimated for NARW, but due to mitigation measures proposed, no PTS (Level A takes) exposures are expected, and no Level A takes have been requested for this species. PTS and behavioral exposures are based on the number of Level A and Level B takes requested in the draft Incidental Take Authorization (ITA) application addendum (JASCO 2023).

B.5.5.2 Noise Exposure from Foundation Drilling

Exposures for foundation drilling activities were only calculated for Level B harassment thresholds because the estimate Level A threshold ranges were so small that no Level A harassment is expected to result from these activities (JASCO 2023). The range to the SPL 120 dB re 1 µPa threshold for non-impulsive, continuous sources was calculated and then used to estimate a daily impact area for each activity, calculated as the area of a circle where the radius is the range to the threshold. The threshold ranges were estimated to be 23,143 feet for all marine mammals during foundation drilling. For the exposure assessment, JASCO (2023) assumed approximately 30 percent of the foundation positions would encounter hard sediments and pile refusal, which would require drilling activities with a 20 percent contingency added to each. This equates to a total of 48 foundations requiring drilling, which are included in the construction schedule shown in Table B-30. The exposure estimates in Table B-36 represent the total exposures for all years of construction based on the higher of the take estimates from either Schedule A or Schedule B for each species, as this is what was used for the final take request in the proposed Project's Incidental Take Regulation (JASCO 2023).

Table B-36: Estimated Number of Marine Mammals Exposed above Level B Harassment Thresholds during Drilling of Foundations (All Years Combined)

Species	Maximum Level B Harassment
Fin whale (*Balaenoptera physalus*)[a]	30
Humpback whale (*Megaptera novaeangliae*)	22
Minke whale (*Balaenoptera acutorostrata*)	78
NARW (*Eubalaena glacialis*)[a]	6
Sei whale (*Balaenoptera borealis*)[a]	5
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	182
Atlantic spotted dolphin (*Stenella frontalis*)	14
Common bottlenose dolphin (*Tursiops truncatus*)	143
Long-finned pilot whale (*Globicephala melas*)	20
Short-finned pilot whale (*Globicephala macrorhynchus*)	6
Risso's dolphin (*Grampus griseus*)	12
Common dolphin (*Delphinus delphis*)	1,575
Sperm whale (*Physeter macrocephalus*)[a]	7
Harbor porpoise (*Phocoena phocoena*)	137
Gray seal (*Halichoerus grypus*)	69
Harbor seal (*Phoca vitulina*)	103
Harp seal (*Pagophilus groenlandicus*)	74

Source: JASCO 2023

NARW = North Atlantic right whale
[a] This is an ESA-listed species.

B.5.5.3 Noise Exposure from Unexploded Ordnance

Due to the mitigation and monitoring measures proposed (EIS Appendix H) and the relatively small size of the peak pressure and acoustic impulse threshold ranges for UXO detonations compared to PTS and TTS ranges, no non-auditory injury or mortality is expected for any species (JASCO 2023). For potential UXO detonations, the modeling followed the study conducted by Hannay and Zykov (2022), which groups potential UXOs into five "bins" based on the maximum UXO charge weights (JASCO 2023). These activities could potentially expose animals to Level A and Level B TTS. The radial distances to the SEL-based criteria and Lpk ranges for PTS and TTS for UXO detonations with 10 dB attenuation are provided in the LOA application (JASCO 2023). The LFC radial threshold distances range from 2 miles in shallow water (12 meters/39 feet or less) to 2.2 miles in deep water (45 meters/147 feet or more), while the HFC distances hover around from 3.8 miles in shallow and deep water. Exposures for potential UXO detonations were estimated by multiplying the impact areas in the LOA application (JASCO 2023) by the highest monthly species density in the deep water OECC segment and the SWDA for the 20- to 45-meter (66- to 147-foot) depths and by the highest monthly species density in the shallow water OECC segment for the 12-meter (39-foot) depth (JASCO 2023). The result of the areas multiplied by the densities were then multiplied by the number of UXOs estimated at each of the depths from preliminary geophysical and camera survey data and the proposed schedule provided in Section B.4.5, Sound Source Calculation, to calculate total estimated exposures in Table B-37.

Table B-37: Maximum Estimated Marine Mammal Exposures above Harassment Thresholds Due to Unexploded Ordinance Detonations[a]

Species	Level A Harassment (PTS SEL_{24h})	Level B Harassment (TTS SEL_{24h})
Fin whale (*Balaenoptera physalus*)[b]	2	14
Humpback whale (*Megaptera novaeangliae*)	2	10
Minke whale (*Balaenoptera acutorostrata*)	7	55
NARW (*Eubalaena glacialis*)[b]	0[c]	27
Sei whale (Balaenoptera borealis)[b]	2	7
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	2	6
Atlantic spotted dolphin (*Stenella frontalis*)	2	2
Common bottlenose dolphin (*Tursiops truncatus*)	2	4
Long-finned pilot whale (*Globicephala melas*)	2	2
Short-finned pilot whale (*Globicephala macrorhynchus*)	2	2
Risso's dolphin (*Grampus griseus*)	2	2
Common dolphin (*Delphinus delphis*)	2	38
Sperm whale (*Physeter macrocephalus*)[b]	2	2
Harbor porpoise (*Phocoena phocoena*)	107	410
Gray seal (*Halichoerus grypus*)	12	226
Harbor seal (*Phoca vitulina*)	25	507
Harp seal (*Pagophilus groenlandicus*)	12	226

Source: JASCO 2023

NARW = North Atlantic right whale; PTS = permanent threshold shift; SEL_{24h} = sound exposure level over 24 hours [weighted by hearing group, in units of dB referenced to 1 $\mu Pa^2 s$]; TTS = temporary threshold shift; UXO = unexploded ordnance
[a] Data are for possible detonation of up to 10 UXOs over 2 years with 10 dB noise attenuation.
[b] This is an ESA-listed species.
[c] Two PTS exposure were estimated for NARW, but due to mitigation measures proposed by the applicant, no PTS (Level A takes) exposures are expected, and no Level A takes have been requested for these species. PTS and behavioral exposures are based on the number of Level A and Level B takes requested in the draft ITA application addendum (JASCO 2023).

B.5.5.4 Noise Exposure from High-Resolution Geophysical Surveys

Proposed HRG surveys assume the use of two pieces of equipment: the Applied Acoustics AA251 Boomer and the GeoMarine Geo Spark 2000 (JASCO 2023). No Level A exposures are expected to occur during HRG surveys from either type of equipment. It was assumed that HRG surveys would be conducted for 24 hours per day for up to 25 days each year (totaling 125 days over the 5-year ITA period) beginning in the first year of foundation installation and extending 2 years beyond the 3-year foundation installation schedule (JASCO 2023). JASCO conducted acoustic modeling for the HRG survey equipment proposed for the Project, and the Level B exposure estimates are provided in Table B-38.

Table B-38: Estimated Marine Mammal Exposures above Level B Harassment Thresholds Annually during High-Resolution Geophysical Surveys

Species	Applied Acoustics AA251 Boomer	GeoMarine Geo Spark 2000
Fin whale (*Balaenoptera physalus*)[a]	3.11	2.47
Humpback whale (*Megaptera novaeangliae*)	2.31	1.83
Minke whale (*Balaenoptera acutorostrata*)	12.17	9.64
NARW (*Eubalaena glacialis*)[a]	4.05	3.21
Sei whale (*Balaenoptera borealis*)[a]	1.38	1.09
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	24.34	19.26
Atlantic spotted dolphin (*Stenella frontalis*)	2.88	2.28
Common bottlenose dolphin (*Tursiops truncatus*)	12.53	9.92
Long-finned pilot whale (*Globicephala melas*)	1.06	0.84
Short-finned pilot whale (*Globicephala macrorhynchus*)	0.78	0.62
Risso's dolphin (*Grampus griseus*)	1.34	1.06
Common dolphin (*Delphinus delphis*)	202.3	160.13
Sperm whale (*Physeter macrocephalus*)[a]	0.79	0.62
Harbor porpoise (*Phocoena phocoena*)	78.41	62.07
Gray seal (*Halichoerus grypus*)	199.35	157.8
Harbor seal (*Phoca vitulina*)	447.89	354.54
Harp seal (*Pagophilus groenlandicus*)	199.35	157.8

Source: JASCO 2023

NARW = North Atlantic right whale
[a] This is an ESA-listed species.

B.5.5.5 Incidental Take Requested

For the proposed Project, the calculated exposure numbers in Tables B-35 through B-38 differ from the total number of takes requested in the LOA application (JASCO 2023). The requested numbers shown in Table B-39 were adjusted from the calculated exposures using the following assumptions, summarized from JASCO 2023:

- For impact pile driving, the greater of the two Level A exposure estimates (SEL_{24h} or PK) was rounded up to a whole number and used to compute the requested Level A take.
- Although it was calculated, no Level A take for NARW from any activity was requested because of the proposed mitigation and monitoring measures (Appendix H).
- For the total requested take for foundation installation, the estimated exposures were corrected for two average group sizes for Construction Schedule A (2-year schedule) and for three average groups sizes under Construction Schedule B (3-year schedule) using group size data (88 Fed. Reg. 37606 [June 8, 2023]).
- The total requested take used the construction schedule that resulted in the greatest number of estimated Level B exposures during foundation installation and drilling when all years were combined and rounded up to a whole number for each species (i.e., Construction Schedule B was assumed for all species except NARW, gray seals [*Halichoerus grypus*], and harp seals [*Pagophilus groenlandicus*]).
- For days when pile installation was assumed to include both vibratory setting and drilling, only Level B take from vibratory setting was included in the total number of requested takes to avoid double counting as this activity resulted in the greater number of estimated exposures.

- Exposure estimates for potential UXO removal were rounded up to a whole number.
- For HRG surveys, the equipment resulting in the greatest number of estimated exposures was carried forward in the total requested take.
- Common dolphin (*Delphinus delphis*) exposures during HRG surveys were increased to 2,000 for the 5 years of HRG surveys based on protected species observer data collected during surveys in 2020 and 2021 (JASCO 2023).
- The blue whale was not modeled with the other species by JASCO (2023) because they are considered rare in the proposed Project area; instead, they were included based on the estimated group size. To allow for maximum flexibility and uncertainty in construction schedules, a 3-year construction schedule was assumed for potential exposures of rare species, assuming one group of each rare species could be exposed above Level A and B thresholds in any 2 years of the 3-year construction schedule.

Table B-39: Total Requested Incidental Take for All Activities for the 5-Year Effective Period of the Incidental Take Regulation

Species	Takes by Level A Harassment	Takes by Level B Harassment
Fin whale (*Balaenoptera physalus*)	36	403
Humpback whale (*Megaptera novaeangliae*)	33	282
Minke whale (*Balaenoptera acutorostrata*)	148	1,058
NARW (*Eubalaena glacialis*)	0	132
Sei whale (*Balaenoptera borealis*)	8	67
Blue whale (*Balaenoptera musculus*)	2	113
Sperm whale (*Physeter macrocephalus*)	2	3,465
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	2	3,465
Atlantic spotted dolphin (*Stenella frontalis*)	2	419
Common bottlenose dolphin (*Tursiops truncatus*)	2	3,747
Long-finned pilot whale (*Globicephala melas*)	2	461
Short-finned pilot whale (*Globicephala macrorhynchus*)	2	79
Risso's dolphin (*Grampus griseus*)	2	790
Common dolphin (*Delphinus delphis*)	2	49,502
Harbor porpoise (*Phocoena phocoena*)	125	2,426
Gray seal (*Halichoerus grypus*)	15	3,586
Harbor seal (*Phoca vitulina*)	28	3,895
Harp seal (*Pagophilus groenlandicus*)	15	4,395

Source: JASCO 2023

NARW = North Atlantic right whale

The applicant's self-imposed mitigation measures, including use of soft-start procedures, protected species observers, and PAM would reduce the risk of threshold-level exposures to marine mammals. BOEM could further reduce potential impacts on marine mammals by implementing additional mitigation and monitoring measures outlined in EIS Appendix H, which could include long-term PAM; daily, pre-construction PAM and visual surveys; a sunrise and sunset prohibition on pile driving; and requiring the use of noise reduction technologies during all pile-driving activities to achieve a minimum broadband attenuation (reduction) of 10 dB.

The specific noise attenuation technologies for the proposed Project have not yet been selected. Potential options include a noise mitigation system, hydro sound damper, noise abatement system, a bubble curtain(s), another similar technology, or a combination of several systems (COP Appendix III-M;

Epsilon 2023; JASCO 2023). In addition to the use of noise attenuation system(s), the applicant has committed to complete sound field verification and to have a second attenuation technology on hand, which would be deployed if sound field verification demonstrates a need for greater attenuation. Exposure estimates and underwater noise associated with the proposed Project and the resulting anticipated take of marine mammals is based upon achieving 10 dB reduction of pile-driving noise and potential UXO detonation noise using one or multiple sound attenuation technologies. Should greater attenuation be achieved, fewer individuals than estimated would be exposed to harassing or injurious levels of sound. These measures would reduce noise impacts during construction and the likelihood of impacts on individual marine mammals but would not result in a change to the significance level of impacts.

B.5.5.6 Summary

As described above, the applicant modeled the potential for marine mammal to be exposed to proposed Project-related harassing or injurious sound levels that may result in take, as defined by the ESA. BOEM has initiated interagency consultation with NMFS under ESA Section 7. Table B-40 presents the maximum amount of marine mammal take for ESA-listed species and is consistent with the amount of Level A and B harassment that is presented in the LOA application (JASCO 2023).

Table B-40: Take of Endangered Species Act-listed Marine Mammals due to Exposure to All Potential Noise-Producing Proposed Project Activities[a]

Species	TTS/Behavioral Response	Auditory Injury (PTS)
NARW (*Eubalaena galcialis*)	132	0
Fin whale (*Balaenoptera physalus*)	403	36
Sperm whale (*Physeter macrosephalus*)	113	2
Sei whale (*Balaenoptera borealis*)	67	9
Blue whale (*Balaenoptera musculus*)	4	2

Source: JASCO 2023

dB = decibel; PTS = permanent threshold shift; NARW = North Atlantic right whale; TTS = temporary threshold shift; UXO = unexploded ordnance

[a] 10 dB broadband noise attenuation was applied to the take calculations for impact pile driving and potential UXO detonations.

B.6 Sea Turtle Sound Exposure Estimates

As discussed in EIS Section 3.8, sea turtles occur seasonally within the RI/MA Lease Areas. Underwater noise generated by impact pile driving during installation of WTG and ESP foundations; vibratory pile setting during installation of WTG and ESP foundations; foundation drilling during installation of the WTG and ESP foundations; potential UXO detonations; HRG surveys; vessel activity; and WTG operation would increase sound levels in the marine receiving environment and may result in potential adverse impacts on sea turtles in the proposed Project area including PTS and behavioral disturbances. Exposure modeling was conducted for up to 132 foundations using 12-meter (39-foot) monopiles, 13-meter (42-foot) monopiles, and 4-meter (13-foot) pin piles. Sea turtle sound exposure estimates were only modeled for impact pile driving (Appendix III-M; Epsilon 2023); therefore, potential impacts from the remaining sound sources are based on the qualitative assessment of underwater noise provided in EIS Section 3.8.

In general, sea turtle auditory perception is thought to occur through a combination of both bone and water conduction rather than air conduction (Lenhardt and Harkins 1983; Lenhardt et al. 1985). The outermost part of the sea turtle ear, or tympanum, is covered by a thick layer of skin covering a fatty layer that conducts sound in water to the middle and inner ear. This is a distinguishing feature from terrestrial and semi-aquatic turtles. This thick outer layer makes it difficult for turtles to hear well in air, but it facilitates the transfer of sound from the aqueous environment into the ear (Ketten et al. 1999). The middle ear has two components that are encased by bone, the columella and extracolumella, which provide the pathway for sound from the tympanum on the surface of the turtle head to the inner ear consisting of the cochlea and basilar membrane. This arrangement enables sea turtles to hear low-frequency sounds while underwater. The middle ear is also connected to the throat by the Eustachian tube. Because there is air in the middle ear, it is generally believed that sea turtles detect sound pressure rather than particle motion. Vibrations can also be conducted through the bones of the carapace to reach the middle ear. Based on studies of semi-aquatic turtles, Christensen-Dalsgaard et al. (2012) speculated that the sea turtle ear may not be specialized for bone conduction, but rather that sound-induced pulsations may drive the tympanic disc if the middle ear cavity is air-filled. A detailed description of sea turtle auditory anatomy and different hearing capabilities of each species are available in Reese et al. (2023).

Hearing in sea turtles has been measured through electrophysiological and/or behavioral studies both in air and water on a limited number of life stages for each of the five species. In general, sea turtles hear best in water between 100 to 750 Hz, do not hear well above 1 kHz, and are generally less sensitive to sound than marine mammals (Reese et al. 2023; Papale et al. 2020). While there are still substantial data gaps on hearing sensitivity across species and throughout ontogeny, there is data on loggerhead hearing capabilities at the post-hatchling (Lavender et al. 2012; 2014), juvenile (Bartol et al. 1999; Lavender et al. 2012, 2014b), and adult stages (Martin et al. 2012). The primary data available on sea turtle hearing abilities are summarized in Table B-41.

Table B-41: Hearing Capabilities of Sea Turtles

Sea Turtle Species	Hearing Range (Hz)	Hearing Highest Sensitivity (Hz)	Source
Green sea turtle (*Chelonia mydas*)	60–1,000	300–500	Ridgway et al. 1969
	100–800	600–700 (juveniles) 200–400 (subadults)	Bartol and Ketten 2006; Ketten and Bartol 2005
	50–1,600	50–400	Piniak et al. 2016
Loggerhead (*Caretta caretta*)	250–1,000	250	Bartol et al. 1999
	50–1,100	100–400	Martin et al. 2012; Lavender et al. 2014
Kemp’s Ridley (*Lepidochelys kempii*)	100–500	100–200	Bartol and Ketten 2006; Ketten and Bartol 2005
Leatherback (*Dermochelys coriacea*)	50–1,200 (underwater)	100–400	Piniak et al. 2012

Hz = hertz

Table B-42 outlines the acoustic thresholds for the onset of PTS and behavioral disruptions for sea turtles for impulsive and non-impulsive noise sources. Also known as auditory fatigue, TTS is the milder form of hearing impairment that is non-permanent and reversible and results from exposure to high-intensity sounds for short durations or lower intensity sounds for longer durations. TTS thresholds, though not considered in this assessment, are available for sea turtles.

TTS is typically applied when assessing regulatory impacts of high-order detonations like military operations or explosions; however, as more research is done, TTS may play a bigger role in sea turtle impact assessment in the future. Until more studies improve the understanding of TTS in sea turtles, ranges to TTS thresholds and TTS exposures should be considered qualitative, and mitigation measures designed to reduce PTS exposures should also contribute to reducing the risk of the TTS exposures.

For behavioral thresholds, no distinction is made between impulsive and non-impulsive sources. Behavioral criteria were developed by the U.S. Navy in consultation with NMFS and were derived from measurements conducted during exposure to airgun noise presented in McCauley et al. 2000 and Finneran et al. 2017. The received SPL at which sea turtles have been observed exhibiting behavioral responses to airgun pulses, 175 dB re 1 µPa, is also expected to be the received sound level at which sea turtles would exhibit behavioral responses when exposed to impact pile driving (impulsive) and vibratory pile setting (non-impulsive) activities (Finneran et al. 2017).

Table B-42: Acoustic Thresholds for Onset of Acoustic Impacts (Permanent Threshold Shift, Temporary Threshold Shift, or Behavioral Disturbance) for Endangered Species Act-Listed Sea Turtles

Impulsive Sources					Non-Impulsive Sources	
PTS		TTS		Behavioral Disturbance	PTS	Behavioral Disturbance
Lpk	SEL_{24h}[a]	Lpk	SEL_{24h}[a]	SPL	SEL_{24h}[a]	SPL
232	204	226	189	175	220	175

Source: Finneran et al. 2017
Lpk = peak sound pressure level in units of decibels referenced to 1 micropascal; PTS = permanent threshold shift; SEL_{24h} = sound exposure level over 24 hours in units of decibels referenced to 1 micropascal squared second; SPL = root-mean-square sound pressure level in units of decibels referenced to 1 micropascal; TTS = temporary threshold shift
[a] SEL_{24h} thresholds include frequency weighting for sea turtles as described by Finneran et al. (2017).

NMFS has adopted criteria used by the U.S. Navy to assess the potential for non-auditory injury from underwater explosive sources as presented in Finneran et al. (2017). The criteria include thresholds for the following non-auditory impacts: mortality, lung injury, and gastrointestinal injury. Unlike auditory thresholds, these depend upon an animal's mass and depth. Table 3-43 provides mass estimates used in the assessment from Finneran et al. (2017). Table B-29 provides the equations used to estimate these thresholds based on animal mass and depth in the water column.

Single blast events within a 24-hour period are not presently considered by NMFS to produce behavioral impacts if they are below the onset of TTS thresholds for frequency-weighted SEL_{24h} and unweighted peak SPL in units of decibels referenced to 1 micropascal (Lpk). As only one charge detonation per day is planned for the proposed Project, the effective disturbance threshold for single events in each 24-hour period is the TTS onset (Table B-42).

Table B-43: Representative Mass Estimates Used for Assessing Impulse-based Onset of Lung Injury and Mortality Threshold Exceedance Distances

Species	Hatchling Mass (kilograms)	Adult Mass (kilograms)
Loggerhead sea turtle	8.7	70
Green sea turtle	8.7	110
Kemp's ridley sea turtle	6.25	32
Leatherback sea turtle	35.18	300

Source: Finneran et al. (2017)

As with marine mammals, the potential for underwater noise to result in adverse impacts on a sea turtle depends on the received sound level, the frequency content of the sound relative to the hearing ability of the animal, the duration of the exposure, and the context of the exposure. Potential impacts range from subtle changes in behavior at low received levels to strong disturbance impacts or PTS at high received levels. Auditory masking may also occur when sound signals used by sea turtles (e.g., predator vocalizations and environmental cues) overlap in time and frequency with another sound source (e.g., pile driving). Popper et al. (2014) determined that continuous noise produced at frequencies and sound levels detectable by sea turtles can mask signal detection. As with behavioral impacts, the consequences of masking to sea turtle fitness are unknown. The frequency range of best hearing sensitivity estimated for sea turtles is estimated at 100 to 1,000 Hz (Table B-41). Masking is, therefore, more likely to occur with sound sources that have dominant low frequency spectrums such as vessel activities, vibratory pile setting, and WTG operations. These sound sources are also considered continuous, meaning they are present within the water column for longer durations and, therefore, have a higher chance of affecting sea turtle auditory perception.

The COP (Appendix III-M; Epsilon 2023) includes acoustic modeling of underwater sound generated and potential impacts on sea turtle species during pile installation using the same methods as described previously in Section B.4.

For modeling used in this analysis and the COP (Appendix III-M; Epsilon 2023), sea turtle densities were obtained from the U.S. Navy Operating Area Density Estimate database on the Strategic Environmental Research and Development Program Spatial Decision Support System portal (U.S. Navy 2012, 2017) and the Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles (Kraus et al. 2016a). These data are summarized seasonally (winter, spring, summer, and fall). Because the results from Kraus et al. (2016a) use more recent data, those were used preferentially where possible. The COP (Appendix III-M; Epsilon 2023) notes that the winter densities of sea turtles in the SWDA were likely overestimated because these estimates are provided as a range of potential densities within each grid square, and the maximum density always exceeds zero. Thus, winter densities were reported, even though turtles are unlikely to be present in winter because the COP (Appendix III-M; Epsilon 2023) assumed maximum densities for all seasons. Details on data handling to develop these estimates are available in the COP (Appendix III-M; Epsilon 2023). These estimates suggest that leatherback sea turtles are the most likely species of sea turtle to be found in the proposed Project area followed by loggerhead sea turtles, and their densities would be highest during the summer and fall (Appendix III-M; Epsilon 2023).

Table B-44 shows the number of sea turtles estimated to be exposed to sound levels above potential PTS and behavioral disturbance threshold criteria during foundation installation activities, which include a combination of vibratory pile setting followed by impact pile driving and impact pile driving only, modeled in the COP (Appendix III-M; Epsilon 2023).

Table B-44: Number of Animals Exposed to Noise at or Above Thresholds for All Foundation Types[a] over All 3 Years of Construction under the Proposed Action with 10 Decibel Noise Attenuation

Common Name (Scientific Name)	PTS (Lpk)	PTS (SEL_{24h})	Behavior (SPL)
Kemp’s ridley sea turtle (*Lepidochelys kempii)*	0	0.02	0.27
Leatherback sea turtle (*Dermochelys coriacea*)	0	4.17	5.40
Loggerhead sea turtle (*Caretta caretta*)	0	1.11	9.85
Green sea turtle (*Chelonia mydas*)	0	0.11	0.66

Source: COP Appendix III-M; Epsilon 2023

dB = decibel; Lpk. = peak sound pressure level in units of dB referenced to 1 micropascal; PTS = permanent threshold shift; SEL_{24h} = sound exposure level over 24 hours in units of dB referenced to 1 micropascal squared second; SPL = root-mean-square sound pressure level in units of dB referenced to 1 micropascal

[a] The exposure estimates include all foundations proposed for the Project as a combination of foundations installed with vibratory setting of piles followed by impact pile driving and foundations installed with impact pile driving alone.

B.7 Impacts on Marine Mammals Potentially Present in the Proposed Project Area

This section provides supplemental information for the discussion of potential impacts on marine mammals provided in EIS Section 3.7 for marine mammal species that may face additional risk from certain impact-producing factor (IPF) based on their current population status and life history traits that make them more susceptible to anthropogenic impacts. All factors that would influence the risk of impacts are discussed in the following subsections.

B.7.1 North Atlantic Right Whales

The NARW is known to inhabit continental shelf and coastal waters in the northwest Atlantic, ranging from calving grounds in the southeastern United States to feeding grounds in New England waters and the Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence in Canadian waters (Hayes et al. 2023). There are two critical habitat areas for NARWs in U.S. waters: all U.S. waters within the Gulf of Maine are designated as a foraging area critical habitat, while waters off the southeastern United States are designated as a calving area critical habitat (81 Fed. Reg. 4837 [February 26, 2016]). The Mid-Atlantic OCS between the two critical habitat areas has been identified as a principal migratory corridor and, thus, an important habitat for NARWs as they travel between breeding and feeding grounds (Hayes et al. 2023; CETAP 1982). This migratory pathway is considered a biologically important area for the species (LaBrecque et al. 2015). While some individuals undergo yearly migrations between summer months at their northern feeding grounds and winter months at their southern breeding grounds, the location of most individuals throughout much of the year is poorly understood. Year-round presence in all habitat areas has been recorded, including off southern New England (O'Brien et al. 2022a). NARW distribution and patterns of habitat use has shifted both spatially and temporally beginning in 2010 (Davis et al. 2017), likely in response to shifting prey resources. Fewer individuals appear to the Great South Channel and Bay of Fundy, whereas larger numbers have been seen in Cape Cod Bay and the region south of Martha's Vineyard and Nantucket (Leiter et al. 2017; Stone et al. 2017).

The NARW is a large, relatively stock whale that can range in length from 55.8 to 59 feet. One of the most distinguishing features of the right whale is their prominently curved jawline and whitish callosities, or areas of roughened skin, covering the top of their rostrum and head, which can be up to one-third of their body length (Jefferson et al. 1993). The callosities form a unique pattern on the animal's head, enabling individual identification similar to a fingerprint and fundamental to demographic and movement studies. Foraging habits of NARWs show a clear preference for the zooplanktonic copepod, *Calanus finmarchicus* (Mayo et al. 2001). The NARW distribution and movement patterns within their foraging grounds is highly correlated with concentrations and distributions of their prey, which exhibit high variability within and between years (Pendleton et al. 2012). Due to the heightened energetic requirements of pregnant and nursing females, yearly reproductive success of the population is directly related to foraging success and the abundance of *C. finmarchicus* (Meyer-Gutbrod et al. 2015), which in turn is correlated with decadal-scale variability in climate and ocean patterns (Greene and Pershing 2000).

Skim feeding is an important activity identified in effects assessments because it demonstrates a critical behavior (feeding) that could be disrupted by introduced noise. Similarly, NARWs spend extended periods of time at the water's surface actively socializing in what are known as surface active groups; surface active groups have been documented in all habitat regions; during all seasons; involve all age classes; and include mating behaviors, play, and the maintenance of social bonds (Parks et al. 2007). The extensive and biologically critical surface behaviors of NARWs, such as surface skim feeding and surface-active groups, represent a vulnerable time for NARW as they are exposed to an increased risk for ship strike when active at or near the surface.

The NARW is listed as Endangered under the ESA and Critically Endangered by the International Union for Conservation of Nature (IUCN) Red List (Cooke 2020; Hayes et al. 2023). NARWs are considered to be one of the most critically endangered large whale species in the world (Hayes et al. 2023). The Western North Atlantic population size was estimated to be 338 individuals in the most recent NMFS stock assessment report, which used a hierarchical, state-space Bayesian open population model of sighting histories from the photo-identification recapture database through November 2022 (Hayes et al. 2023). Between 2011 and 2020, the population has declined in overall abundance by 29.7 percent, further evidenced by the decrease in the abundance estimate from 451 in 2018 to the current 2021 estimate of 338 individuals (Hayes et al. 2023). This decline in abundance follows a previous positive population trend from 1990 to 2011 that saw an increase of 2.8 percent per year from an initial abundance estimate of 270 individuals in 1998 (Hayes et al. 2023). Over time, there have been periodic swings of per capita birth rates (Hayes et al. 2023), although current birth rates continue to remain below expectations (Pettis et al. 2022), with an approximately 40 percent decline in reproductive output for the species since 2010 (Kraus et al. 2016b).

Researchers have identified 17 calves for the 2024 calving season as of February 1, 2024, though one of the calves was observed with severe injuries consistent with a vessel strike off Amelia Island, Florida, in January 2024. During the 2023 calving season (defined as calves born between mid-November 2022 and mid-April 2023), 12 calves were observed (down from 15 during the 2022 season and 20 during the 2021 season) (NMFS 2024a). Although the increasing birth rate is a beneficial sign, it is still significantly below what is expected, and the rate of mortality is still higher than what is sustainable (Pettis et al. 2022; NMFS 2024a). A reduction in adult female survival rates relative to male survival rates has caused a divergence between male and female abundance. In 1990, there were an estimated 1.15 males per female, and by 2015, estimates indicated 1.46 males per female (Pace et al. 2017).

Net productivity rates do not exist, as the western North Atlantic stock lacks any definitive population trend (Hayes et al. 2023). The average annual human-related mortality/injury rate exceeds that of the calculated potential biological removal (PBR) of 0.7, and due to its listing as Endangered under the ESA, this population is classified as strategic and depleted under the Marine Mammals Protection Act (Hayes et al. 2023). Estimated human-caused mortality and serious injury between 2016 and 2020 was 8.1 whales per year, of which 5.7 whales per year are attributed to fisheries interactions and the remainder 2.4 whales per year caused by vessel strike (Hayes et al. 2023). However, it is likely that not all mortalities are documented, and modeling suggests that the mortality rate for the period from 2014 to 2018 may be up to 27.4 animals (Hayes et al. 2023; Pace 2021). There have been elevated numbers of mortalities reported since 2017, which prompted NMFS to designate an unusual mortality event (UME) for NARWs (NMFS 2024b). These elevated mortalities have continued into 2024, totaling 36 mortalities, 35 serious injuries, and 51 sublethal injuries or illness (NMFS 2024b). Based on the mortalities for which the carcasses could be examined, preliminary analyses indicate that most of the reported mortalities are likely to be human caused, predominantly from entanglement in fishing gear or vessel collisions (NMFS 2024b). Although the majority of the mortalities occurred in Canadian waters, the U.S. population is not separated from those in Canada; therefore, the impacts of mortality affect the population considered in the assessment process. While vessel strikes and entanglements in fishing gear represent the most significant threat to NARWs, other risks to the population include acoustic disturbance and masking, climate change, and climate-driven shifts in prey species (Hayes et al. 2023).

In 1994, NMFS designated critical habitat for the NARW population in the North Atlantic Ocean (59 Fed. Reg. 28805 [June 23, 1983]). This critical habitat designation included portions of Cape Cod Bay and Stellwagen Bank, the Great South Channel, and waters adjacent to the coasts of South Carolina, Georgia, and the east coast of Florida. These areas were determined to provide critical feeding, nursery, and calving habitat for the North Atlantic population of NARWs. In 2016, NMFS revised the NARW critical habitat by expanding the previously designated areas. The areas designated as critical habitat currently contain approximately 29,763 square nautical miles of marine habitat, located in the Gulf of Maine and Georges Bank region (Unit 1) and off the southeast U.S. coast (Unit 2). Although both Units 1 and 2 are outside of the proposed Project area, Project vessels may transit through Unit 1 depending on the ports selected and the routes that may be taken by vessels transiting to/from Canada and Europe. Unit 2, which contains the physical and biological features essential to NARW calving habitat, occurs outside of the proposed Project, and no proposed Project vessels are expected to transit through the coastal habitat of Unit 2.

Kraus et al. (2016b) suggests that threats to the population are still pervasive and may be getting worse. Indicators of this trend include declining overall body condition (Rolland et al. 2016) and very high and increasing rates of entanglement in fishing gear (Knowlton et al. 2012, 2016), suggesting previous management interventions have not measurably reduced entanglement or entanglement-related mortality (Pace et al. 2015). Research has revealed the substantial energy drain on individual whales from drag related to ongoing entanglements, which likely results in reduced health and fitness (van der Hoop et al. 2015, 2017). Other studies indicate noise from shipping increases stress hormone levels (Rolland et al. 2012), and modeling suggests that their communication space can be reduced substantially by vessel noise in busy traffic lanes (Hatch et al. 2012). In addition to anthropogenic threats, NARWs also face environmental stressors including algal toxins, oceanographic changes from climate change, and, as discussed above, reduced prey availability (Rolland et al. 2007; Doucette et al. 2012; Fortune et al. 2013). These combinations of factors threaten the survival of this species (Pettis et al. 2017, 2022). If reduced *C. finmarchicus* abundance results in a decrease in reproduction similar to that observed in the late 1990s, which authors hypothesize has occurred during the past 5 years, extinction of the NARW could take place in as little as 27 years (Meyer-Gutbrod et al. 2018).

The greatest risk to NARW from the proposed Project is from vessel traffic and interactions with fishing gear, which would be present both with and without the proposed Project. Given the number of vessel strikes documented under the UME (NMFS 2024b), ongoing activities which are not associated with offshore wind development, specifically with the proposed Project, are a greater driver of the risk to NARW. These impacts would be expected to continue and potentially increase with the additional vessel traffic associated with future offshore wind projects. However, the proposed Project would adhere to vessel strike avoidance measures such as visual monitoring and speed restrictions (Appendix H) which would reduce the risk of vessel strikes and associated mortality. Similarly, the risk faced by entanglements in fishing gear is a result of ongoing non-offshore wind activities given the number of records under the existing UME (NMFS 2024b). The presence of the proposed Project structures (i.e., WTG and ESP foundations) would contribute to the risk of entanglement if discarded fishing gear were caught in the structures; however, BOEM would require the applicant to routinely monitor for the presence of fishing gear around the WTG and ESP foundations (Appendix H), which would help reduce the likelihood of any NARW becoming entangled. All other IPFs discussed in the Final EIS are not expected to result in mortality. Noise-producing activities such as impact pile driving and potential UXO detonations could result in auditory injury (i.e., PTS), but with mitigation measures such as noise attenuation devices reducing the sound produced by these activities by 10 dB; visual and acoustic monitoring before, during and after the activity; seasonal restrictions dictating these activities would only occur between May and December, outside the key seasons which NARW are present in the proposed Project area; and shutdown and soft-start procedures for impact pile driving (Appendix H; COP Appendix III-M; Epsilon 2023), no long-term impacts that would rise to the population level are expected to occur due to noise for this species.

B.7.2 Fin Whales

Fin whales are very common over the continental shelf waters from Cape Hatteras, North Carolina, northwards (Hayes et al. 2022). They are typically found along the 328-foot (100-meter) isobath but may also occur in shallower and deeper water, including submarine canyons along the shelf break (Kenney and Winn 1986). Fin whales are migratory, moving seasonally into and out of feeding areas, but their overall migration pattern is complex, and specific routes are not known (Hayes et al. 2022). Although the species occurs year-round in a wide range of latitudes and longitudes, the density of individuals in any one area changes seasonally. Thus, their movements overall are patterned and consistent, but distribution of individuals in a given year may vary according to their energetic and reproductive condition and climatic factors (NMFS 2019b). Acoustic detections from recorders deployed off Nantucket, Massachusetts indicate a year-round presence for fin whales in the vicinity of the proposed Project area, with the highest occurrence in the winter (Palka et al. 2021). Detections were reported for all recorders, regardless of depth, showing fin whales may make use of the entire continental shelf in this region (Palka et al. 2021).

Fin whales are fast swimmers and are often found in social or feeding groups of two to seven individuals (NMFS 2022b). These whales feed during summer and are known to have site fidelity to feeding grounds in New England during this period (Seipt et al. 1990). Fin whales in the North Atlantic feed on pelagic crustaceans (mainly euphausiids or krill) and schooling fish such as capelin (*Mallotus villosus*), Atlantic herring (*Clupea harengus*), and sand lance (Borobia et al. 1995) by skimming the water or lunge feeding. Several studies suggest that distribution and movements of fin whales along the east coast of the United States is influenced by the availability of sand lance (Kenney and Winn 1986; Payne et al. 1990). A biologically important area for feeding has been delineated for the area east of Montauk Point, New York, to the west boundary of the RI/MA Lease Areas between the 49-foot (15-meter) and 164-foot (50-meter) depth contour from March to October (LaBrecque et al. 2015).

Fin whales have been listed as Endangered under the ESA since the act's passage in 1973 (35 Fed. Reg. 8491 [June 2, 1970]). Fin whales in Atlantic U.S. waters belong to the western North Atlantic stock. The best available abundance estimate for the western North Atlantic stock is 6,802, with a minimum population estimate of 5,573 based on shipboard and aerial surveys conducted in 2016 and the 2016 Northeast Fisheries Science Center and Department of Fisheries and Oceans Canada surveys (Hayes et al. 2022). The extents of these two surveys do not overlap; therefore, the survey estimates were added together. NMFS has not conducted a population trend analysis due to insufficient data and irregular survey design (Hayes et al. 2022). The best available information indicates that the gross annual reproduction rate is 8 percent, with a mean calving interval of 2.7 years. For 2015 through 2019, the minimum annual rate of human-caused (i.e., vessel strike and entanglement in fishery gear) mortality and serious injury was 1.85 per year (Hayes et al. 2022). No critical habitat has been designated for fin whales within or near the proposed Project area. Similar to NARW, the greatest risk of vessel strike and entanglement are from ongoing non-offshore wind activities, and the addition of vessel traffic and fishing gear impacts from the proposed Project would not appreciably contribute to additional risk to this species. This species has a PBR of 11 individuals; with only up to 2 individuals documented sustaining serious injury or mortality (Hayes et al. 2022), the likelihood of mortalities exceeding the PBR is low. This species does face a slightly higher risk of exposure to noise sufficient to result in auditory injuries from the proposed Project because the anticipated construction window of May through December overlaps with the season that fin whales are expected to have higher densities in the proposed Project area (EIS Section 3.7; BOEM 2023a). However, auditory injuries (i.e., PTS) do not result in mortality or prevent an individual from reproducing and foraging, so this would not count as a removal of the individual from the population. Additionally, while the total number of fin whales exposed to above-threshold noise exceeds the annual PBR (Section B.4), the other mitigation measures listed previously for NARW reduce the potential risk of these exposures.

B.7.3 Sei Whales

Sei whales occurring in the U.S. Atlantic Exclusive Economic Zone (EEZ) belong to the Nova Scotia stock. This stock is distributed across the continental shelf waters from the northeast U.S. coast northward to south of Newfoundland (Hayes et al. 2022). This species is highly mobile, and there is no indication that any population remains in a particular area year-round (NMFS 2011). Sei whale occurrence in a particular feeding ground is considered unpredictable or irregular (Schilling et al. 1992) but may be correlated to incursions of relatively warm waters of the Irminger Current off West Greenland (Hayes et al. 2022). Olsen et al. (2009) also indicated that sei whales' movements appear to be associated with oceanic fronts, thermal boundaries, and specific bathymetric features. Further, climate change may affect sei whale habitat availability and food availability, as migration, feeding, and breeding locations may be affected by ocean currents and water temperature (NMFS 2011).

This species is typically sighted on the U.S. Atlantic mid-shelf and the shelf edge and slope (Olsen et al. 2009). Sei whales are usually observed alone or in small groups of two to five animals. Previously, sei whales were believed to occasionally occur in the inshore waters of the Gulf of Maine (Schilling et al. 1992); However, Baumgartner et al. (2011) reported sei whale observations during springtime in the Great South Channel from 2004 to 2010, suggesting that these whales are relatively common in the area. Acoustic detections from recorders deployed off Nantucket show a similar pattern in sei whale presence, with vocalizations detected year-round but a higher number of detections in the spring (Palka et al. 2021). The number of daily detections on the recorders also showed sei whales prefer deeper waters along the shelf edge, although vocalizations were also present at the shallower recorders (Palka et al. 2021).

Sei whales dive 5 to 20 minutes and feed on zooplankton (primarily on calanoid copepods), with a secondary preference for euphausiids (Christensen et al. 1992), krill, small schooling fish, and cephalopods (including squid) by both gulping, skimming, and lunging. They prefer to feed at dawn and may exhibit unpredictable behavior while foraging and feeding on prey (NMFS 2023c).

The current best abundance estimate for this stock is 6,292 individuals (Hayes et al. 2022). Between 2015 and 2019, the average annual minimum human-caused mortality and serious injury was 0.8 sei whales per year (Hayes et al. 2022). Threats to sei whales include vessel strike and entanglement in fisheries gear. No population trend is available for this stock. No critical habitat has been designated for sei whales within or near the proposed Project area. Similar to NARW and fin whales, the primary threats to sei whales include vessel strike and entanglement in fisheries gear. The greatest risk from these IPFs is a result of ongoing, non-offshore wind activities and the planned offshore wind projects would not appreciably contribute to increase risk to this species. Additionally, sei whales are expected to be present in low numbers in the proposed Project area, and the total number of individuals exposed per year to noise above the auditory injury thresholds (JASCO 2023) is not expected to result in population-level impacts.

B.7.4 Humpback and Minke Whales

The humpback whale can be found worldwide in all major oceans from the equator to subpolar latitudes. Humpback whales found in the proposed Project area belong to the Gulf of Maine Stock. In the summer, humpbacks are found in high-latitude feeding grounds, while during the winter months, individuals migrate to tropical or subtropical breeding grounds to mate and give birth (Hayes et al. 2020). North Atlantic humpback whales feed during the summer in various locations in cooler, temperate regions, including the Gulf of Maine, Newfoundland/Labrador, the Gulf of St. Lawrence, Greenland, Iceland, and Norway, including Svalbard (Wenzel et al. 2020). Available photo-identification and genotyping data indicate humpbacks from all these feeding grounds migrate to the primary winter breeding ground in the Dominican Republic (Wenzel et al. 2020). However, smaller numbers have been observed wintering around the Cape Verde Islands (Wenzel et al. 2020; Cooke 2018). Not all individuals migrate every year, as sightings of humpback whales in the U.S. Northeast Atlantic waters occur throughout the year. In the U.S. Northeast, humpbacks primarily feed on sand lance and other schooling fishes (Risch et al. 2013).

Minke whales are globally distributed in temperature, tropical, and high-latitude waters. Minke whales found in the proposed Project area belong to the Canadian East Coast Stock (Hayes et al. 2022). In the North Atlantic, their distribution changes seasonally, with more time spent near the continental shelf during the summer and fall. In contrast, during winter and spring, they tend to concentrate in deeper ocean waters. Higher densities of minke whales are observed in New England during the spring and fall months

(Hayes et al. 2022). Minke whales in the North Atlantic primarily feed on herring and schooling fish (Lomac-MacNair et al. 2022).

Neither humpback or minke whales in the proposed Project area are listed under the ESA (Hayes et al. 2020, 2022); however, an active UME has been declared for humpback whales due to suspected human interactions from vessel strike, entanglement, or infectious disease (NMFS 2024c). Since 2016, there have been 212 reported humpback whale strandings along the U.S. East Coast, approximately 40 percent of which showed evidence of human interaction from either a vessel strike or entanglement (NMFS 2024c). Available data indicate that this stock of humpback whale is characterized by a positive population trend, with an estimated increase in abundance of 2.8 percent per year (Hayes et al. 2020). The PBR for humpback whales is 22, and the estimated annual human-caused mortality and serious injury between 2014 and 2018 was 15.25 whales per year (Hayes et al. 2020).

There are no current population trends or net productivity rates for minke whales due to insufficient data (Hayes et al. 2022). The PBR for this stock is estimated to be 170 (Hayes et al. 2022). The estimated annual human-caused mortality and serious injury from 2015 to 2019 was 10.55 per year attributed to fishery interactions, vessel strikes, and non-fishery entanglement in both the United States and Canada (Hayes et al. 2022). A UME was declared for minke whales in 2017 due to an increase in mortalities resulting from suspected human interaction (e.g., entanglement) and infectious disease, but this UME is pending closure as of 2024 (NMFS 2024d). Since 2017, there have been 164 reported minke whale strandings along the U.S. East Coast (NMFS 2024d).

Similar to the other baleen whale species discussed previously, the greatest risk of vessel strike and entanglement in fisheries gear is a result of ongoing, non-offshore wind activities, and the proposed Project activities would not appreciably contribute to increased risk for this species. The total number of annual exposures estimated for these species for noise meeting or exceeding the auditory injury thresholds (Section B.4) is not expected to result in population-level impacts.

B.7.5 Sperm Whales

Sperm whales are widely distributed throughout the deep waters of the North Atlantic; distribution along the U.S. east coast is concentrated along the shelf break and over the slope (CETAP 1982; Hayes et al. 2020). An exception to this pattern is found in the shallow continental shelf waters of southern New England, where relatively high numbers of sightings have been reported, particularly between late spring and autumn (Scott and Sadove 1997).

Geographic distribution of sperm whales appears to be linked to social structure. Most females form lasting bonds with other related females and their young and form social units of usually 12 females (NMFS 2023d). While females generally stay with the same unit all their lives in and around tropical waters, young males will leave when they are between 4 and 21 years old to form “bachelor schools” with other males of about the same age and size. As males get older and larger, they leave their bachelor schools and begin to migrate toward the poles; the largest males are usually solitary and often found alone (NMFS 2023d). Sperm whales hunt for food during deep dives, with feeding occurring at depths of 1,640 to 3,281 feet (NMFS 2010). Deepwater squid make up the majority of their diet; other prey types include sharks, skates, and fish that occupy deep ocean waters (NMFS 2023d).

The stock structure of the Atlantic population of sperm whales is poorly understood. It is not clear whether the western North Atlantic population is discrete from the eastern North Atlantic population (Hayes et al. 2020). However, the portion of the population found within the U.S. EEZ likely belongs to a larger stock in the western North Atlantic. Sperm whales are listed as Endangered under the ESA as a single, global population, but the best available estimate for the North Atlantic stock, which is expected to occur in the proposed Project area, is 4,349 individuals (Hayes et al. 2020). There were no reports of fishery-related mortality or serious injury between 2013 and 2017, and while there were 12 strandings documented during this period, none showed any indications of human interaction (Hayes et al. 2020). No critical habitat has been designated for sperm whales within or near the proposed Project area.

No vessel strikes for this species have been reported since 2013. However, sperm whales do face a risk from this IPF (Hayes et al. 2020). As discussed previously, ongoing activities from non-offshore wind projects are expected to result in the greatest risk for this species, but future offshore wind development would not appreciably contribute to this risk. This species, unlike the other large whale species previously discussed, belong to the MFC hearing group (NMFS 2018b) so the risk of experiencing noise above auditory injury thresholds is lower than the baleen whale species belonging to the LFC hearing group. As a result, the total number of individuals exposed per year to noise above the auditory injury thresholds (JASCO 2023) is not expected to result in population-level impacts.

B.7.6 All Other Mid-Frequency Cetacean Species

The other dolphin and small whale species that belong to the MFC hearing group expected to occur in the proposed Project area are not listed under the ESA and are therefore expected to be less susceptible to potential impacts from Alternative A and Alternative B. The estimated annual PTS exposures for all these species (Section B.4) are below the annual PBR (Table 3.7-3 in EIS Section 3.7) so the risk of any consequences to the population due to proposed Project-related noise is expected to be low. Based on the most recent stock assessment reports available for these species, they also face a risk of entanglement in fishing gear, but the number of reported mortalities and serious injuries from the past few years does not exceed the PBR (Hayes et al. 2022) and would therefore not be expected to result in population-level consequences. Although smaller cetaceans are also at risk of vessel strikes, these species tend to be more agile, powerful swimmers and are more capable of avoiding collisions with oncoming vessels (MMS 2007).

Ongoing, non-offshore wind activities present a risk of entanglement in fishing gear that would not be expected to substantially increase as a result of the proposed Project activities; however, the presence of the proposed Project structures may result in discarded fishing gear being caught around the foundations, creating an entanglement risk for dolphin and small whale species. However, as discussed for NARW previously, BOEM would require the applicant to routinely monitor for the presence of derelict fishing gear around the proposed Project structures, which would help reduce the likelihood of any dolphin or small whale species becoming entangled in fishing gear. Additionally, the presence of the proposed Project structures may also result in a reef effect in which fish aggregating around the foundations would form biological hotspots that could support species range shifts and expansions and changes in the biological community structure resulting from a changing climate (Raoux et al. 2017; Methratta and Dardick 2019; Degraer et al. 2020). The aggregated fishes could provide additional foraging opportunities for dolphins and small whale species present within the proposed Project area, as has been documented for other projects in Europe (Hammar et al. 2010; Lindeboom et al. 2011).

B.7.7 Harbor Porpoises

Harbor porpoises in the proposed Project Area belong to the Gulf of Maine/Bay of Fundy stock, distributed in U.S. and Canadian Atlantic waters. Their distribution changes seasonally. During the summer, they concentrate in coastal waters, staying in depths less than 150 meters. In non-summer months, they have been observed in coastal to deep waters (>1,800 meters deep) (Westgate et al. 1998). Specifically, in summer, they are mainly concentrated in the northern Gulf of Maine, southern Bay of Fundy, and around the southern tip of Nova Scotia. In the fall, they disperse from New Jersey to Maine, with some distribution farther north and south. In winter, they are observed off New Jersey to North Carolina, with lower densities from New York to New Brunswick, Canada. Despite these seasonal changes, harbor porpoises do not exhibit a distinct migratory route (Hayes et al. 2022). Gulf of Maine

Harbor porpoises primarily feed on schooling fishes, showing a preference for herring and small gadids. However, these same schooling fishes are also targeted by larger fishes, which become the focus of commercial fisheries. This creates an overlap in foraging areas between harbor porpoises and fisheries (Read 2013).

Harbor porpoises present in the proposed Project area are not listed under the ESA, but they are listed as Least Concern by the IUCN Red List and are considered non-strategic under the Marine Mammals Protection Act (Braulik et al. 2020; Hayes et al. 2022). The best available abundance estimate for the Gulf of Maine/Bay of Fundy stock occurring in the proposed Project area is 95,543 based on combined survey data from NOAA and Fisheries and Oceans Canada between the Gulf of St. Lawrence / Bay of Fundy/Scotian Shelf and Central Virginia (Hayes et al. 2022). A population trend analysis is not available because data are insufficient for this species (Hayes et al. 2022). The PBR for this stock is 851, and the estimated human-caused annual mortality and serious injury from 2015 to 2019 was 164 (Hayes et al. 2022). This species faces major anthropogenic impacts because of its nearshore habitat. Historically, Greenland populations were hunted in large numbers for food and oil. Currently, they continue to suffer incidental mortality from western North Atlantic fishing activities such as gillnets and bottom trawls (Hayes et al. 2022). Harbor porpoises also face threats from contaminants in their habitat, vessel traffic, habitat alteration due to offshore development, and climate-related shifts in prey distribution (Hayes et al. 2022). There is no designated critical habitat for this species near the proposed Project area.

Harbor porpoises belong to the HFC hearing group, which have lower acoustic thresholds for PTS (NMFS 2018b), resulting in higher ranges to the thresholds relative to the other hearing groups and subsequently higher numbers of annual exposures for this species (JASCO 2023). Although the number of annual PTS exposures is higher, they still do not exceed the annual PBR of 851 for this species (Hayes et al. 2022). As such, the risk of any population-level consequences due to proposed Project-related noise is expected to be low. Harbor porpoises also face a risk of entanglement in fishing gear, which is primarily a result of ongoing, non-offshore wind activities; thus, the increased risk of secondary entanglement in fishing gear caught around the proposed Project structures would not contribute a substantial increase in risk for this species. Given the proposed mitigation (Appendix H), the likelihood of entanglement in fishing gear around the proposed Project structures is low for any harbor porpoise present in the proposed Project area. Similar to the discussion for dolphins and small whale species, the reef effect resulting from the presence of the structures could provide additional foraging opportunities for this species as documented for other artificial reef sites (Mikkelsen et al. 2013).

B.7.8 Seals

The species of seals potentially present in the proposed Project area include gray, harbor, and harp seals, none of which are listed under the ESA (Hayes et al. 2022). A UME was declared in June 2022 for harbor and gray seals in response to an increase in the number of sick and dead individuals reported along the southern and central coast of Maine; however, this UME is limited to seals stranding in Maine, and the cause of the strandings has been determined to be avian influenza rather than human interactions (NMFS 2024e). This UME was closed in January 2024, with a total count of 181 seals stranded—including 143 harbor seals, 28 gray seals, and 10 seals of unidentified species (NMFS 2024e).

Human-caused IPFs that present risk to seal species include fisheries interactions and vessel strikes (Hayes et al. 2022), which are primarily a result of ongoing, non-offshore wind activities; thus, the proposed Project would not appreciably contribute to increased risk to these species. Furthermore, the potential increase in the risk of entanglement in fishing gear resulting from the presence of offshore wind structures would not exceed PBR for any seal species and would be reduced with the proposed monitoring and mitigation of fishing gear around the proposed Project structures (Appendix H). The reef effect due to the presence of the proposed Project structures may also provide additional foraging opportunities for seal species as evidenced by other studies of artificial reef habitat (Arnould et al. 2015; Russell et al. 2014).

The total number of annual PTS exposures estimated for these species for noise meeting or exceeding the auditory injury thresholds (Section B.4) is lower than the PBR for each species, indicating that risk of any consequences to the population due to proposed Project-related noise is low.

B.8 Impacts on Sea Turtles Potentially Present in the Proposed Project Area

This section provides supplemental information for the discussion of potential impacts on sea turtles provided in EIS Section 3.8 for sea turtle species that may face additional risk from certain IPFs based on their current population status and life history traits that make them more susceptible to anthropogenic impacts. All factors that would influence the risk of impacts are discussed in the following subsections.

B.8.1 Loggerhead Sea Turtles

Loggerhead sea turtles have a worldwide distribution and inhabit temperate and tropical waters, including estuaries and continental shelves of both hemispheres. Globally, loggerhead sea turtles are divided into nine distinct population segments (DPS) with varying federal (ESA) statuses. Individuals that occur in the proposed Project area are members of the Northwest Atlantic DPS.

Female loggerhead sea turtles in the western North Atlantic nest from late April through early September. Individual females might nest several times within one season and usually nest at intervals of every 2 to 3 years. For their first 7 to 12 years of life, loggerhead sea turtles inhabit pelagic waters near the North Atlantic Gyre and are called pelagic immatures. When loggerhead sea turtles reach 16 to 24 inches straight-line carapace length, they begin recruiting to coastal inshore and nearshore waters of the OCS through the U.S. Atlantic and Gulf of Mexico and are referred to as benthic immatures. Benthic immature loggerheads have been found in waters from Cape Cod, Massachusetts, to southern Texas. Most recent estimates indicate that the benthic immature stage ranges from ages 14 to 32 years; they reach sexual maturity at approximately 20 to 38 years of age. Loggerhead sea turtles are largely present year-round in waters south of North Carolina but will forage during summer and fall as far north as the northeastern United States and Canada and migrate south as water temperatures drop. Prey species for omnivorous juveniles include crab, mollusks, jellyfish, and vegetation at or near the surface. Coastal subadults and adults feed on benthic invertebrates, including mollusks and decapod crustaceans (TEWG 2009). The most recent (2010) regional abundance estimate for loggerhead sea turtles in the Northwest Atlantic OCS water was approximately 588,000 individuals (NEFSC and SEFSC 2011). The three largest nesting subpopulations responsible for most of the production in the western North Atlantic (Peninsular Florida, Northern United States, and Quintana Roo, Mexico) have all been declining since at least the late 1990s, indicating a downward trend for this population (TEWG 2009).

Critical habitat for Northwest Atlantic Ocean DPS of loggerhead sea turtles was designated in 2014 (79 Fed. Reg. 39755 [July 10, 2014]; 79 Fed. Reg. 51264 [August 28, 2014]). The species' critical habitat includes overwintering, migratory, and nearshore reproductive habitat extending from North Carolina to Mississippi. Additionally, critical sargassum habitat extends from offshore Texas to as far north as New Jersey, though the northern extent of this habitat is located far beyond the OCS edge (NMFS 2022a). No designated critical habitat occurs within the proposed Project area. Factors affecting the conservation and recovery of this species include beach development, related human activities that damage nesting habitat, and light pollution (NMFS and USFWS 2008). In-water threats include bycatch in commercial fisheries, vessel strikes, anthropogenic noise, marine debris, legal and illegal harvest, oil pollution, and predation by native and exotic species (NMFS and USFWS 2008).

The greatest risk to loggerhead sea turtles from the proposed Project is from vessel traffic and interactions with fishing gear, which would be present both with and without the proposed Project. Vessel-animal collisions are a measurable and increasing source of mortality and injury for sea turtles; the percentage of stranded loggerhead sea turtles with injuries that were apparently caused by vessel strikes increased from approximately 10 percent in the 1980s to over 20 percent in 2004, although some stranded turtles may have been struck post-mortem (NMFS and USFWS 2008). Sea turtles are expected to be most vulnerable to vessel strikes in coastal foraging areas and may not be able to avoid collisions when vessel speeds exceed 2 knots (Hazel et al. 2007). Vessels traveling at higher speeds pose a higher risk to sea turtles. To reduce the risk of lethal injury to loggerhead sea turtles from vessel strikes by 50 percent, Sapp (2010) found that small vessels (10 to 30 feet in length) had to slow down to 7.5 knots; the probability of lethal injury decreased by 60 percent for vessels idling at 4 knots. Foley et al. (2008) further indicated that vessel speed greater than 4 knots may cause serious injury or mortality to sea turtles. The recovery plan for loggerhead sea turtles (NMFS and USFWS 2008) notes from 1997 to 2005, 14.9 percent of all stranded loggerheads in the U.S. Atlantic and Gulf of Mexico were documented as having some type of propeller or collision injuries, although it is not known what proportion of these injuries occurred before or after the turtle died. However, the proposed Project would adhere to vessel strike avoidance measures such as visual monitoring and speed restrictions (Appendix H), which would reduce the risk of vessel strikes and associated mortality. Similarly, the risk faced by entanglements in fishing gear due to the presence of proposed Project structures could increase the risk of sea turtle entanglement in both lines and nets and increasing the risk of injury and mortality due to ingestion, infection, starvation, or drowning (Nelms et al. 2016; Gall and Thompson 2015; Shigenaka et al. 2010; Barnette 2017). However, as discussed for marine mammals in Section B.7, Impacts on Marine Mammals, BOEM would require the applicant to routinely monitor for the presence of fishing gear around the WTG and ESP foundations (Appendix H), which would help reduce the likelihood of any loggerhead sea turtle becoming entangled. All other IPFs discussed in the EIS are not expected to result in mortality. Noise-producing activities such as impact pile driving and potential UXO detonations could result in auditory injury (i.e., PTS), but with mitigation measures such as noise attenuation devices reducing the sound produced by these activities by 10 dB; visual and acoustic monitoring before, during and after the activity; and shutdown and ramp-up procedures for impact pile driving (Appendix H; COP Appendix III-M; Epsilon 2023), and though impacts on individuals may occur, no long-term impacts that would rise to the population level are expected to occur due to noise for this species.

B.8.2 Leatherback Sea Turtles

The leatherback sea turtle is primarily a pelagic species and distributed in temperate and tropical waters worldwide. The leatherback is the largest, deepest diving, most migratory, widest ranging, and most pelagic of the sea turtles (NMFS 2023e). Adult leatherback sea turtles forage in temperate and subpolar regions of all oceans. Satellite tagged adults reveal migratory patterns in the North Atlantic that can include a circumnavigation of the North Atlantic Ocean basin, following ocean currents that make up the North Atlantic Gyre and preferentially targeting warm-water mesoscale ocean features such as eddies and rings as favored foraging habitats (Hays et al. 2006). Soft-bodied animals such as jellyfish and salps are the major component of the leatherback diet; they are also known to feed on sea urchins, squid, crustaceans, tunicates, fish, blue-green algae, and floating seaweed (NMFS 2023e; USFWS 2022a).

Historically, the most important nesting ground for the leatherback was the Pacific coast of Mexico. However, because of exponential declines in leatherback nesting, French Guiana in the Western Atlantic now has the largest nesting population. Other important nesting sites for the leatherback include Papua New Guinea, Papua-Indonesia, and the Solomon Islands in the Western Pacific. In the U.S., nesting sites include the Florida east coast; Sandy Point, U.S. Virgin Islands; and Puerto Rico. U.S. nesting occurs from March through July. On average, individual females nest every 2 to 3 years, laying an average of 5 to 7 nests per season with an average clutch size of 70 to 80 eggs (USFWS 2022a).

The leatherback sea turtle has been federally listed as Endangered under the ESA since 1970 and is considered Vulnerable by the IUCN Red List (IUCN 2022; NMFS 2023e). In 2017, NMFS received a petition to identify the northwest Atlantic subpopulation as a DPS and list it as Threatened under the ESA. In response to this petition, NMFS initiated a status review for the leatherback sea turtle to include new data made available since the original listing (82 Fed. Reg. 57565 [December 6, 2017]). The status review was completed, and NMFS concluded there was not sufficient evidence to designate any DPS for leatherback sea turtles. Threats to this population include fisheries bycatch, habitat loss, nest predation, and marine pollution (USFWS 2022a). While critical habitat for this species was designated in waters adjacent to Sandy Point Beach, U.S. Virgin Islands in 1979 (44 Fed. Reg. 17710 [March 23, 1979]), there is no designated critical habitat within the proposed Project area. Similar to loggerhead sea turtles, the greatest risk of vessel strike and entanglement are from ongoing non-offshore wind activities, and the addition of vessel traffic and fishing gear impacts from the proposed Project would not appreciably contribute to additional risk to this species. However, with the proposed mitigation measures (Appendix H), the risk of a vessel strike that results in mortality or serious injury is lowered, and the likelihood of entanglement in fishing gear caught on proposed Project structures is extremely low. Additionally, with mitigation measures implemented, no long-term impacts that would rise to the population level are expected to occur due to noise for this species.

B.8.3 Kemp's Ridley Sea Turtle

Kemp's ridley sea turtles occur off the coast of the Gulf of Mexico and along the U.S. Atlantic Coast (TEWG 2000). Juveniles inhabit the U.S. Atlantic Coast from Florida to the Canadian Maritime Provinces. In late fall, Atlantic juveniles/subadults travel northward to forage in the coastal waters off Georgia through New England, then return southward for the winter (Stacy et al. 2013; New York State Department of Environmental Conservation 2022). Preferred habitats include sheltered areas along the coastline, such as estuaries, lagoons, and bays (NMFS 2022c). Kemp's ridley sea turtles are opportunistic foragers, feeding on decapod crustaceans, shellfish, and fish (NMFS 2022c). Sixty percent of Kemp's ridley nesting occurs on beaches near Rancho Nuevo, Tamaulipas, Mexico. The nesting season spans from April through July (NMFS and USFWS 2007). On average, individual females nest every 1 to 2 years, with an average of 1 to 3 clutches every season and an average clutch size of 110 eggs per nest (NMFS and USFWS 2007).

The Kemp's ridley sea turtle population was severely decimated in 1985 due to intensive egg collection and fishery bycatch, with only 702 nests counted during the entire year (NMFS and USFWS 2015; Bevan et al. 2016). After initiation of conservation measures, the population increased through 2009; however, since 2009, there has been a noted decline in nests (NMFS and USFWS 2015). Evaluations of hypothesized causes of the nesting setback, including the Deepwater Horizon oil spill in 2010, have been inconclusive, and experts suggest that various natural and anthropogenic causes could have contributed to the nesting setback either separately or synergistically (Caillouet et al. 2018). Despite the increased number of local strandings in 2014, recent models indicate a persistent reduction in survival and/or recruitment to the nesting population, suggesting that the population is not recovering. Current threats include bycatch from some fisheries, marine debris, and boat strikes (NMFS and USFWS 2015). There is no designated critical habitat for Kemp's ridley sea turtles, and although they typically only nest in the Southeast and Mid-Atlantic U.S. states, there has been one report of Kemp's ridley sea turtle nesting in the Gateway National Recreation Area in Long Island, New York, in 2018 (Yun 2018).

Similar to loggerhead sea turtles, the greatest risk of vessel strike and entanglement are from ongoing non-offshore wind activities, and the addition of vessel traffic and fishing gear impacts from the proposed Project would not appreciably contribute to additional risk to this species. However, with the proposed mitigation measures (Appendix H), the risk of a vessel strike that results in mortality or serious injury is lowered, and the likelihood of entanglement in fishing gear caught on proposed Project structures is extremely low. Additionally, with mitigation measures implemented, no long-term impacts that would rise to the population level are expected to occur due to noise for this species.

B.8.4 Green Sea Turtle

Green sea turtles have a worldwide distribution and can be found in both tropical and subtropical waters (NMFS and USFWS 1991; NatureServe 2022). In the Western North Atlantic Ocean, they can be found from Massachusetts to Texas, as well as in waters off Puerto Rico and the U.S. Virgin Islands (NMFS and USFWS 1991). Green sea turtles are divided into 11 DPSs with varying ESA statuses. Individuals found in Virginia are members of the North Atlantic DPS. Depending on the life stage, green sea turtles inhabit high-energy oceanic beaches, convergence zones in pelagic habitats, and benthic feeding grounds in shallow protected waters (NMFS and USFWS 1991). Green sea turtles are known to make long-distance migrations between their nesting and feeding grounds. Hatchlings occupy pelagic habitats and are omnivorous. Juvenile foraging habitats include coral reefs, emergent rocky bottoms, sargassum spp. mats, lagoons, and bays (USFWS 2022b). Once mature, green sea turtles leave pelagic habitats and enter benthic foraging grounds, primarily feeding on seagrasses and algae (Bjorndal 1997), although they will occasionally feed on sponges and invertebrates (NMFS 2023f).

The primary nesting beaches for the North Atlantic DPS of green sea turtles are Costa Rica, Mexico, Florida, and Cuba. In the U.S., the species also nest in North Carolina, South Carolina, Georgia, the U.S. Virgin Islands, and Puerto Rico (USFWS 2022b). Nesting seasons vary by region. On average, individual females nest every 2 to 4 years, laying an average of 3.3 nests per season at approximately 13-day intervals. The average clutch size is approximately 136 eggs, and incubation ranges from 45 to 75 days (USFWS 2022b). According to Seminoff et al. (2015), nesting trends are generally increasing for this DPS. The only critical habitat for green sea turtles has been designated in Puerto Rico around Culebra Island (NMFS 2023f), which is outside the proposed Project area.

Similar to loggerhead sea turtles, the greatest risk of vessel strike and entanglement are from ongoing non-offshore wind activities, and the addition of vessel traffic and fishing gear impacts from the proposed Project would not appreciably contribute to additional risk to this species. However, with the proposed mitigation measures (Appendix H), the risk of a vessel strike that results in mortality or serious injury is lowered, and the likelihood of entanglement in fishing gear caught on proposed Project structures is extremely low. Additionally, with mitigation measures implemented, no long-term impacts that would rise to the population level are expected to occur due to noise for this species.

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