United States Department of Commerce National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Request for an Incidental Harassment Authorization to Allow the Non-Lethal Take of Marine Mammals Incidental to Construction Activities in the Vineyard Wind BOEM Lease Area OCS-A 0501

April 2019

Submitted to:

NATIONAL MARINE FISHERIES SERVICE
Office of Protected Resources
1315 East-West Hwy, F/PR1 Room 13805
Silver Spring, MD 20910-3282

Submitted by:

VINEYARD WIND

700 Pleasant Street, Suite 510
New Bedford, MA 02740

Submitted to:

Jolie Harrison, Division Chief
Permits and Conservation Division, Office of Protected Resources
1315 East–West Hwy, F/PR1 Room 13805
Silver Spring, MD 20910-3282
Jolie.Harrison@noaa.gov

Submitted by:

Vineyard Wind, LLC
700 Pleasant Street, Suite 510
New Bedford, MA 02740

Prepared by:

JASCO Applied Sciences (USA) Inc.
8630 Fenton Street, Suite 218
Silver Spring, MD 20910 USA
Tel: +1-301-565-3500
www.jasco.com

and

LGL Ecological Research Associates, Inc.
4103 South Texas Avenue, Suite 211
Bryan, TX, 77802
http://www.lgl.com

April 11, 2019

Version 4.1
Document No. 01648

Suggested citation:

JASCO and LGL. 2019. *Request for an Incidental Harassment Authorization to Allow the Non-Lethal Take of Marine Mammals Incidental to Construction Activities in the Vineyard Wind BOEM Lease Area OCS-A 0501*. Version 4.1, Document No. 01648. Prepared by JASCO Applied Sciences (USA) Ltd. and LGL Ecological Research Associates, for Vineyard Wind, LLC.

Disclaimer:

Contents

[redacted]

Figures

[redacted]

[redacted]

Tables

[redacted]

[redacted]

[redacted]

Acronyms and Abbreviations

AMAPPS	Atlantic Marine Assessment Program for Protected Species
BIA	Biologically Important Area
BOEM	Bureau of Ocean Energy Management
CeTAP	Cetacean and Turtle Assessment Program
COP	Construction and Operations Plan
dB	decibels
DP	Dynamic positioning
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
ESP	electrical service platform
ft	feet
FWRAM	Full Wave Range Dependent Acoustic Model
G&G	Geophysical and geotechnical
h	hour
HF	high frequency (cetacean hearing group)
Hz	Hertz
IHA	Incidental Harassment Authorization
in	inch
IWC	International Whaling Commission
JASMINE	JASCO Animal Simulation Model Including Noise Exposure
kg	kilogram
kHz	kilohertz
kJ	kilojoule
km	kilometer
L_E	cumulative sound exposure level
LF	low frequency (cetacean hearing group)
L_p	sound pressure level
L_{pk}	peak pressure level
m	meter
MF	mid-frequency (cetacean hearing group)
mi	mile
MMPA	Marine Mammal Protection Act
MONM	Marine Operations Noise Model
μPa	micro-Pascal
m/s	meters per second
MW	megawatt
NARW	North Atlantic Right Whale
NEFSC	Northeast Fisheries Science Center

NLPSC	Northeast Large Pelagic Survey Collaborative
NOAA	National Oceanic and Atmospheric Administration
nm	nautical mile
NMFS	National Marine Fisheries Service
OCS	Outer Continental Shelf
OECC	Offshore Export Cable Corridor
OSP	Optimum Sustainable Population
PAM	passive acoustic monitoring
PDSM	Pile Driving Source Model
PK	peak
PSO	protected species observer
PTS	permanent threshold shift
PW	phocid in water (hearing group)
RWSAS	Right Whale Sightings Advisory System
SEFSC	Southeast Fisheries Science Center
SEL	sound exposure level
SEL^{cum}	cumulative sound exposure level
SPL	sound pressure level
SPUE	Sightings per unit effort
RI/MA & MA WEAs	Rhode Island/Massachusetts and Massachusetts Wind Energy Areas
rms	root mean square
RWSAS	Right Whale Sighting Advisory System
TP	Transition Piece
TTS	temporary threshold shift
U.S.C	United States Code
USFWS	US Fish and Wildlife Service
Vineyard Wind	Vineyard Wind, LLC
WDA	Wind Development Area
WEA	Wind Energy Area
WTG	wind turbine generator

1. Description of Specified Activity

Vineyard Wind, LLC (Vineyard Wind) is proposing to construct an 800 megawatt (MW) commercial wind energy project (the Project) in Lease Area OCS-A 0501, offshore Massachusetts. The Project will consist of offshore wind turbine generators (WTGs) and electrical service platform(s) (ESP[s]), an onshore substation, offshore and onshore cabling, and onshore operations and maintenance facilities. Vineyard Wind intends to install the WTGs and ESPs in the northeast portion of the 675 square kilometer (km^2) (166,886 acre) Lease Area, referred to as the Wind Development Area (WDA), (Figure 1). WTGs will be arranged in a grid-like pattern with spacing of 1.4–1.9 kilometers (km) (0.76–1.0 nautical miles [nm]) between turbines. Each WTG will independently generate approximately eight to 10 MW of electricity and will interconnect with the ESP(s) via the inter-array submarine cable system. The offshore export cable transmission system will connect the ESP(s) to a landfall location in either Barnstable or Yarmouth, MA.

At its nearest point, the WDA is just over 23 km (14 miles [mi]) from the southeast corner of Martha's Vineyard and a similar distance from Nantucket. Water depths in the WDA generally range from approximately 37–49.5 meters (m) (121–162 feet [ft]). The WDA has high wind speeds, excellent seafloor conditions, moderate water depths, and reasonable proximity to multiple grid connection locations in an area of high electrical load and a need for new generation capacity.

The Project has significant environmental benefits. The electricity generated by the WTGs, which do not emit air pollutants, will displace electricity generated by higher-polluting fossil fuel-powered plants and significantly reduce emissions from the ISO New England power grid over the lifespan of the Project. Based on air emissions data for New England power generation facilities from EPA's Emissions & Generation Resource Integrated Database (eGRID), the Project is expected to reduce CO_2 emissions from the ISO NE system by approximately 1,630,000 tons per year (tpy). In addition, NO_x and SO_x emissions across the New England grid are expected to be reduced by approximately 1,050 tpy and 860 tpy, respectively. Furthermore, the Project is likely to benefit marine mammals and other marine life. These benefits include reduction in greenhouse gasses that induce climate change which in turn potentially impacts species' ranges and access to prey as prey species' shift or decline, a particular concern for migratory species, such as some baleen whales which rely on high-latitude areas for feeding. In addition to these important environmental benefits, the Project is expected to bring significant employment and other economic benefits to the south coast of Massachusetts and the region. Finally, the Project should be an important foundational step in creating a thriving, utility scale, domestic offshore wind industry.

The Construction and Operations Plan (COP) provides a detailed description of the Project, including tentative construction schedules in Sections 3 and 4 of Volume I (October 2018). The COP was submitted for review to the Bureau of Ocean Energy Management (BOEM) on December 19, 2017. Supplemental information relating to the potential for additional acoustic and non-acoustic impacts to marine mammals and sea turtles during Project construction was submitted for review in August 2018 and a revised version of the COP was submitted October 22, 2018. Submission of the COP documentation initiated the permitting process and the National Environmental Policy Act (NEPA) review.

The Project lies within the Atlantic Exclusive Economic Zone (EEZ), waters that support several marine mammal species (Table 3) and is therefore subject to review under the Marine Mammal Protection Act (MMPA) (16 United States Code [U.S.C.] 1362). Section 101(a) of the MMPA prohibits the "taking" of marine mammals except under certain situations. MMPA defines the term "take" as: to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal. MMPA regulations define harassment in two categories relevant to pile driving operations. These are:

- Level A: any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild, and
- Level B: any act of pursuit, torment or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing a disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild (16 U.S.C. 1362).

Section 101(a)(5) provides for an exception to the take prohibitions of the MMPA, and allows, upon request, the unintentional incidental take of small numbers of marine mammals by US citizens who engage in a specified activity within a specified geographic region. Incidental take is an unintentional, but not unexpected, take of a marine mammal.

The energy generated from pile driving activities associated with the installation of WTG and ESP foundations has the potential to take marine mammals in the vicinity of the Offshore Project Area by both Level A and Level B harassment. No lethal takes are anticipated. Sounds from other construction activities, including topside installation, scour protection, and cable laying, were considered (Volume III of the COP Appendix III-M). These activities produce sounds generally consistent with those from routine vessel operations and are not expected to contribute significantly to the Project’s acoustic footprint. According to the Navigational Risk Assessment, the WDA currently experiences moderate levels of vessel traffic, with some increased vessel traffic during the summer months (see Appendix III-I of Volume III of the COP). However, according to the BOEM environmental assessment (BOEM 2014b; NMFS 2018b), coastal vessel traffic in the vicinity of the Massachusetts Wind Energy Area (MA WEA) is relatively high. Therefore, marine mammals in the Offshore Project Area are regularly subjected to commercial shipping noise in the vicinity of the MA WEA and would potentially be habituated to vessel noise as a result of this exposure (BOEM 2014b). Because noise associated with these Project construction activities is likely to be similar to routine vessel traffic noise, incidental take of marine mammals is unlikely and therefore these activities are not considered further in this application. Additionally, takes of marine mammals by vessel collision are not expected, given the monitoring and mitigation plans proposed for the Project. This Incidental Harassment Authorization (IHA) application only requests incidental takes of marine mammals that may result from exposure to sounds from pile driving.

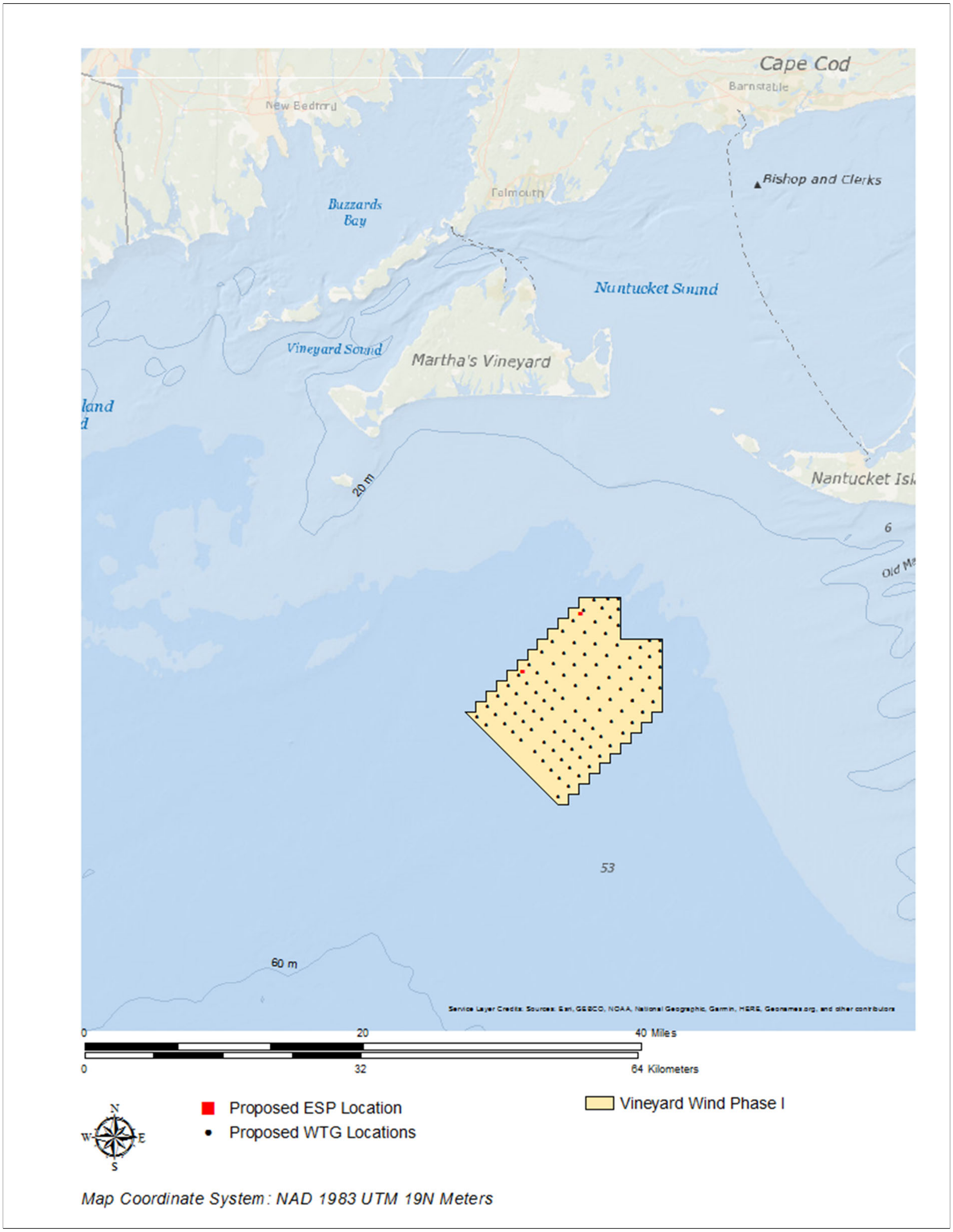

Figure 1. Location of the Vineyard Wind WDA within the northern portion of Lease Area OCS-A 0501.

1.1. Offshore Project Elements and Construction Activities

The Project's key offshore elements are described in detail in Section 3.1 of Volume I of the COP. These elements include the WTGs and their foundations, the ESPs and their foundations, scour protection for all foundations, the inter-array cables, the inter-link cable that connects the ESPs, and the offshore export cables. The WTGs, the ESPs, the inter-array cables, the inter-link cable, and portions of the offshore export cables are located in federal waters. The balance of the export cable run is located in Massachusetts waters. The construction of these elements will involve several activities that will generate underwater sounds including cable laying, construction vessel activities, and pile driving. Section 1.5.3 of Volume I of the COP provides a tentative schedule and high-level construction plan which is summarized below in Section 2 of this request.

1.1.1. Cable Laying

Section 5.2.2.1.2 of the COP, Volume III, describes cable installation in marine waters. Cable burial operations will occur both in the WDA for the inter-array cables connecting the WTGs to the ESPs and in the offshore export cable corridor (OECC) for the cables carrying power from the ESPs to landfall.

Inter-array cables will connect radial "strings" of six to 10 WTGs to the ESPs. Up to a maximum of two offshore export cables will connect the offshore ESPs to the shore. An inter-link cable will connect the ESPs to each other. The offshore export and inter-array cables will be buried beneath the seafloor at a target depth of up to 1.5-2.5 m (5-8 ft). Installation of an offshore export cable is anticipated to last ~16 days. The estimated installation time for the inter-array cables is ~60 days. Installation days are not continuous and do not include equipment preparation or down time that may result from weather, marine mammal observations or maintenance.

Some dredging may be required prior to cable laying due to the presence of sand waves. The upper portions of sand waves may be removed via mechanical or hydraulic means in order to achieve the proper burial depth below the stable sea bottom.

The majority of the export and inter-link cable is expected to be installed using simultaneous lay and bury via jet plowing. Likewise, the majority of the inter-array cable is expected to be installed via jet plowing after the cable has been placed on the seafloor. Other methods, such as mechanical plowing or trenching, may be needed in areas of coarser or more consolidated sediment, rocky bottom, or other difficult conditions in order to ensure a proper burial depth. The jet plowing tool may be based from a seabed tractor or a sled deployed from a vessel. A mechanical plow is also deployed from a vessel.

In order to assess the impacts of these activities, a set of computer simulation models was used. Details of these models are provided in Appendix II-A of the COP, Volume III. The model results indicate that most of the suspended sediment mass would settle out quickly and would not be transported for significant distances by the currents. Thus, potential impacts from suspended sediments resulting from cable laying are not expected to result in takes of marine mammals.

Potential noise impacts from cable installation are expected to derive primarily from the vessel(s) laying the cable. For example, during a similar type of underwater construction activity, Robinson et al. (2011) measured sound levels radiated from marine aggregate dredgers, mainly trailing suction hopper dredges (TSHDs) during normal operation. Robinson et al. (2011) concluded that because of the operation of the propulsion system, noise radiated at <500 Hz is similar to that of a merchant vessel "travelling at modest speed" (for self-propelled dredges). During dredging operations, sound levels above the vessel noise are radiated between 1 and 2 kHz, generated by the impact and abrasion of the sediment passing through the draghead, suction pipe, and pump. These components would not be present during cable lay operations, so these higher frequency sounds are not anticipated. Additionally, field studies conducted offshore New Jersey, Virginia, and Alaska show that noise generated by using vibracores, CPTs, and drilling boreholes diminishes below the NMFS Level B harassment thresholds (120 decibels [dB] for continuous sound sources) relatively quickly and is unlikely to cause harassment to marine mammals (NMFS 2009; Reiser, Funk, Rodrigues, & Hannay, 2011; TetraTech, 2014). Based on these studies, sounds from cable laying activities are anticipated to be comparable to vessel noise impacts expected in the WDA for other general construction and installation vessel activities.

1.1.2. Construction Vessel Activity

Construction vessel activity is described in Section 7.8.2.1 of the COP, Volume III. During construction and installation of the ~800 MW Project, it is anticipated that an average of approximately 25 vessels will operate during a typical work day in the WDA and along the OECC. Many of these vessels will remain in the WDA or OECC for days or weeks at a time, potentially making only infrequent trips to port for bunkering and provisioning, as needed. Therefore, although an average of ~25 vessels will be involved in construction activities on any given day, fewer vessels will transit to and from New Bedford Harbor or a secondary port each day. The actual number of vessels involved in the Project at one time is highly dependent on the Project's final schedule, the final design of the Project's components, and the logistics solution used to achieve compliance with the Jones Act.

Vessel traffic in the vicinity of the Massachusetts Wind Energy Area is relatively high; therefore, marine mammals in the area are presumably habituated to vessel noise (BOEM 2014b; NMFS 2018b). In addition, construction vessels would be stationary on site for significant periods of time and the large vessels would travel to and from the site at low speeds, which would produce lower noise levels than vessel transit at higher speeds.

As part of various construction related activities, including cable laying and construction material delivery, DP thrusters may be utilized to hold vessels in position or move slowly. Sound produced through use of DP thrusters is similar to that produced by transiting vessels and DP thrusters are typically operated either in a similarly predictable manner or used for short durations around stationary activities. Sound produced by DP thrusters would be preceded by, and associated with, sound from ongoing vessel noise and would be similar in nature; thus, any marine mammals in the vicinity of the activity would be aware of the vessel's presence, further reducing the potential for startle or flight responses on the part of marine mammals. Monitoring of past projects that entailed use of DP thrusters has shown a lack of observed marine mammal responses as a result of exposure to sound from DP thrusters (NMFS 2018b). As DP thrusters are not expected to result in take of marine mammals, these activities are not analyzed further in this document.

1.1.3. Pile Driving Equipment Descriptions

Two foundation types are proposed for the Project: monopiles and jackets. WTGs and ESPs may be placed on either type of foundation.

A monopile is a single, hollow cylinder fabricated from steel that is secured in the seabed. Monopile dimensions are shown on Figure 2. Monopiles are an equipment type that have been used successfully at many offshore wind energy locations. They currently account for more than 80% of the installed foundations in Europe, with more than 3,350 units installed (Wind Europe, 2017).

The jacket design concept consists of three to four piles, a large lattice jacket structure, and a transition piece (TP) (Figure 3). The jacket structure is supported/secured by pre-installed driven piles (one per leg). Alternatively, the jacket is secured to the sea floor via slender piles that are driven through "sleeves" or guides mounted to the base of each leg of the jacket structure.

Jackets accounted for 12% of the number of foundations installed in 2016 in Europe, which brings their total market share to 6.6% (Wind Europe, 2017). Jackets are also widely used for other offshore applications, including oil and gas production platforms.

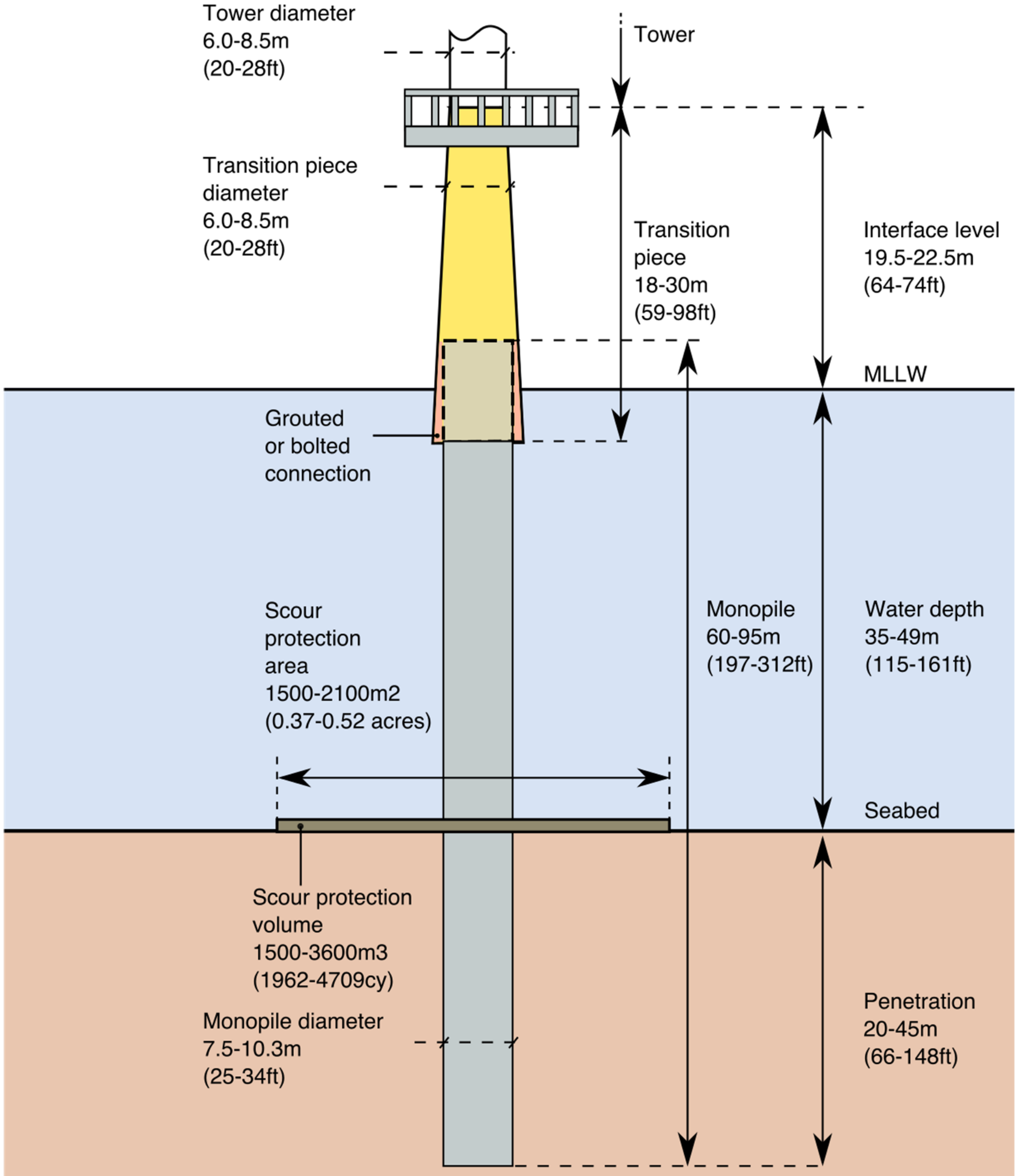

Figure 2. Schematic drawing of a monopile foundation (Figure 3.1-3 of the Vineyard Wind Draft Construction and Operations Plan Volume I; Vineyard Wind, 2018).

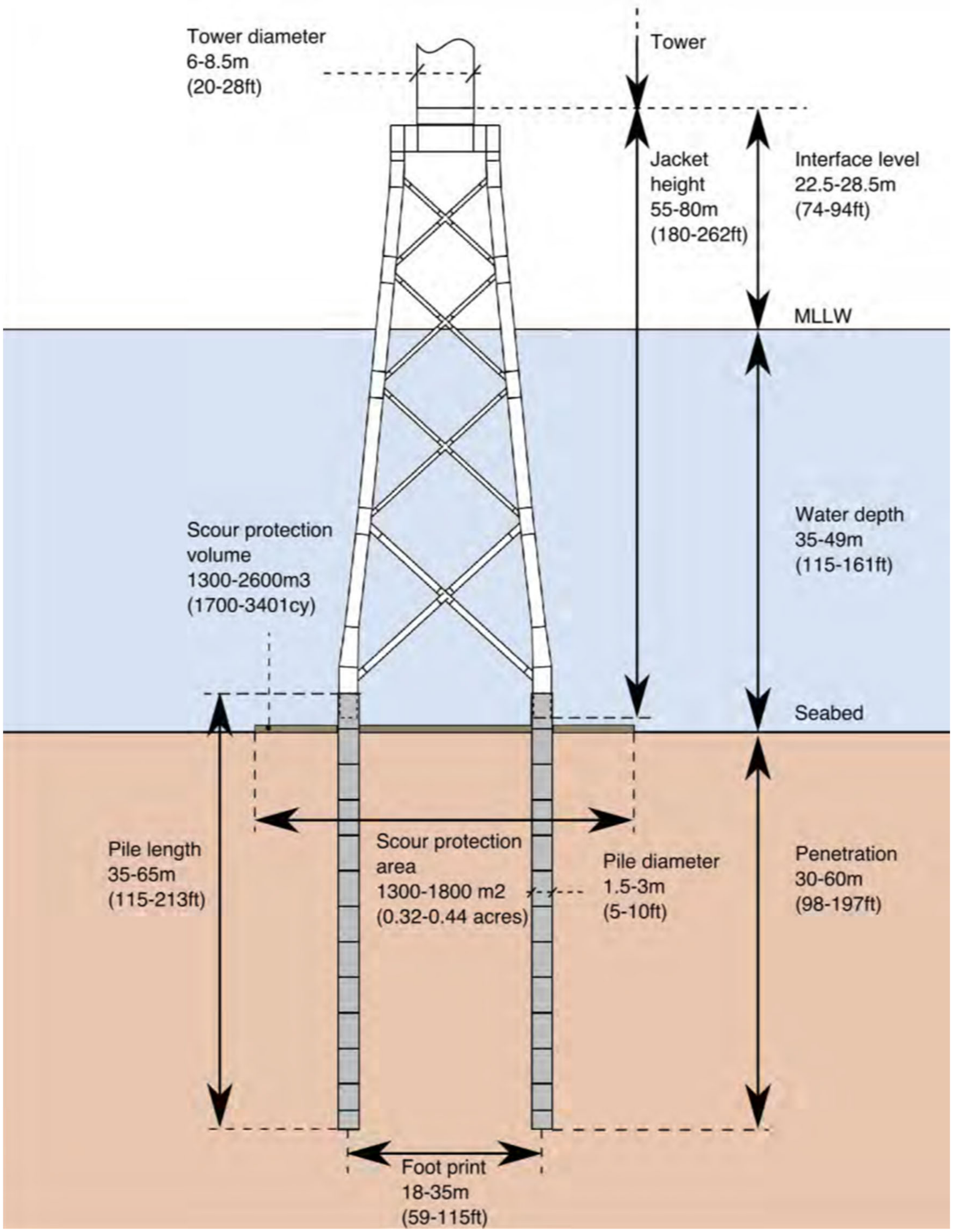

Figure 3. Schematic drawing of a jacket foundation (Figures 3.1-6 of the Vineyard Wind Draft Construction and Operations Plan Volume I; Vineyard Wind, 2018).

1.1.4. Monopile and Jacket Installation

The monopiles and jacket foundations will be installed by one or two heavy lift or jack-up vessel(s). The main installation vessel(s) will likely remain at the WDA during the installation phase and transport vessels, tugs, and/or feeder barges will provide a continuous supply of foundations to the WDA. If Jones Act compliant vessels are available, the foundation components could be picked up directly in the marshalling port by the main installation vessel(s).

At the WDA, the main installation vessel will upend the monopile with a crane, and place it in the gripper frame, before lowering the monopile to the seabed. The gripper frame, depending upon its design, may be placed on the seabed scour protection materials to stabilize the monopile's vertical alignment before and during piling. Once the monopile is lowered to the seabed, the crane hook is released, and the hydraulic hammer is picked up and placed on top of the monopile. Figure 4 shows a vessel lowering a monopile and typical jack-up installation vessels.

The pile driving will begin with a soft-start to ensure that the monopile remains vertical and allow any motile marine life to leave the area before the pile driving intensity is increased. The intensity (i.e., hammer energy level) will be gradually increased based on the resistance that is experienced from the sediments. The expected maximum hammer size for monopiles is up to 4,000 kilojoules (kJ). However, energy use is anticipated to be far less than 4,000 kJ. A typical pile-driving operation is expected to take less than approximately three hours to achieve the target penetration depth. It is anticipated that a maximum of two piles can be driven into the seabed per day. Concurrent monopile driving is not planned. No drilling of monopiles is anticipated, but it could be required if a large boulder or monopile refusal is encountered. Similarly, use of a vibratory hammer is not anticipated, but could be used if deemed appropriate by the installation contractor. Both drilling and vibratory hammer installation are expected to produce less sound in the marine environment than impact hammer installation.

Figure 4. Typical monopile and jacket foundation installation vessels (Figure 4.2-5 of Volume I of the Vineyard Wind Draft Construction and Operations Plan; Vineyard Wind, 2018).

1.2. Project Installation Scenarios

Vineyard Wind is proposing to install up to 100 WTGs and up to two electrical service platforms (ESPs) in the WDA. Two types of foundations were considered in the acoustic modeling study conducted to estimate the potential number of incidental marine mammal exposures:

- Monopile foundations varying in size with a maximum of 10.3 m (33.8 ft) diameter piles, and
- Jacket-style foundation using 3 m (9.8 ft) diameter (pin) piles.[1]

The 10.3 m (33.8 ft) monopile foundation is the largest potential pile diameter proposed for the Project and represents the Maximum Design envelope[2] for monopile foundations. Piles for monopile foundations will be constructed for specific locations with maximum diameters ranging from ~8 m (26.2 ft) up to ~10.3 m (33.8 ft) and an expected median diameter of ~9 m (29.5 ft). Jacket foundations each require the installation of three to four jacket securing piles, known as jacket piles, of ~3 m (9.8 ft) diameter. The piles for the monopile foundations are up to 95 m (311.7 ft) in length and will be driven to a penetration depth of 20–45 m (65.6–147.6 ft) (mean penetration depth 30 m [98.4 ft]). The 3 m (9.8 ft) diameter jacket piles for the jacket foundations are up to ~65 m (213.3 ft) in length and will be driven to a penetration depth of 30–75 m (98.4–196.9 ft) (mean penetration depth of 45 m [147.6]) (Table 3.1-3 and 3.1-4 of Volume I of the COP). An IHC S-4000 hammer was modeled for driving piles for the monopile foundations and an IHC S-2500 hammer was used in modeling for driving the 3 m (9.8 ft) jacket piles. Representative hammering schedules of increasing hammer energy with increasing penetration depth were modeled, resulting in, generally, higher intensity sound fields as the hammer energy and penetration increases. Acoustic modeling details and summary are provided in Appendix III-M of Volume III of the COP.

Two installation scenarios were considered:

1. the Maximum Design envelope consisting of ninety 10.3 m (33.8 ft) WTG monopile foundations, 10 jacket foundations, and two jacket foundations for ESPs, and
2. the maximum of the Most Likely installation configuration consisting of 100 10.3 m (33.8 ft) WTG monopile foundations and two jacket foundations for ESPs (Table 1).

Table 1. Modeling scenarios

Scenario	WTG monopiles (pile size: 10.3 m [33.8 ft])	WTG jacket foundations (pile size 3 m [9.8 ft])	ESP jacket foundations (pile size 3 m [9.8 ft])	Total # piles	Total # locations
Maximum design envelope	90	10	2	138	102
Most likely	100	--	2	108	102

[1] Foundation dimensions are approximate. The 10.3 m monopile and 3 m jacket pile were modeled as the maximum dimension to provide conservative estimates of Level A and Level B harassment. A more realistic likely configuration is a 9 m monopile.
[2] The Project is being developed and permitted using an “Envelope” concept. The evolution of offshore wind technology and installation techniques often outpaces the speed of permitting processes. The Envelope concept allows for optimized projects once permitting is complete while ensuring a comprehensive review of the project by regulators and stakeholders, as BOEM recognized in its National Offshore Wind Strategy. The flexibility provided in the Envelope is important because it precludes the need for numerous permit modifications as infrastructure or construction techniques evolve after permits are granted but before construction commences.

1.3. Activities Resulting in the Potential Incidental Take of Marine Mammals

The Project pile driving could result in incidental take of marine mammals by Level A and Level B harassment caused by underwater sound from these activities. When piles are driven with impact hammers, they deform, sending a bulge travelling down the pile that radiates sound into the surrounding air, water, and seabed. This sound may be received as a direct transmission from the source to biological receivers such as marine mammals, sea turtles, and fish; through the water, as the result of reflected paths from the surface, or re-radiated into the water from the seabed (Figure 5). Sound transmission depends on many environmental parameters, such as the sound speeds in water and substrates, and sound production parameters of the pile and how it is driven, including the pile material, size (length, diameter, and thickness), and the type and energy of the hammer.

Noise generated by impact pile driving consists of regular, pulsed sounds of short duration. These pulsed sounds are typically high energy with fast rise times. Exposure to these sounds may result in Level A or Level B harassment depending on proximity to the sound source and a variety of environmental and biological conditions (Dahl, de Jong, & Popper, 2015; J. R Nedwell et al., 2007). Illingworth & Rodkin (2007) measured an unattenuated sound pressure within 10 m (33 ft) at a peak of 220 dB re 1 µPa for a 2.4 m (96 inch [in]) steel pile driven by an impact hammer, and Brandt, Diederichs, Betke, and Nehls (2011) found that for a pile driven in a Danish wind farm in the North Sea, the peak pressure at 720 m (0.4 nm) from the source was 196 dB re 1 µPa. Studies of underwater sound from pile driving finds that most of the acoustic energy is below one to two kHz, with broadband sound energy near the source (40 Hz to >40 kHz) and only low-frequency energy (<~400 Hz) at longer ranges (Bailey et al., 2010; Erbe, 2009; Illingworth & Rodkin, 2007). There is typically a decrease in sound pressure and an increase in pulse duration the greater the distance from the noise source (Bailey et al., 2010). Maximum noise levels from pile driving usually occur during the last stage of driving each pile where the highest hammer energy levels are used (Betke, 2008).

In order to initiate impact pile driving the pile must be upright, level, and stable. The preferred option to achieve this is by utilizing a pile frame which sits on the sea floor and holds the pile and the secondary option is to utilize a pile gripper which is attached to the installation vessel and holds the pile. In the unlikely scenario that both preferred options have unforeseen challenges, vibratory hammering may be utilized as a contingency. If required, a vibratory hammer will be used before impact hammering begins to ensure the pile is stable in the sea bed and level for impact hammering. Vibratory hammering is accomplished by rapidly alternating (~250 Hz) forces to the pile. The resultant overall sound levels associated with a vibratory hammering are typically less than impact hammering. The exposure to vibratory hammer sounds is unlikely to induce injury because of its lower peak pressure levels and its relatively short duration (anticipated to be less than 10 min; however, in rare cases it may take up to 30 minutes).

To estimate the potential effects to marine mammals of pile driving noise generated during the Project's construction, JASCO modeled pile driving sound output, acoustic propagation, and animal movement using industry standard models under two installation scenarios: 1) the Maximum Design envelope consisting of ninety 10.3 m (33.8 ft) WTG monopile foundations, 10 jacket foundations, and two jacket foundations for ESPs, and 2) the maximum of the Most Likely installation configuration consisting of one hundred 10.3 m (33.8 ft) WTG monopile foundations and two jacket foundations for ESPs. Modeling was conducted at two pile driving sites within the WDA – one in the southwest and one in the northeast—to provide representative propagation and sound fields for the Offshore Project Area. Impact hammering will be used on all piles and for most of the time pile driving occurs. Since impact hammering produces stronger peak sound pressure levels than vibratory pile driving, impact hammering was used in the modeling to estimate potential effects on marine mammals. Given the unlikely limited use of vibratory pile driving, the lower sound pressure levels it produces, and conservative model assumptions, any Level B takes resulting from vibratory hammering are included within the takes requested. Furthermore, any vibratory hammering would also offset the amount of impact hammering needed. The modeling results are reported in Section 6, and Appendix A contains a detailed description of the modeling, including modeling procedures and assumptions.

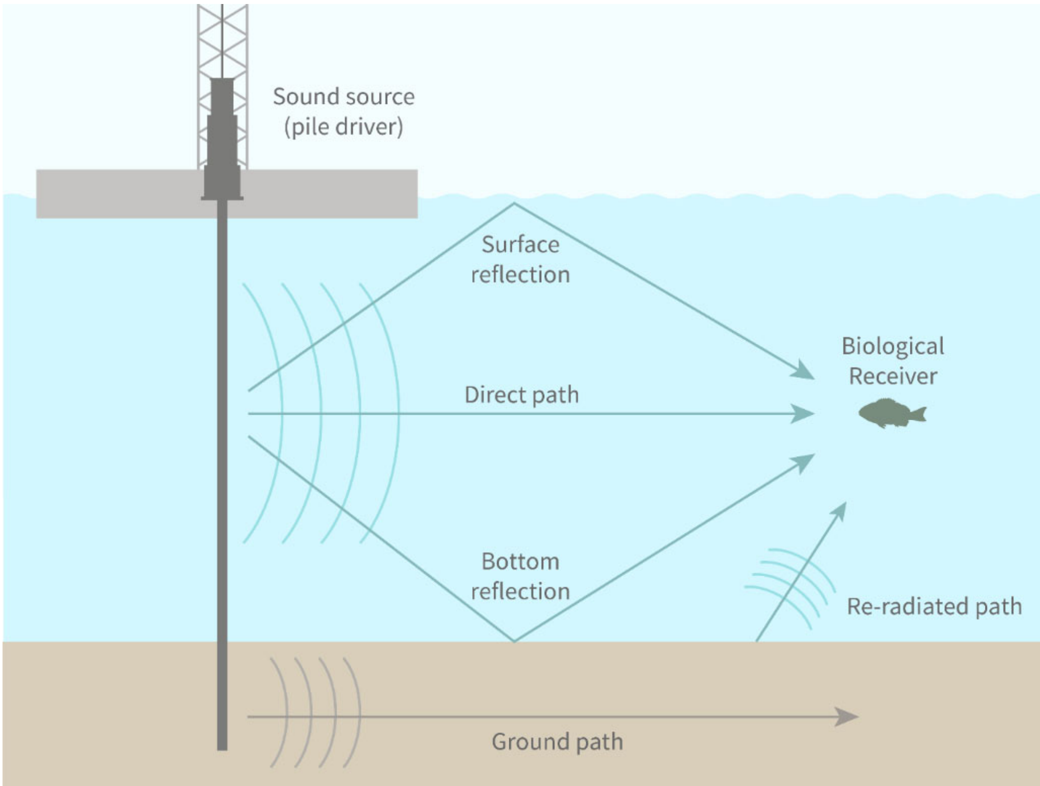

Figure 5. Sound propagation paths associated with pile driving (adapted from Buehler, Oestman, Reyff, Pommerenck, & Mitchell, 2015).

2. Dates, Duration, and Specified Geographic Region

2.1. Dates of Construction Activities

Construction of the Project is planned to begin in late 2019, beginning with onshore activities. Pile driving activities related to this request for IHA authorization and permitted takes are scheduled to commence in the third quarter of 2020 and continue through to approximately the third quarter of 2021 with a break in pile driving between January 1 and April 30 per the mitigation protocol (see Section 11). An alternative schedule includes pile driving activities from the second quarter of 2021 (May) to the fourth quarter of 2021.

2.2. Pile Driving Schedule

The total planned duration of offshore construction activities is approximately 17–22 months, depending on which option is chosen. Pile driving activities may occur over a total of approximately eight months in either option; however, piling of a single pile is anticipated to only occur for up to a few hours at a maximum, and most installations are anticipated to last less than a few hours. There will also be time between piling events to mobilize to the next location and prepare for the next installation. Table 2 shows the expected pile driving schedule that was used in the Maximum Design scenario of the acoustic modeling (Section 6). The modeling assumed installation of one monopile foundation per day and two monopile foundations per day, distributed across the same calendar period (May through December). It was assumed that the jacket foundations (four piles) are installed in one day. It was also assumed that no concurrent pile driving would be performed. The pile driving schedules for modeling were created to better understand when the majority of pile driving is likely to occur throughout the year based on the number of expected suitable weather days available in months when pile driving is planned. The number of suitable weather days per month was obtained from historical weather data. Per the schedule shown in Table 2, there are 119 days when pile driving is likely to occur during the May to December period; however, given that there are fewer than 119 foundations, actual piling days will be less.

[redacted]

[redacted]	[redacted]	[redacted]			
		[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

2.3. Specific Geographical Region of Activity

Pile driving will occur in the WDA in the northern portion of the Vineyard Wind Lease Area OCS-A 0501 (Figure 1). The WDA is just over 23 km (14 mi) from the southeast corner of Martha's Vineyard and a similar distance to Nantucket.

3. Species and Number of Marine Mammals

3.1. Species Present

Forty-two marine mammal species have been documented within the US Atlantic EEZ (CeTAP 1982; USFWS 2014; S.A. Hayes, Josephson, Maze-Foley, & Rosel, 2018; Roberts et al., 2016). Sixteen of these species are not expected to occur within the Offshore Project Area based on a lack of sightings and their known habitat preferences and distributions (USFWS 2014; S.A. Hayes et al., 2018; R. D. Kenney & Vigness-Raposa, 2010; S. D. Kraus et al., 2016; Roberts et al., 2016). These are: the West Indian Manatee (*Trichechus manatus latirostris*), Bryde's Whale (*Balaenoptera edeni*), Beluga Whale (*Delphinapterus leucas*), Northern Bottlenose Whale (*Hyperoodon ampullatus*), Killer Whale (*Orcinus orca*), Pygmy Killer Whale (*Feresa attenuata*), False Killer Whale (*Pseudorca crassidens*), Melon-Headed Whale (*Peponocephala electra*), White-Beaked Dolphin (*Lagenorhynchus albirostris*), Pantropical Spotted Dolphin (*Stenella attenuata*), Fraser's Dolphin (*Lagenodelphis hosei*), Rough-Toothed Dolphin (*Steno bredanensis*), Clymene Dolphin (*Stenella clymene*), Spinner Dolphin (*Stenella longirostris*), Hooded Seal (*Cystophora cristata*), and Ringed Seal (*Pusa hipsida*). These species are not considered further in this application.

Table 3 lists the 26 marine mammal species that may occur, at least occasionally, within the WDA, along with the relative likelihood of their occurrence in the WDA and any special status accorded by the US Endangered Species Act (ESA), the MMPA, and the Massachusetts ESA. This includes six species of large baleen whales (mysticetes); 17 species of large and small toothed whales, dolphins, and porpoise (odontocetes); and three species of earless seals (phocid pinnipeds). It is unlikely that all 26 species would be present in the WDA during in-water construction for the Project because some of these species migrate seasonally or prefer different habitat.

Species that are considered "common" in the Offshore Project Area are: the North Atlantic Right Whale (NARW; *Eubalaena glacialis*), Humpback Whale (*Megaptera novaeangliae*), Fin Whale (*Balaenoptera physalus physalus*), Sei Whale (*Balaenoptera borealis borealis*), Minke Whale (*Balaenoptera acutorostrata acutorostrata*), Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*), Short-Beaked Common Dolphin (*Delphinus delphis delphis*), Common Bottlenose Dolphin (*Tursiops truncatus truncatus*), Harbor Porpoise (*Phocoena phocoena*), Harbor Seal (*Phoca vitulina vitulina*), and Gray Seal (*Halichoerus grypus atlantica*) (BOEM 2014b; S.A. Hayes et al., 2018; R. D. Kenney & Vigness-Raposa, 2010; S. D. Kraus et al., 2016; Roberts et al., 2016). Because of their common use of the WDA and surrounding areas, these species are likely to be exposed to stressors, such as noise, increased vessel traffic, and structures in the water that may result in short-term, localized disturbance of individuals and/or long-term, localized modification of habitat. Sections 4.2 and 4.3 describe the behavior and ecology, acoustics (uses of sound and hearing ability), distribution, best abundance estimates, and status of each of these species.

Species that occur less frequently, yet with some regularity, in the Offshore Project Area are identified as "uncommon" and include the Sperm Whale (*Physeter macrocephalus*), Risso's Dolphin (*Grampus griseus*), Long-Finned Pilot Whale (*Globicephalus melas*), and Harp Seal (*Pagophilus groenlandicus*). Sighting and distribution data suggest that Risso's Dolphins and Sperm Whales typically occur in deeper waters along the continental slope and oceanic waters (S.A. Hayes et al., 2018; Roberts et al., 2016), though both species were observed during the Northeast Large Pelagic Survey Collaborative (NLPSC) aerial surveys of the RI/MA & MA WEAs during 2011–2015 (S. D. Kraus et al., 2016). In that study, there were two sightings of individual Risso's Dolphins in spring, one sighting of a single Sperm Whale in fall, and three sightings totaling eight Sperm Whales in summer. Long-Finned Pilot Whales are mainly distributed along the US continental shelf edge in winter and early spring, then move onto Georges Bank, the Gulf of Maine, and more northerly waters where they remain through late fall (Sean A. Hayes, Josephson, Maze-Foley, & Rosel, 2017). There are two pilot whale species (Long-Finned and Short-Finned [*Globicephalus macrorhynchus*] Pilot Whales) with distributions that overlap in the latitudinal range of the Offshore Project Area (Sean A. Hayes et al., 2017; Roberts et al., 2016). Because it is difficult to discriminate the two species at sea, sightings, and thus the densities calculated from them, are generally reported together as *Globicephala* spp. (Sean A. Hayes et al., 2017; Roberts et al., 2016). However, Short-Finned Pilot Whales are generally considered to be a more tropical species, so it is likely that most pilot whales found in the Offshore Project Area will be Long-Finned Pilot Whales. Pilot whales were observed 11 and three times in the spring and summer, respectively, during the S. D. Kraus et al. (2016) aerial surveys of the RI/MA & MA WEAs during 2011–2015. Finally, Harp Seals typically occur north of the Offshore Project Area, though they strand annually in Massachusetts and Rhode Island (S.A. Hayes et al., 2018). These five uncommon species can be reasonably expected to experience at least a small amount of exposure to stressors related to construction activities in the WDA and so are considered further in Section 4 and are used in the exposure modeling and take estimation.

There are 10 other cetacean species that are considered to be “rare” in the Offshore Project Area based on sighting and distribution data (Table 3). These are: Blue Whales (*Balaenoptera musculus musculus*), Dwarf and Pygmy Sperm Whales (*Kogia sima* and *K. breviceps*), Cuvier’s Beaked Whale (*Ziphius cavirostris*), four species of Mesoplodont Beaked Whale—Blainsville’s (*Mesoplodon densirostris*), Gervais’ (*M. europaeus*), Sowerby’s (*M. bidens*), and True’s (*M. mirus*) Beaked Whales, Atlantic Spotted Dolphin (*Stenella frontalis*), and Striped Dolphin (*Stenella coeruleoalba*) (S.A. Hayes et al., 2018; R. D. Kenney & Vigness-Raposa, 2010; S. D. Kraus et al., 2016; Roberts et al., 2016). The exposure probability of these species is quite low, and they are not considered further in the modeling analysis.

Table 3. Marine mammals that may occur in the WDA.

Common name (species name) and stock	Special status[a] (ESA/NOAA Fisheries/MA ESA)	Occurrence in offshore Project area[b]	Seasonality in Offshore Project area[c]	Abundance[d] (NOAA Fisheries best available)	Abundance[e] (Roberts et al. 2015, 2016, 2017)
Mysticetes					
North Atlantic Right Whale (*Eubalaena glacialis*) Western Atlantic Stock	Endangered/Strategic/Endangered	Common	Winter and spring (December to May)	458	292 Winter, 394 Spring, 358 Summer, 124 Fall
Humpback Whale (*Megaptera novaeangliae*) Gulf of Maine Stock	Not Listed/Strategic/Endangered	Common	Year-round, but mainly spring and summer	335	248 Winter, 1,773 Summer
Fin Whale (*Balaenoptera physalus physalus*) Western North Atlantic Stock	Endangered/Strategic/Endangered	Common	Year-round, but mainly spring and summer	1,618	3,005
Sei Whale (*Balaenoptera borealis borealis*) Nova Scotia Stock	Endangered/Strategic/Endangered	Common	Spring and summer (March to June)	357	210 Winter, 453 Summer
Minke Whale (*Balaenoptera acutorostrata acutorostrata*) Canadian East Coast Stock	Not Listed/None/Not Listed	Common	Spring, summer, and fall (March to September)	2,591	652 Winter, 3,014 Summer
Blue Whale (*Balaenoptera musculus musculus*) Western North Atlantic Stock	Endangered/Strategic/Endangered	Rare	Mainly winter, but rare year-round	Unknown	11
Odontocetes					
Sperm Whale (*Physeter macrocephalus*) North Atlantic Stock	Endangered/Strategic/Endangered	Uncommon	Mainly summer and fall	2,288	4,199[f]
Dwarf and Pygmy Sperm Whale (*Kogia sima* and *Kogia breviceps*) Western North Atlantic Stock	Not Listed/None/Not Listed	Rare	NA	3,785	678
Cuvier's Beaked Whale (*Ziphius cavirostris*) Western North Atlantic Stock	Not Listed/None/Not Listed	Rare	NA	6,532	7,731
Blainville's, Gervais', True's, and Sowerby's Beaked Whales (*Mesoplodon densitostris*, *M. europaeus*, *M. mirus*, and *M. bidens*) Western North Atlantic Stock	Not Listed/None/Not Listed	Rare	NA	7,092	5,937[g]
Risso's Dolphin (*Grampus griseus*) Western North Atlantic Stock	Not Listed/None/Not Listed	Uncommon	Year-round	18,250	7,732

Common name (species name) and stock	Special status[a] (ESA/NOAA Fisheries/MA ESA)	Occurrence in offshore Project area[b]	Seasonality in Offshore Project area[c]	Abundance[d] (NOAA Fisheries best available)	Abundance[e] (Roberts et al. 2015, 2016, 2017)
Pilot Whale, Long-Finned (*Globicephalus melas*) Western North Atlantic Stock	Not Listed/Strategic/Not Listed	Uncommon	Year-round	5,636	27,597[h]
Pilot Whale, Short-Finned (*Globicephalus macrorhynchus*) Western North Atlantic Stock	Not Listed/Strategic/Not Listed	Rare	NA	21,515	27,597[h]
Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*) Western North Atlantic Stock	Not Listed/None/Not Listed	Common	Year-round	48,819	37,180
Short-Beaked Common Dolphin (*Delphinus delphis delphis*) Western North Atlantic Stock	Not Listed/None/Not Listed	Common	Year-round, but more abundant in summer	70,184	86,098
Atlantic Spotted Dolphin (*Stenella frontalis*) Western North Atlantic Stock	Not Listed/None/Not Listed	Rare	NA	44,715	55,436
Striped Dolphin (*Stenella coeruleoalba*) Western North Atlantic Stock	Not Listed/None/Not Listed	Rare	NA	54,807	75,657
Common Bottlenose Dolphin (*Tursiops truncatus truncatus*)[h] Western North Atlantic Offshore Stock	Not Listed/None/Not Listed	Common	Year-round	77,532	97,476[i]
Harbor Porpoise (*Phocoena phocoena phocoena*) Gulf of Maine/Bay of Fundy Stock	Not Listed/None/Not Listed	Common	Year-round, but less abundant in summer	79,833	13,782 Winter, 60,281 Summer
Pinnipeds					
Harbor Seal (*Phoca vitulina vitulina*) Western North Atlantic Stock	Not Listed/None/Not Listed	Common	Year-round, but rare in summer	75,834	Winter 15,002, Summer 98,747
Gray Seal (*Halichoerus grypus atlantica*) Western North Atlantic Stock	Not Listed/None/Not Listed	Common	Year-round	27,131	Winter 15,002, Summer 98,747
Harp Seal (*Pagophilus groenlandicus*) Western North Atlantic Stock	Not Listed/None/Not Listed	Uncommon	Winter and spring	Unknown[j]	Winter 15,002, Summer 98,747

Common name (species name) and stock	Special status[a] (ESA/NOAA Fisheries/MA ESA)	Occurrence in offshore Project area[b]	Seasonality in Offshore Project area[c]	Abundance[d] (NOAA Fisheries best available)	Abundance[e] (Roberts et al. 2015, 2016, 2017)

a. Special status accorded by the US Endangered Species Act (ESA), NOAA Fisheries (S.A. Hayes et al., 2018), and Massachusetts Endangered Species Act (ESA; see Mass.gov).

b. Occurrence in the Offshore Project Area was mainly derived from S.A. Hayes et al. (2018), R. D. Kenney and Vigness-Raposa (2010), Kraus et al. (2016), and Roberts et al. (2016).

c. Seasonality was mainly derived from S. D. Kraus et al. (2016), R. D. Kenney and Vigness-Raposa (2010).

d. "Best Available" population estimate is from NOAA Fisheries Stock Assessment Reports (Hayes et al., 2018).

e. Abundance estimates are from habitat-based density modeling of the entire Atlantic EEZ from Roberts et al. (2016), except: Fin Whale, Humpback Whale, Minke Whale, North Atlantic Right Whale, Sei Whale, Cuvier's Beaked Whale, Mesoplodont beaked whales, pilot whale, Sperm Whale, and Harbor Porpoise abundances are updated values from Roberts, Mannocci, and Halpin (2017) and seal abundance estimates are from Roberts et al. (2015, unpublished) and are for all seals in the US Atlantic EEZ as a group.

f. Roberts et al. (2017) Sperm Whale abundance estimate consists of 223 for the shelf area and 3,976 for the slope and abyss.

g. The four Mesoplodont beaked whale species are grouped in Roberts et al. (2017).

h. Long-Finned and Short-Finned Pilot Whales are grouped in Roberts et al. (2017).

i. Common Bottlenose Dolphins occurring in the Offshore Project Area likely belong to the Western North Atlantic Offshore Stock. It is possible that some could belong to the Western North Atlantic Northern Migratory Coastal Stock, but the northernmost range of that stock is south of the Project area. That stock is considered Strategic by NOAA Fisheries because it is designated as depleted under the MMPA.

j. S.A. Hayes et al. (2018) report insufficient data to estimate the population size of harp seals in US waters; however, the best estimate for the whole population is 7.4 million.

4. Affected Species Status and Distribution

4.1. Affected Species

As discussed in Section 3, there are 15 species (including pilot whales as a single species guild) of marine mammals that occur either commonly or uncommonly (but regularly) in the Offshore Project Area (Table 3), and thus may experience some level of exposure to stressors from the construction activities of the Project. The NARW, Fin Whale, Sei Whale, and Sperm Whale are all considered Endangered under the ESA. These four species, as well as the Humpback Whale and two pilot whale species, are all considered Strategic under the MMPA. The sections below provide additional details on the species that are likely to occur in the Offshore Project Area.

4.2. Cetaceans

4.2.1. North Atlantic Right Whale (*Eubalaena glacialis*)

NARWs are among the rarest of all marine mammal species in the Atlantic Ocean. They average approximately 15 m (50 ft) in length (NOAA Fisheries, 2018o). They have stocky, black bodies with no dorsal fin, and bumpy, coarse patches of skin on their heads called callosities. NARWs feed mostly on zooplankton and copepods belonging to the *Calanus* and *Pseudocalanus* genera (S.A. Hayes et al., 2018). NARWs are slow-moving grazers that feed on dense concentrations of prey at or below the water's surface, as well as at depth (NOAA Fisheries, 2018o). Research suggests that NARWs must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo & Marx, 1990). These dense zooplankton patches are a primary characteristic of the spring, summer, and fall NARW habitats (Robert D. Kenney, Hyman, Owen, Scott, & Winn, 1986; Robert D. Kenney, Winn, & Macaulay, 1995).

4.2.1.1. Distribution

The NARW is a migratory species that travels from high-latitude feeding waters to low-latitude calving and breeding grounds, though this species has been observed feeding in winter in the mid-Atlantic region and has been recorded off the coast of New Jersey in all months of the year (Whitt, Dudzinski, & Laliberté, 2013). These whales undertake a seasonal migration from their northeast feeding grounds (generally spring, summer, and fall habitats) south along the US east coast to their calving grounds in the waters of the southeastern US (R. D. Kenney & Vigness-Raposa, 2010). NARWs are usually observed in groups of less than 12 individuals, and most often as single individuals or pairs. Larger groups may be observed in feeding or breeding areas (T.A Jefferson, Webber, & Pitman, 2008).

NARWs are considered to be comprised of two separate stocks: Eastern and Western Atlantic stocks. The Eastern North Atlantic stock was largely extirpated by historical whaling (Aguilar, 1986). NARWs in US waters belong to the Western Atlantic stock. This stock ranges primarily from calving grounds in coastal waters of the southeastern US to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence (S.A. Hayes et al., 2018).

Surveys demonstrate the existence of seven areas where NARWs congregate seasonally: the coastal waters of the southeastern US, the Great South Channel, Jordan Basin, Georges Basin along the northeastern edge of Georges Bank, Cape Cod and Massachusetts Bays, the Bay of Fundy, and the Roseway Basin on the Scotian Shelf (S.A. Hayes et al., 2018). National Oceanic and Atmospheric Administration (NOAA) Fisheries has designated two critical habitat areas for the NARW under the ESA: the Gulf of Maine/Georges Bank region, and the southeast calving grounds from North Carolina to Florida (DoC, 2016b). Two additional critical habitat areas in Canadian waters, Grand Manan Basin and Roseway Basin, were identified in Canada's final recovery strategy for the NARW (Brown et al., 2009).

The Northeast Fisheries Science Center (NEFSC) observed NARWs three times in the WDA during two of the Atlantic Marine Assessment Program for Protected Species (AMAPPS) surveys (NEFSC & SEFSC, 2011b, 2012, 2014a, 2014b, 2015, 2016). All three sightings were in 2014: two observations of NARWs in the WDA were in the winter during an aerial survey; one observation was in the spring during a shipboard survey (NEFSC & SEFSC, 2014b).

S. D. Kraus et al. (2016) observed NARWs in the RI/MA & MA WEAs in winter and spring and observed 11 instances of courtship behavior. The greatest sightings per unit effort (SPUE) in the RI/MA & MA WEAs by S. D. Kraus et al. (2016) was in March, with a concentration of spring sightings in the WDA and winter sightings in the OECC. Seventy-seven unique individual NARWs were observed in the RI/MA & MA WEAs over the duration of the Northeast Large Whale Pelagic Survey (October 2011 to June 2015) (S. D. Kraus et al., 2016). Monthly SPUE for NARWs by S. D. Kraus et al. (2016) are shown in Figure 6. No calves were observed. S. D. Kraus et al. (2016) acoustically detected NARWs with passive acoustic monitoring (PAM) within the Massachusetts Wind Energy Area (MA WEA) on 43% of project days (443/1,020 days) and during all months of the year. Acoustic detections do not differentiate between individuals, so detections on multiple days could be the same or different individuals. NARWs exhibited notable seasonal variability in acoustic presence, with maximum occurrence in the winter and spring (January through March), and minimum occurrence in summer (July, August, and September). The mean detection range for NARWs using PAM was 15–24 km (49.2–78.7 ft), with a mean radius of 21 km (13 mi) (95% confidence interval of 3 km [1.8 mi]) for the PAM system within the WDA.

This species was not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 geophysical and geotechnical (G&G) surveys for the Project (Vineyard Wind, 2016, 2017). Roberts et al. (2016) predict that the highest density of NARWs in the MA WEA and adjacent waters occurs in April, and S. D. Kraus et al. (2016) reported greatest levels of SPUE of NARWs in the WDA in March (Figure 6). Aerial survey studies conducted in the Offshore Project Area did not record sightings of NARW for the months of May to October, and reported only four sightings in December across all survey years (October 2011 to June 2015) (S. D. Kraus et al., 2016).

4.2.1.2. Abundance

Roberts et al. (2016) habitat-based density models provide abundance estimates of 535 NARWs in the US Atlantic EEZ during winter (November–February), 416 during spring (March–April), 379 during summer (May–July), and 334 during fall (August–October) months. S.A. Hayes et al. (2018) report a minimum of 455 individuals in this stock. The best estimate of the NARW population size according the NARW Consortium is 451 (Pettis, Pace, Schick, & Hamilton, 2017). This comes from the Pace, Corkeron, and Kraus (2017) model, which also reported a 99.99% probability of NARW population decline from 2010 to 2015. This estimate does not consider that NARWs have been experiencing an Unusual Mortality Event (UME) since June 2017, with 19 documented deaths as of July 24, 2018 (NOAA Fisheries, 2018c). This unusual mortality event appears to be driven by entanglement in fishing gear and blunt force trauma associated with ship strikes mainly in the Gulf of St. Lawrence, Canada. Cause of death findings for the unusual mortality event are based on seven necropsies of dead NARWs found in Canada in the Gulf of St. Lawrence (Daoust, Couture, Wimmer, & Bourque, 2017; NOAA Fisheries, 2018c).

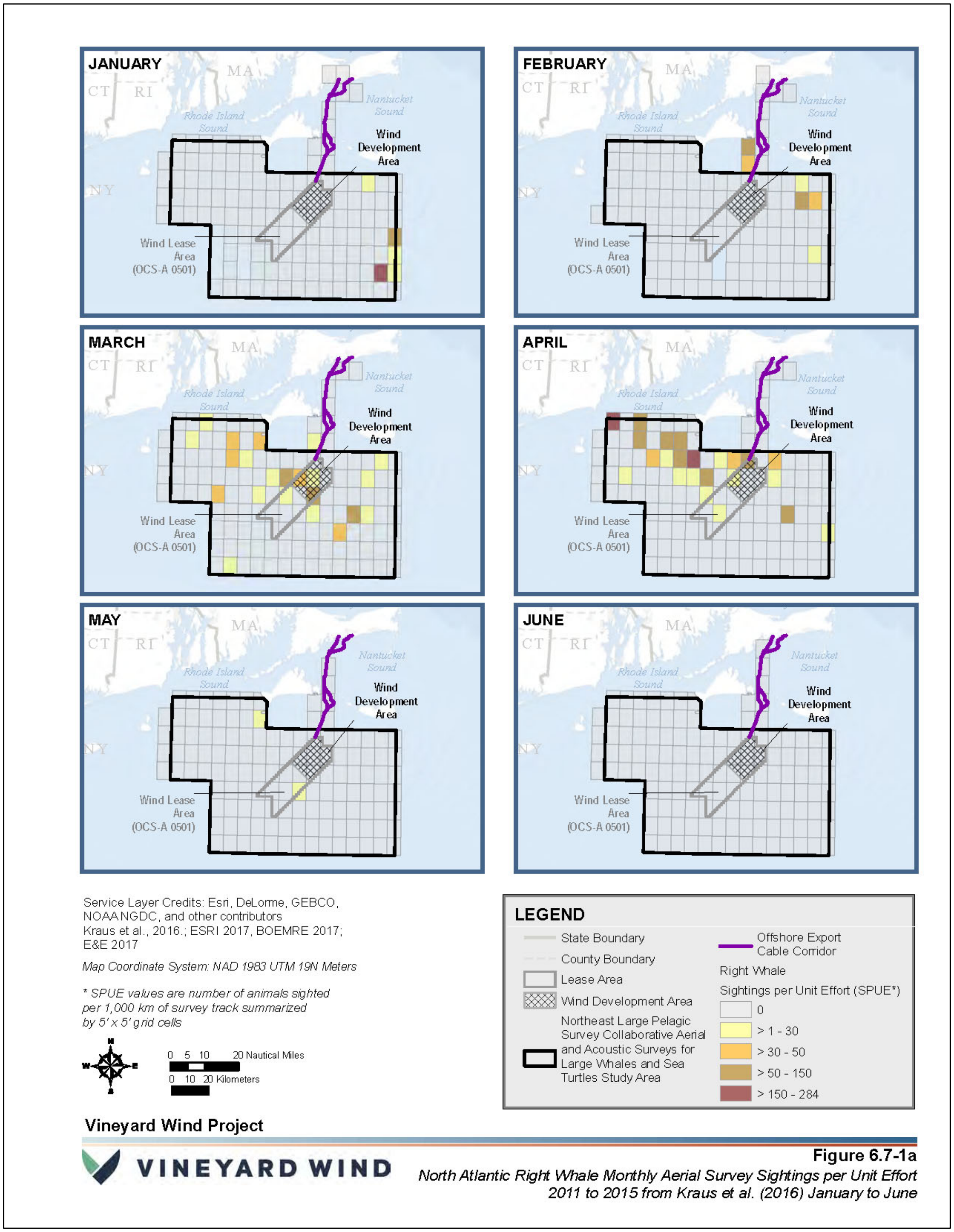

Figure 6. Monthly Sightings Per Unit Effort of North Atlantic Right Whales from S. D. Kraus et al. (2016) (Figure 6.7-1 of the Vineyard Wind Draft Construction and Operations Plan Volume I; Vineyard Wind, 2018).

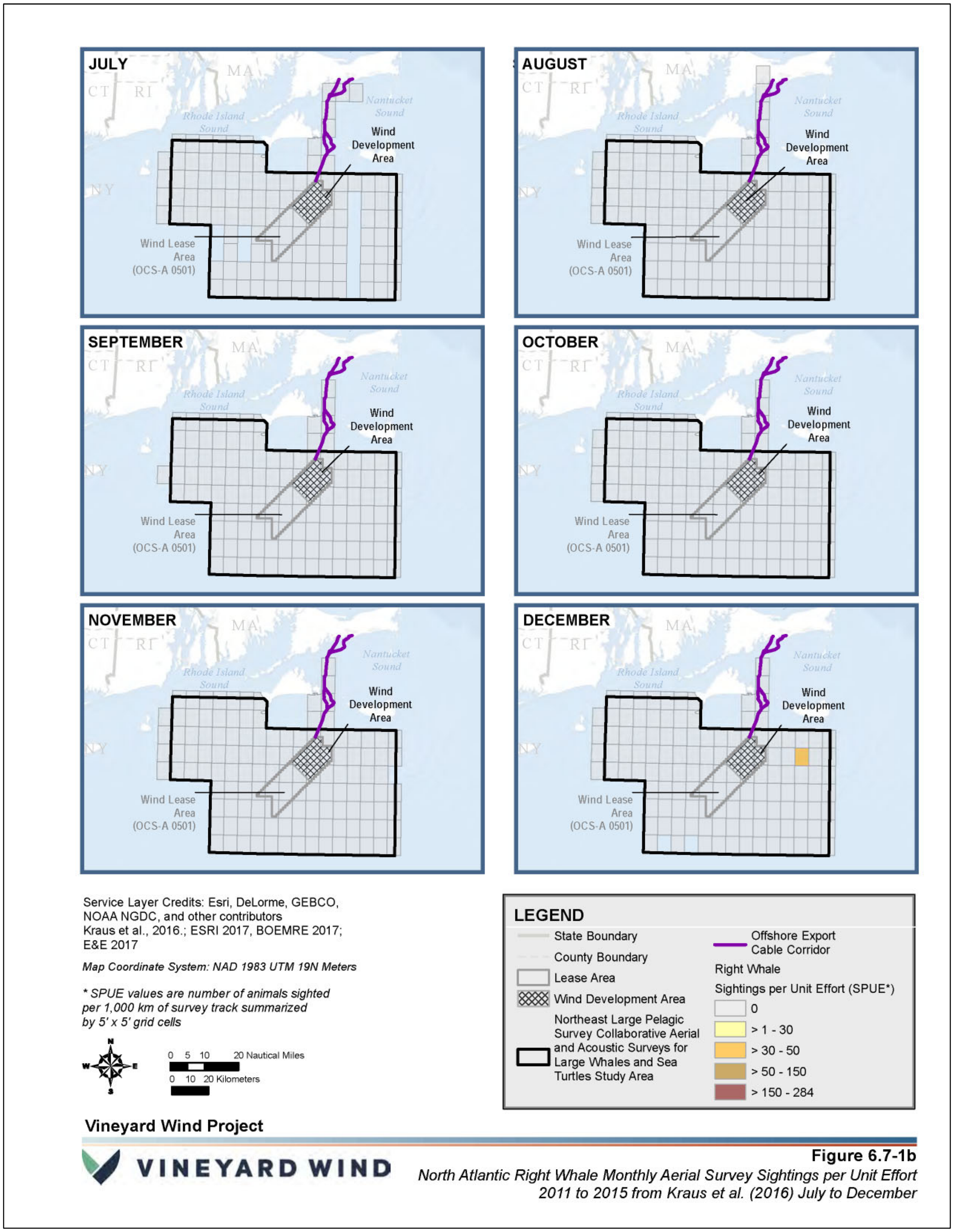

Figure 7 continued. Monthly Sightings Per Unit Effort of North Atlantic Right Whales from S. D. Kraus et al. (2016) (Figure 6.7-1 of the Vineyard Wind Draft Construction and Operations Plan Volume I; Vineyard Wind, 2018).

4.2.1.3. Status

The size of the Western Atlantic stock is considered extremely low relative to its Optimum Sustainable Population (OSP) in the US Atlantic EEZ (S.A. Hayes et al., 2018). The Western Atlantic Stock of NARWs is classified as a Strategic stock under the MMPA and is listed as Endangered under the ESA and MA ESA. Historically, the population suffered severely from commercial overharvesting and has more recently been threatened by incidental fishery entanglement and vessel collisions (Knowlton & Kraus, 2001; Scott D. Kraus et al., 2005; Pace et al., 2017).

To protect this species from ship strikes, NOAA Fisheries designated Seasonal Management Areas (SMAs) in US waters in 2008 (DoC, 2008). All vessels greater than 19.8 m (65 ft) in overall length must operate at speeds of 10 knots (5.1 meters per second [m/s]) or less within these areas during specific time periods. The Block Island Sound SMA overlaps with the southern portion of the Lease Area and is active between November 1 and April 30 each year (Figure 7). The Great South Channel SMA lies to the Northeast of the WDA and is active April 1 to July 31. In addition, the rule provides for the establishment of Dynamic Management Areas (DMAs) when and where NARWs are sighted outside SMAs. DMAs are generally in effect for two weeks and the 10 knots (5.1 m/s) or less speed restriction is voluntary.

The Lease Area is encompassed by a NARW Biologically Important Area ("BIA") for migration from March to April and from November to December (LaBrecque, Curtice, Harrison, Van Parijs, & Halpin, 2015). To determine BIAs, experts were asked to evaluate the best available information and to summarize and map areas important to cetacean species' reproduction, feeding, and migration. The purpose of identifying these areas was to help resource managers with planning and analysis. The NARW BIA for migration includes the RI/MA & MA WEAs and beyond to the continental slope, extending northward to offshore of Provincetown, MA and southward to halfway down the Florida coast (LaBrecque et al., 2015).

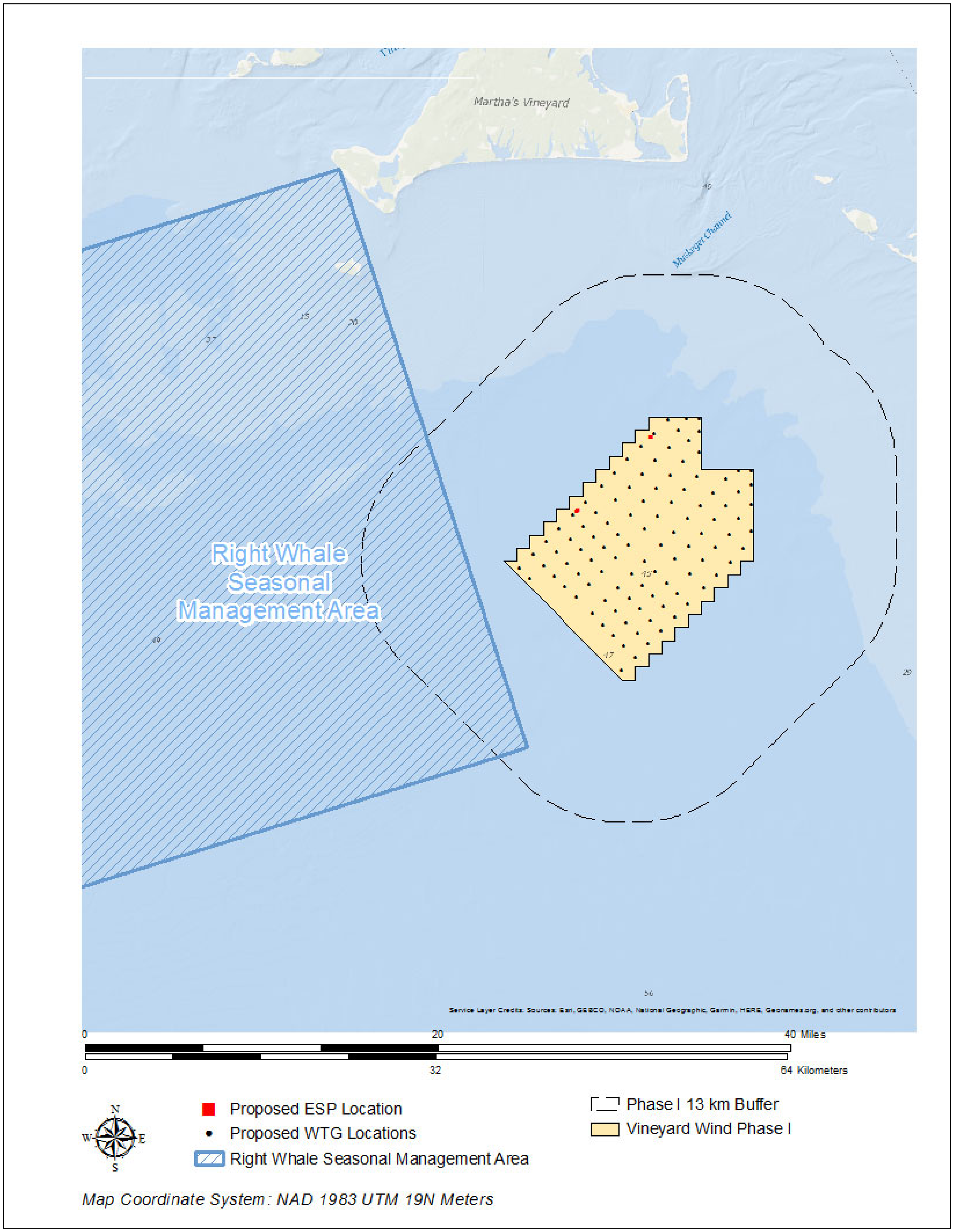

Figure 7. Map showing the location of the NARW SMA and the Lease Area.

4.2.2. Humpback Whale (*Megaptera novaeangilae*)

Humpback Whale females are larger than males and can reach lengths of up to 18 m (60 ft) (NOAA Fisheries, 2018k). Humpback Whale body coloration is primarily dark gray, but individuals have a variable amount of white on their pectoral fins, belly, and flukes. These distinct coloration patterns are used by scientists to identify individuals. These baleen whales feed on small prey often found in large concentrations, including krill and fish such as Herring and Sand Lance (R. D. Kenney & Vigness-Raposa, 2010). Humpback Whales use unique behaviors, including bubble nets, bubble clouds, and flicking of their flukes and fins, to herd and capture prey (NMFS 1991).

4.2.2.1. Distribution

In the North Atlantic, six separate Humpback Whale sub-populations have been identified by their consistent maternally determined fidelity to different feeding areas (Clapham & Mayo, 1987). These populations are found in the Gulf of Maine, Gulf of St. Lawrence, Newfoundland/Labrador, western Greenland, Iceland, and Norway (S.A. Hayes et al., 2018). The large majority of Humpback Whales that inhabit the waters in the US Atlantic EEZ belong to the Gulf of Maine stock.

Humpback Whales in the Gulf of Maine stock typically feed in the waters between the Gulf of Maine and Newfoundland during spring, summer, and fall, but have been observed feeding in other areas, such as off the coast of New York (Sieswerda, Spagnoli, & Rosenthal, 2015). Some Humpback Whales from most feeding areas, including the Gulf of Maine, migrate to the West Indies (including the Antilles, Dominican Republic, Virgin Islands, and Puerto Rico) in the winter, where they mate and calve their young (Katona & Beard, 1990; Palsbøll et al., 1997). However, not all Humpback Whales from the Gulf of Maine stock migrate to the West Indies every winter because significant numbers of animals are observed in mid- and high-latitude regions at this time (Swingle, Barco, Pitchford, Mclellan, & Pabst, 1993).

NEFSC observed Humpback Whales nine times in the WDA during three of the AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). Six observations were in the summer of 2013 during a shipboard survey; one observation was in spring 2014 during a shipboard survey; and two observations were during fall of 2016 during an aerial survey (NEFSC & SEFSC, 2014a, 2014b, 2016).

S. D. Kraus et al. (2016) observed Humpback Whales in the RI/MA & MA WEAs and surrounding areas during all seasons. Humpback Whales were observed most often during spring and summer months, with a peak from April to June. Calves were observed 10 times and feeding was observed 10 times during the S. D. Kraus et al. (2016) study. That study also observed one instance of courtship behavior. Although Humpback Whales were only rarely seen during fall and winter surveys, acoustic data indicate that this species may be present within the MA WEA year-round, with the highest rates of acoustic detections in winter and spring (S. D. Kraus et al., 2016). Humpback Whales were acoustically detected in the MA WEA on 56% of acoustic survey days (566/1,020 days). Acoustic detections do not differentiate between individuals, so detections on multiple days could be the same or different individuals. The mean detection range for Humpback Whales using PAM was 30–36 km (18.6–22.3 mi), with a mean radius of 36 km (22.3 mi) (95% confidence interval of 5 km [3.1 mi]) for the PAM system within the WDA. S. D. Kraus et al. (2016) estimated that 63% of acoustic detections of Humpback Whales represented whales within their study area. This species was not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 G&G surveys for the Project (Vineyard Wind, 2016, 2017).

4.2.2.2. Abundance

The most recent ocean basin-wide estimate of the North Atlantic Humpback Whale population is 11,570 (Palsbøll et al., 1997). Roberts et al. (2016) habitat-based density models provide abundance estimates of 205 Humpback Whales in the US Atlantic EEZ during winter (December–March) and 1,637 during summer (April–November) months. The best available population estimate for the Gulf of Maine stock from NOAA Fisheries stock assessments is 335 individuals and this population appears to be increasing (S.A. Hayes et al., 2018).

4.2.2.3. Status

The entire Humpback Whale species was previously listed as Endangered under the ESA. However, in September 2016, NOAA Fisheries identified 14 Distinct Population Segments (DPSs) of Humpback Whales and revised the ESA listing for this species (DoC, 2016a). Four DPSs were listed as Endangered, one as Threatened, and the remaining nine DPSs were deemed not warranted for listing. Humpback Whales in the US Atlantic EEZ belong to the West Indies DPS, which is considered not warranted for listing under the ESA (DoC, 2016a). The state of Massachusetts lists the Humpback Whale as Endangered under the MA ESA. For the period 2011 through 2015, the minimum annual rate of human-caused mortality and serious injury to the Gulf of Maine Humpback Whale stock averaged 8.25 animals per year (S.A. Hayes et al., 2018). This stock is considered Strategic by NMFS because the US fishery-caused mortality and serious injury exceeds the potential biological removal (PBR) for this stock; however, NMFS acknowledges that uncertainties in this assessment may have produced an incorrect determination (S.A. Hayes et al., 2018). Humpback Whales in the Western North Atlantic have been experiencing a UME since January 2016 that appears to be related to larger than usual number of vessel collisions (NOAA Fisheries, 2018a). In total, 76 mortalities were documented through July 25, 2018, as part of this event (NOAA Fisheries, 2018a). A BIA for Humpback Whales for feeding has been designated northeast of the Lease Area from March through December (LaBrecque et al., 2015).

4.2.3. Fin Whale (*Balaenoptera physalus*)

Fin Whales are the second largest species of baleen whale, with a maximum length of about 22.8 m (75 ft), in the Northern Hemisphere (NOAA Fisheries, 2018f). These whales have a sleek, streamlined body with a V-shaped head that makes them fast swimmers. This species has a distinctive coloration pattern: the dorsal and lateral sides of the body are black or dark brownish-gray and the ventral surface is white. The lower jaw is dark on the left side and white on the right side. Fin Whales feed on krill (*Euphausiacea*), small schooling fish (e.g., Herring [*Clupea harengus*], Capelin [*Mallotus villosus*], Sand Lance [*Ammodytidae* spp.]), and squid (*Teuthida* spp.) by lunging into schools of prey with their mouths open (R. D. Kenney & Vigness-Raposa, 2010). Fin Whales are the dominant large cetacean species during all seasons from Cape Hatteras to Nova Scotia, having the largest standing stock, the largest food requirements, and, therefore, the largest influence on ecosystem processes of any baleen whale species (Hain, Ratnaswamy, Kenney, & Winn, 1992; Robert D. Kenney, Scott, Thompson, & Winn, 1997).

4.2.3.1. Distribution

Fin Whales off the eastern US, Nova Scotia, and the southeastern coast of Newfoundland are believed to constitute a single stock under the present International Whaling Commission (IWC) management scheme (Donovan, 1991), which has been called the Western North Atlantic stock.

Fin Whales occur year-round in a wide range of latitudes and longitudes, but the density of individuals in any one area changes seasonally (NOAA Fisheries, 2018f). Fin Whales are the most commonly observed large whales in continental shelf waters from the mid-Atlantic coast of the US to Nova Scotia (CeTAP 1982; Hain et al., 1992; David E. Sergeant, 1977; Sutcliffe & Brodie, 1977). The Fin Whale's range in the western North Atlantic extends from the Gulf of Mexico and Caribbean Sea to the southeastern coast of Newfoundland (S.A. Hayes et al., 2018). While Fin Whales typically feed in the Gulf of Maine and the waters surrounding New England, mating and calving (and general wintering) areas are largely unknown (Hain et al., 1992; S.A. Hayes et al., 2018). It is likely that Fin Whales occurring in the US Atlantic EEZ undergo migrations into Canadian waters, open-ocean areas, and perhaps even subtropical or tropical regions. However, the popular notion that entire Fin Whale populations make distinct annual migrations like some other mysticetes has questionable support (S.A. Hayes et al., 2018).

Based on an analysis of neonate stranding data, Hain et al. (1992) suggest that calving takes place during October to January in latitudes of the US mid-Atlantic region.

NEFSC observed Fin Whales six times in the WDA during three of the AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). One observation was in the summer of 2013 during a shipboard survey; three observations were in the summer of 2016 during a shipboard survey; and two observations were during fall of 2016 during an aerial survey (NEFSC & SEFSC, 2014a, 2014b, 2016).

S. D. Kraus et al. (2016) suggest that, compared to other baleen whale species, Fin Whales have a high multi-seasonal relative abundance in the RI/MA & MA WEAs and surrounding areas. Fin Whales were observed in the MA WEA in spring and summer. This species was observed primarily in the offshore (southern) regions of the RI/MA & MA WEAs during spring and was found closer to shore (northern areas) during the summer months (Figure 8) (S. D. Kraus et al., 2016). Calves were observed three times and feeding was observed nine times during the S. D. Kraus et al. (2016) study. Although Fin Whales were largely absent from visual surveys in the RI/MA & MA WEAs in the fall and winter months (S. D. Kraus et al., 2016), acoustic data indicated that this species was present in the RI/MA & MA WEAs during all months of the year. Fin Whales were acoustically detected in the MA WEA on 87% of study days (889/1,020 days). Acoustic detection data indicated a lack of seasonal trends in Fin Whale abundance with slightly less detections from April to July (S. D. Kraus et al., 2016). As the detection range for Fin Whale vocalizations is more than 200 km (108 nm), detected signals may have originated from areas far outside of the RI/MA & MA WEAs; however, arrival patterns of many Fin Whale vocalizations indicated that received signals likely originated from within the S. D. Kraus et al. (2016) study area. This species was not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 G&G surveys for the Project (Vineyard Wind, 2016, 2017).

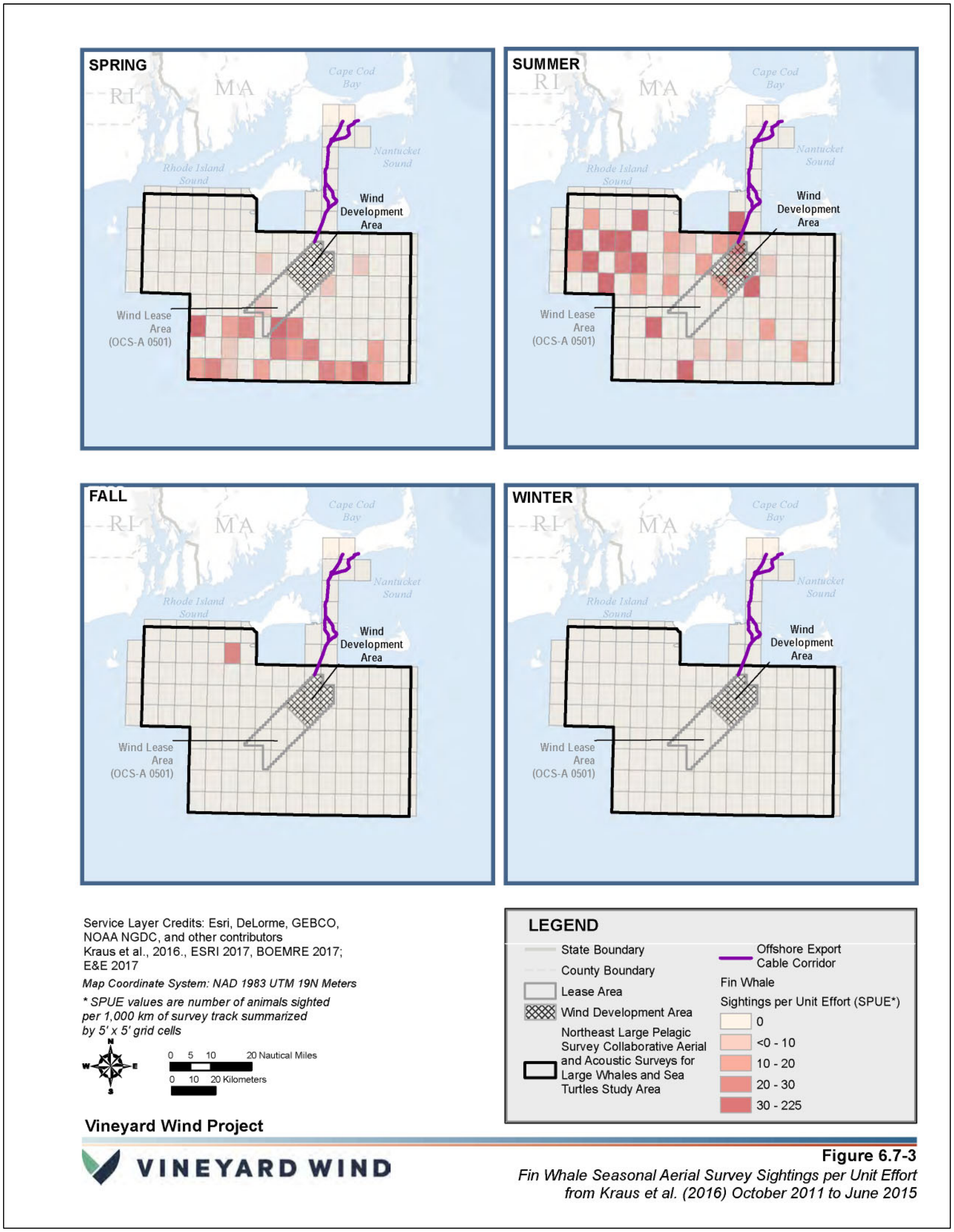

Figure 8. Seasonal Sightings Per Unit Effort of Fin Whales from S. D. Kraus et al. (2016) (Figure 6.7-3 of the Vineyard Wind Draft Construction and Operations Plan Volume I; Vineyard Wind, 2018).

4.2.3.2. Abundance

Roberts et al. (2016) habitat-based density models suggest an abundance estimate of 4,633 Fin Whales in the US Atlantic EEZ. The best available abundance estimate for the Western North Atlantic Fin Whale stock in US waters from NMFS stock assessments is 1,618 individuals (S.A. Hayes et al., 2018).

4.2.3.3. Status

The status of this stock relative to its OSP in the US Atlantic EEZ is unknown, but the North Atlantic population is listed as Endangered under the ESA and MA ESA, and NMFS considers this a Strategic stock. There are currently no critical habitat areas established for the Fin Whale under the ESA. The Lease Area is flanked by two BIAs for feeding for Fin Whales – the area to the northeast is considered a BIA year-round, while the area off the tip of Long Island to the southwest is a BIA from March to October (LaBrecque et al., 2015).

4.2.4. Sei Whale (*Balaenoptera borealis*)

Sei Whales are a baleen whale that can reach lengths of about 12–18 m (40–60 ft) (NOAA Fisheries, 2018q). This species has a long, sleek body that is dark bluish-gray to black in color and pale underneath (NOAA Fisheries, 2018q). Their diet is comprised primarily of plankton, schooling fish, and cephalopods. Sei Whales generally travel in small groups (two to five individuals), but larger groups are observed on feeding grounds (NOAA Fisheries, 2018q).

4.2.4.1. Distribution

The stock that occurs in the US Atlantic EEZ is the Nova Scotia stock, which ranges along the continental shelf waters of the northeastern US to Newfoundland (Sean A. Hayes et al., 2017). Sighting data suggest Sei Whale distribution is largely centered in the waters of New England and eastern Canada (Sean A. Hayes et al., 2017; Roberts et al., 2016). There appears to be a strong seasonal component to Sei Whale distribution. Sei Whales are relatively widespread and most abundant in New England waters from spring to fall (April to July). During winter, the species is predicted to be largely absent (Roberts et al., 2016).

NEFSC observed Sei Whales two times in the WDA during one of the AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). The two observations were made in the summer of 2016 during a shipboard survey (NEFSC & SEFSC, 2016).

S. D. Kraus et al. (2016) observed Sei Whales in the RI/MA & MA WEAs and surrounding areas only between the months of March and June. The number of Sei Whale observations was less than half that of other baleen whale species in the two seasons in which Sei Whales were observed (spring and summer). This species demonstrated a distinct seasonal habitat use pattern that was consistent throughout the study (Figure 9). Calves were observed three times and feeding was observed four times during the S. D. Kraus et al. (2016) study. Sei Whales were not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 G&G surveys for the Project (Vineyard Wind, 2016, 2017); however, the survey was conducted during October and November when Sei Whale occurrence is not anticipated due to the seasonal nature of their occurrence in this region. Sei Whales are expected to be present but much less common than Fin, Minke, Humpback, and NARWs based on S. D. Kraus et al. (2016) sighting rates.

4.2.4.2. Abundance

Roberts et al. (2016) habitat-based density models provide abundance estimates of 98 Sei Whales in the US Atlantic EEZ during winter (December–March), 627 during spring (April–June), 717 during summer (July–September), and 37 during fall (October–November) months. The best available abundance estimate for the Nova Scotia stock of Sei Whales from NMFS stock assessments is 357 individuals. This estimate is considered an underestimate because the full known range of the stock was not surveyed, the estimate did not include availability-bias correction for submerged animals, and there was uncertainty regarding population structure (Sean A. Hayes et al., 2017). Abundance data for Sei Whales from Roberts et al. (2016) were used in this assessment (Table 3).

4.2.4.3. Status

Sei Whales are listed as Endangered under the ESA and MA ESA and the Nova Scotia stock is considered Strategic by NMFS. There are no critical habitat areas designated for the Sei Whale under the ESA. A BIA for feeding for Sei Whales occurs east of the Lease Area from May through November (LaBrecque et al., 2015).

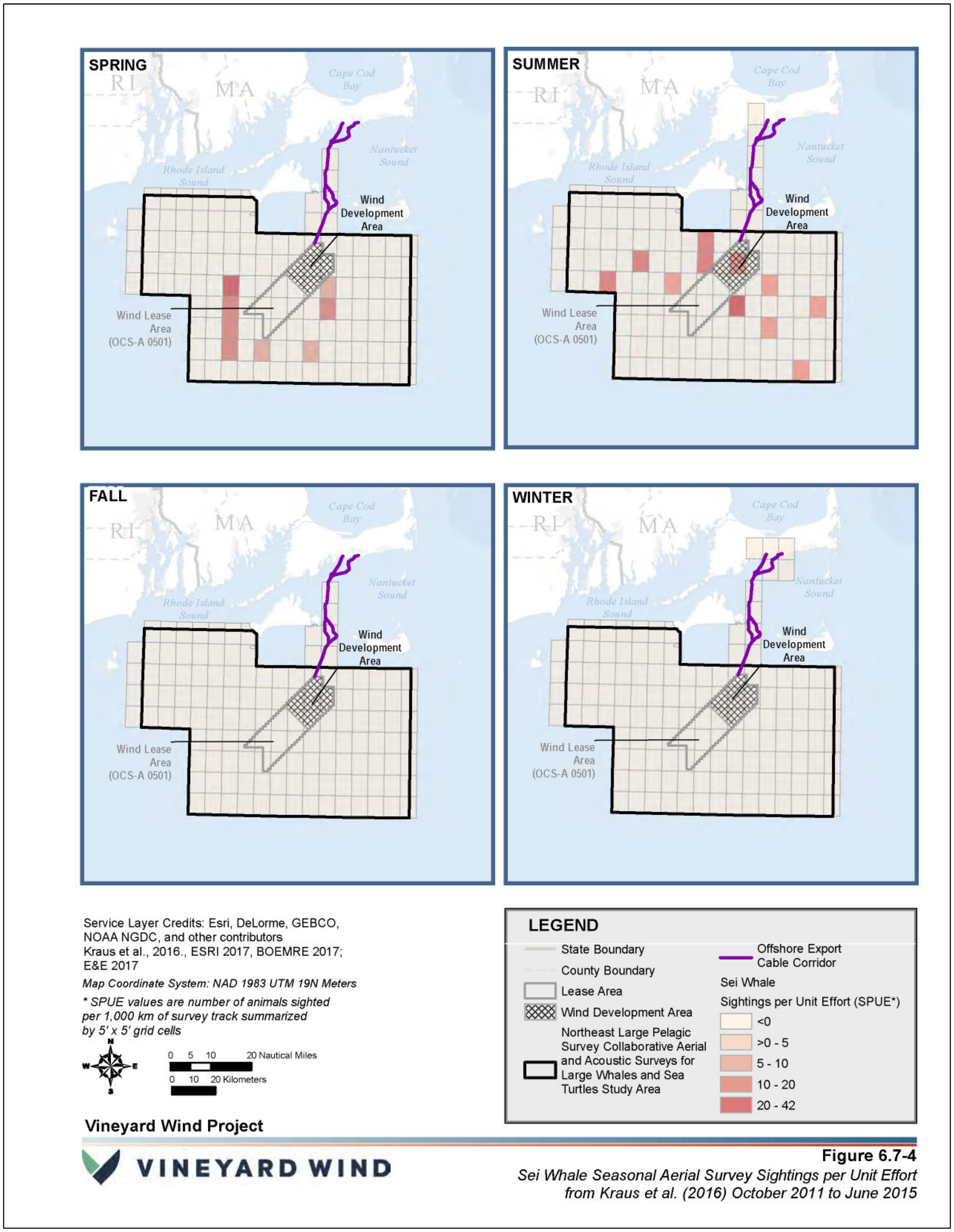

Figure 9. Seasonal Sightings Per Unit Effort of Sei Whales from S. D. Kraus et al. (2016) (Figure 6.7-4 of the Vineyard Wind Draft Construction and Operations Plan Volume I; Vineyard Wind, 2018).

4.2.5. Minke Whale (*Balaenoptera acutorostrata*)

Minke Whales are a baleen whale species reaching 10 m (35 ft) in length (NOAA Fisheries, 2018n). This species has a cosmopolitan distribution in temperate, tropical, and high latitude waters (S.A. Hayes et al., 2018). The Minke Whale is common and widely distributed within the US Atlantic EEZ and is the third most abundant great whale (any of the larger marine mammals of the order Cetacea) in the EEZ (CeTAP 1982). This species has a dark gray-to-black back and a white ventral surface (NOAA Fisheries, 2018n). Its diet is comprised primarily of crustaceans, schooling fish, and copepods. Minke Whales generally travel in small groups (one to three individuals), but larger groups have been observed on feeding grounds (NOAA Fisheries, 2018n).

4.2.5.1. Distribution

In the North Atlantic, there are four recognized populations: Canadian East Coast, West Greenland, Central North Atlantic, and Northeastern North Atlantic (Donovan, 1991). Until better information becomes available, Minke Whales in the US Atlantic EEZ are considered part of the Canadian East Coast stock, which inhabits the area from the western half of the Davis Strait (45°W) to the Gulf of Mexico. It is also uncertain if there are separate sub-stocks within the Canadian East Coast stock.

Sighting data suggest that Minke Whale distribution is largely centered in the waters of New England and eastern Canada (S.A. Hayes et al., 2018). Risch et al. (2013) reported a decrease in Minke Whale calls north of 40°N in late fall with an increase in calls between 20° and 30°N in winter and north of 35°N during spring. Mating and calving most likely take place during winter in lower latitude wintering grounds (NOAA Fisheries, 2018n).

NEFSC observed Minke Whales five times in the WDA during four of the AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). One observation was in the fall of 2010 during an aerial survey; one observation was in the spring of 2014 during a shipboard survey; two observations were during the summer of 2016 during a shipboard survey; and one observation was in the fall of 2016 during an aerial survey (NEFSC & SEFSC, 2011a, 2014b, 2016).

S. D. Kraus et al. (2016) observed Minke Whales in the RI/MA & MA WEAs and surrounding areas primarily from May to June. This species demonstrated a distinct seasonal habitat usage pattern that was consistent throughout the study. Though Minke Whales were observed in spring and summer months in the MA WEA, they were only observed in the Lease Area in the spring. Minke Whales were not observed between October and February, but acoustic data indicate the presence of this species in the Offshore Project Area in winter months. Calves were observed twice, and feeding was also observed twice during the S. D. Kraus et al. (2016) study. Minke Whales were acoustically detected in the MA WEA on 28% of project days (291/1,020 days). Minke Whale acoustic presence data also exhibited a distinct seasonal pattern; acoustic presence was lowest in the months of December and January, steadily increased beginning in February, peaked in April, and exhibited a gradual decrease throughout the summer months (S. D. Kraus et al., 2016). Acoustic detection range for this species was small enough that over 99% of detections were limited to within the S. D. Kraus et al. (2016) study area. This species was not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 surveys for the Project (Vineyard Wind, 2016, 2017).

4.2.5.2. Abundance

Roberts et al. (2016) habitat-based density models provide abundance estimates of 740 Minke Whales in the US Atlantic EEZ during winter (November–March) and 2,112 during summer (April–October) months. The best abundance estimate for the US Atlantic EEZ is 2,591 from NOAA Fisheries stock assessments (S.A. Hayes et al., 2018). This estimate is likely biased low because it does not account for a number of Minke Whales in Canadian waters and did not account for availability bias due to submerged animals.

4.2.5.3. Status

Minke Whales are not listed as Threatened or Endangered under the ESA and the Canadian East Coast Stock is not considered Strategic under the MMPA. Minke Whales in the Western North Atlantic have been experiencing a UME since January 2017 with some evidence of human interactions as well as infectious disease (NOAA Fisheries, 2018b). In total, 37 mortalities were documented through July 27, 2018 as part of this event (NOAA Fisheries, 2018b). A BIA for Minke Whales for feeding has been designated east of the Lease Area from March through November (LaBrecque et al., 2015).

4.2.6. Sperm Whale (*Physeter macrocephalus*)

The Sperm Whale is the largest of all toothed whales; males can reach 16 m (52 ft) in length and weigh over 40,823 kilograms ("kg" [45 US tons]), and females can attain lengths of up to 11 m (36 ft) and weigh over 13,607 kg (15 tons) (Whitehead, 2009). Sperm Whales have extremely large heads, which account for 25–35% of the total length of the animal. This species tends to be uniformly dark gray in color, though lighter spots may be present on the ventral surface. Sperm Whales frequently dive to depths of 400 m (1,300 ft) in search of their prey, which includes large squid, fishes, octopus, sharks, and skates (Whitehead, 2009). This species can remain submerged for over an hour and reach depths as great as 1,000 m (3,280 ft). Sperm Whales have a worldwide distribution in deep water and range from the equator to the edges of the polar pack ice (Whitehead, 2002). Sperm Whales form stable social groups and exhibit a geographic social structure; females and juveniles form mixed groups and primarily reside in tropical and subtropical waters, whereas males are more solitary and wide-ranging and occur at higher latitudes (Whitehead, 2002, 2003).

The IWC recognizes only one stock of Sperm Whales for the North Atlantic, and Randall R. Reeves and Whitehead (1997) and Dufault, Whitehead, and Dillon (1999) suggest that Sperm Whale populations lack clear geographic structure. Current threats to the Sperm Whale population include ship strikes, exposure to anthropogenic noise and toxic pollutants, and entanglement in fishing gear (though entanglement risk for sperm whales is relatively low compared to other, more coastal whale species) (NOAA Fisheries, 2018t; Waring, Josephson, Maze-Foley, & Rosel, 2015).

4.2.6.1. Distribution

Sperm Whales mainly reside in deep-water habitats on the Outer Continental Shelf (OCS), along the shelf edge, and in mid-ocean regions (NOAA Fisheries, 2010). However, this species has been observed in relatively high numbers in the shallow continental shelf areas of southern New England (T. M. Scott & Sadove, 1997). Sperm Whale migratory patterns are not well-defined, and no obvious migration patterns have been observed in certain tropical and temperate areas. However, general trends suggest that most populations move poleward during summer months (Waring et al., 2015). In US Atlantic EEZ waters, Sperm Whales appear to exhibit seasonal movement patterns (CeTAP 1982; T. M. Scott & Sadove, 1997). During the winter, Sperm Whales are concentrated to the east and north of Cape Hatteras. This distribution shifts northward in spring, when Sperm Whales are most abundant in the central portion of the mid-Atlantic bight to the southern region of Georges Bank. In summer, this distribution continues to move northward, including the area east and north of Georges Bank and the continental shelf to the south of New England. In fall months, Sperm Whales are most abundant on the continental shelf to the south of New England and remain abundant along the continental shelf edge in the mid-Atlantic bight.

No Sperm Whales were observed in the WDA or OECC during AMAPPS surveys from 2010–2016 (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). S. D. Kraus et al. (2016) observed Sperm Whales four times in the RI/MA & MA WEAs during the summer and fall from 2011 to 2015. Sperm Whales, traveling singly or in groups of three or four, were observed three times in August and September of 2012, and once in June of 2015. Effort-weighted average sighting rates could not be calculated. In the WDA, one Sperm Whale was observed on the northwestern border and in the OECC, and one was observed between the WDA and Nantucket Island. The frequency of Sperm Whale clicks exceeded the maximum frequency of PAM equipment used in S. D. Kraus et al. (2016), so no acoustic data are available for this species from that study. This species was not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 G&G surveys for the Project (Vineyard Wind, 2016, 2017). Sperm Whales are expected to be present but uncommon in the Offshore Project Area based on S. D. Kraus et al. (2016) sightings.

4.2.6.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 5,353 Sperm Whales in the US Atlantic EEZ. Though there is currently no reliable estimate of total Sperm Whale abundance in the entire western North Atlantic, the most recent best available population estimate for the US Atlantic EEZ is 2,288 (Waring et al., 2015). This estimate was generated from the sum of surveys conducted in 2011, and is likely an underestimate of total abundance, because these surveys were not corrected for Sperm Whale dive time.

4.2.6.3. Status

Sperm Whales are listed as endangered under the ESA and MA ESA, and the North Atlantic stock is considered Strategic by NMFS. Total annual estimated average human-caused mortality to this stock during the period from 2008 to 2012 was 0.8 Sperm Whales (Waring et al., 2015). There are no critical habitat areas designated for the Sperm Whale under the ESA.

4.2.7. Risso's Dolphin (*Grampus griseus*)

Risso's Dolphins are located worldwide in both tropical and temperate waters (T.A Jefferson et al., 2008; Thomas A. Jefferson et al., 2014). The Risso's Dolphin attains a body length of approximately 2.6–4 m (8.5–13 ft) (NOAA Fisheries, 2018p). This dolphin has a narrow tailstock and whitish or gray body. The Risso's Dolphin forms groups ranging from 10 to 30 individuals (NOAA Fisheries, 2018p). Risso's Dolphins feed primarily on squid, but also fish such as anchovies (*Engraulidae*), krill, and other cephalopods (NOAA Fisheries, 2018p).

4.2.7.1. Distribution

Risso's Dolphins in the US Atlantic EEZ are part of the Western North Atlantic Stock. The Western North Atlantic stock of Risso's Dolphins inhabits waters from Florida to eastern Newfoundland (Robin W. Baird & Stacey, 1991; Leatherwood, Caldwell, & Winn, 1976). During spring, summer, and fall, Risso's Dolphins are distributed along the continental shelf edge from Cape Hatteras northward to Georges Bank (CeTAP 1982; P. Michael Payne, Selzer, & Knowlton, 1984). During the winter, the distribution extends outward into oceanic waters (P. Michael Payne et al., 1984). The stock may contain multiple demographically independent populations that should themselves be stocks, because the current stock spans multiple eco-regions (Longhurst, 1998; Spalding et al., 2007).

NEFSC observed Risso's Dolphins two times in the WDA during one of the AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). The two observations were made in the summer of 2013 during a shipboard survey (NEFSC & SEFSC, 2014a).

S. D. Kraus et al. (2016) results suggest that Risso's Dolphins occur infrequently in the RI/MA & MA WEAs and surrounding areas. Effort-weighted average sighting rates for Risso's Dolphins could not be calculated. No Risso's Dolphins were observed during summer, fall, or winter, and this species was only observed twice in the spring. It is possible that the Northeast Large Whale Pelagic Survey may have underestimated the abundance of Risso's Dolphins, as this survey was designed to target large cetaceans and the majority of small cetaceans were not identified to species. This species was not observed visually or detected acoustically in the Lease Area during the 2016 geophysical and geotechnical G&G survey for the Project, but 12 visual observations and 10 acoustic detections of marine mammals during the G&G survey were classified as "unidentified" dolphin or porpoise (Vineyard Wind, 2016).

4.2.7.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 7,732 Risso's Dolphins in the US Atlantic EEZ. The best available abundance estimate for Risso's Dolphins in the Western North Atlantic stock from NOAA Fisheries stock assessments is 18,250, estimated from data collected during 2011 surveys (S.A. Hayes et al., 2018).

4.2.7.3. Status

Risso's Dolphins are not listed as Threatened or Endangered under the ESA and this stock is not considered Strategic.

4.2.8. Pilot Whales (*Globicephala* spp.)

Two species of Pilot Whale occur within the Western North Atlantic: the Long-Finned Pilot Whale and the Short-Finned Pilot Whale. These species are difficult to differentiate at sea and cannot be reliably distinguished during most surveys (Sean A. Hayes et al., 2017; Rone & Pace, 2012), so some of the descriptions below refer to both species unless otherwise stated. Pilot Whales have bulbous heads, are dark gray, brown, or black in color, and can reach approximately 7.3 m (25 ft) in length (NOAA Fisheries, 2018l). These whales form large, relatively stable aggregations that appear to be maternally determined (American Cetacean Society, 2018). Pilot Whales feed primarily on squid, although they also eat small to medium-sized fish and octopus when available (NOAA Fisheries, 2018l, 2018s).

4.2.8.1. Distribution

Within the US Atlantic EEZ, both species are categorized into Western North Atlantic stocks. In US Atlantic waters, Pilot Whales are distributed principally along the continental shelf edge off the northeastern US coast in winter and early spring (CeTAP 1982; Abend & Smith, 1999; Hamazaki, 2002; P.M. Payne & Heinemann, 1993). In late spring, Pilot Whales move onto Georges Bank, into the Gulf of Maine, and into more northern waters, where they remain through late fall (CeTAP 1982; P.M. Payne & Heinemann, 1993). Short-Finned Pilot Whales are present within warm temperate to tropical waters and Long-Finned Pilot Whales occur in temperate and subpolar waters. Long-Finned and Short-Finned Pilot Whales overlap spatially along the mid-Atlantic shelf break between New Jersey and the southern flank of Georges Bank (Sean A. Hayes et al., 2017; P.M. Payne & Heinemann, 1993). Long-Finned Pilot Whales have occasionally been observed stranded as far south as South Carolina, and Short-Finned Pilot Whale have stranded as far north as Massachusetts (Sean A. Hayes et al., 2017). The latitudinal ranges of the two species therefore remain uncertain. However, south of Cape Hatteras, most Pilot Whale sightings are expected to be Short-Finned Pilot Whales, while north of approximately 42°N, most Pilot Whale sightings are expected to be Long-Finned Pilot Whales (Sean A. Hayes et al., 2017). Based on the distributions described in Sean A. Hayes et al. (2017), Pilot Whale sightings in the Offshore Project Area would most likely be Long-Finned Pilot Whales.

No Pilot Whales were observed in the WDA or OECC during AMAPPS surveys from 2010¬2016 (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). S. D. Kraus et al. (2016) observed Pilot Whales infrequently in the RI/MA & MA WEAs and surrounding areas. Effort-weighted average sighting rates for Pilot Whales could not be calculated. No Pilot Whales were observed during the fall or winter, and these species were only observed 11 times in the spring and three times in the summer. Two of these sightings included calves. It is possible that the Northeast Large Whale Pelagic Survey may have underestimated the abundance of Pilot Whales, as this survey was designed to target large cetaceans and most small cetaceans were not identified to species (S. D. Kraus et al., 2016). This species was not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 G&G surveys for the Project (Vineyard Wind, 2016, 2017).

4.2.8.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 18,977 Pilot Whales in the US Atlantic EEZ. This estimate includes both Long-Finned and Short-Finned Pilot Whales. The best available population estimates in the US Atlantic EEZ are 5,636 for Long-Finned Pilot Whales and 21,515 for Short-Finned Pilot Whales (Sean A. Hayes et al., 2017). These estimates are from summer 2011 aerial and shipboard surveys covering waters from central Florida to the lower Bay of Fundy (Sean A. Hayes et al., 2017).

4.2.8.3. Status

Total annual estimated average fishery-related mortality or serious injury during 2010–2014 was 38 for Long-Finned Pilot Whales and 192 for Short-Finned Pilot Whales (Sean A. Hayes et al., 2017). Neither Pilot Whale species is listed as threatened or endangered under the ESA. But both stocks are considered Strategic under the MMPA because the mean annual human-caused mortality and serious injury exceeds the PBR (Sean A. Hayes et al., 2017).

4.2.9. Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*)

Atlantic White-Sided Dolphins are found in cold temperate and subpolar waters of the North Atlantic (Cipriano, 2002). The Atlantic White-Sided dolphin is robust and attains a body length of approximately 2.8 m (9 ft) (T.A Jefferson et al., 2008). It is characterized by a strongly “keeled” tail stock and distinctive, white-sided color pattern (BOEM, 2014a). Atlantic White-Sided Dolphins form groups of varying sizes, ranging from a few individuals to over 500 (NOAA Fisheries, 2018d). They feed mostly on small schooling fishes, shrimps, and squids, and are often observed feeding in mixed-species groups with pilot whales and other dolphin species (Cipriano, 2002; T.A Jefferson et al., 2008).

4.2.9.1. Distribution

Atlantic White-Sided Dolphins observed off the eastern US coast are part of the Western North Atlantic stock. This stock inhabits waters from central West Greenland to North Carolina (about 35°N), primarily in continental shelf waters to the 100 m (328 ft) depth contour (Doksæter, Olsen, Nøttestad, & Fernö, 2008). Sighting data indicate seasonal shifts in distribution (Northridge, Tasker, Webb, & Williams, 1997). During January to May, low numbers of Atlantic White-Sided Dolphins are found from Georges Bank to Jeffreys Ledge (off New Hampshire). From June through September, large numbers of Atlantic White-Sided Dolphins are found from Georges Bank to the lower Bay of Fundy. From October to December, they occur at intermediate densities from southern Georges Bank to the southern Gulf of Maine (M. Payne & Heinemann, 1990). There are currently no critical habitats designated for the Atlantic White-Sided Dolphin.

S. D. Kraus et al. (2016) suggest that Atlantic White-Sided Dolphins occur infrequently in the RI/MA & MA WEAs and surrounding areas. Effort-weighted average sighting rates for Atlantic White-Sided Dolphins could not be calculated, because this species was only observed on eight occasions throughout the duration of the study (October 2011-June 2015). No Atlantic White-Sided Dolphins were observed during the winter months, and this species was only sighted twice in the fall and three times in the spring and summer. It is possible that the Northeast Large Pelagic Survey may have underestimated the abundance of Atlantic White-Sided Dolphins, as this survey was designed to target large cetaceans and the majority of small cetaceans were not identified to species. This species was not detected visually or acoustically in the WDA during the 2016 G&G surveys for the Project (though 22 observations were classified as “unidentified dolphin or porpoise”) (unpublished data).

4.2.9.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 37,180 Atlantic White-Sided Dolphins in the US Atlantic EEZ. There are insufficient data to determine seasonal abundance estimates of Atlantic White-Sided Dolphins off the eastern US coast or their status in the US Atlantic EEZ. The best available abundance estimate for the Western North Atlantic stock of Atlantic White-Sided Dolphins is 48,819 individuals, estimated from data collected during a 2011 summer survey (S.A. Hayes et al., 2018).

4.2.9.3. Status

The Atlantic White-Sided Dolphin is not listed as threatened or endangered under the ESA and the Western North Atlantic stock of Atlantic White-Sided Dolphins is not classified as Strategic.

4.2.10. Short-Beaked Common Dolphin (*Delphinus delphis delphis*)

The Short-Beaked Common Dolphin is one of the most widely distributed cetaceans and occurs in temperate, tropical, and subtropical regions (T.A Jefferson et al., 2008). Short-Beaked Common Dolphins can reach 2.7 m (9 ft) in length and have a distinct color pattern with a white ventral patch, yellow or tan flank, and dark gray dorsal “cape” (NOAA Fisheries, 2018r). This species feeds on schooling fish and squid found near the surface at night (NOAA Fisheries, 2018r). They have been known to feed on fish escaping from fishermen’s nets or fish that are discarded from boats (NOAA 1993). These dolphins can gather in schools of hundreds or thousands, although groups generally consist of 30 or fewer individuals (NOAA 1993).

4.2.10.1. Distribution

Short-Beaked Common Dolphins in the US Atlantic EEZ belong to the Western North Atlantic stock, generally occurring from Cape Hatteras, North Carolina to the Scotian Shelf (S.A. Hayes et al., 2018). Short-Beaked Common Dolphins are a highly seasonal, migratory species. In the US Atlantic EEZ this species is distributed along the continental shelf between the 100–2,000 m (328–6,561.6 ft) isobaths and is associated with Gulf Stream features (CeTAP 1982; Hamazaki, 2002; S.A. Hayes et al., 2018; Selzer & Payne, 1988). Short-Beaked Common Dolphins occur from Cape Hatteras northeast to Georges Bank (35° to 42°N) during mid-January to May and move as far north as the Scotian Shelf from mid-summer to fall (Selzer & Payne, 1988). Migration onto the Scotian Shelf and continental shelf off Newfoundland occurs when water temperatures exceed 11°C (51.8°F) (Gowans & Whitehead, 1995; D. E. Sergeant, Mansfield, & Beck, 1970). Breeding usually takes place between the months of June and September and females have an estimated calving interval of two to three years (S.A. Hayes et al., 2018).

NEFSC observed Short-Beaked Common Dolphins 10 times in the WDA during seven AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). One observation was in the fall of 2010 during an aerial survey; two observations were in the fall of 2012 during an aerial survey; three observations were during the summer of 2014 during a shipboard survey; one was during the summer of 2014 during a shipboard survey; one observation was during the summer of 2016 during a shipboard survey; one observation was in the summer of 2016 during an aerial survey; and one was in the fall of 2016 during an aerial survey (NEFSC & SEFSC, 2011a, 2012, 2014a, 2014b, 2016).

S. D. Kraus et al. (2016) suggested that Short-Beaked Common Dolphins occur year-round in the RI/MA & MA WEAs and surrounding areas. Short-Beaked Common Dolphins were the most frequently observed small cetacean species within the S. D. Kraus et al. (2016) study area. Short-Beaked Common Dolphins were observed in the RI/MA & MA WEAs in all seasons and observed in the Lease Area in spring, summer, and fall. Short-Beaked Common Dolphins were most frequently observed during the summer months; observations of this species peaked between June and August. Two sightings of Short-Beaked Common Dolphins in the S. D. Kraus et al. (2016) study included calves, two sightings involved feeding behavior, and three sightings involved mating behavior. Sighting data indicate that Short-Beaked

Common Dolphin distribution tended to be farther offshore during the winter months than during spring, summer, and fall. It is possible that the Northeast Large Whale Pelagic Survey may have underestimated the abundance of Short-Beaked Common Dolphins, because this survey was designed to target large cetaceans and the majority of small cetaceans were not identified to species (S. D. Kraus et al., 2016). Short-Beaked Common Dolphins were the most frequently observed or detected animal during the 2016 survey in the Lease Area and one was also visually observed during the 2017 G&G survey (Vineyard Wind, 2016, 2017). During 2016 G&G survey, Short-Beaked Common Dolphins were visually observed 123 times and acoustically detected 50 times. Also, 12 visual observations and 10 acoustic detections of marine mammals during the 2016 G&G survey and one visual observation during the 2017 G&G survey were classified as "unidentified" dolphin or porpoise (Vineyard Wind, 2016, 2017).

4.2.10.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 86,098 Short-Beaked Common Dolphins in the US Atlantic EEZ. The best population estimate in the US Atlantic EEZ for the Western North Atlantic Short-Beaked Common Dolphin is 70,184 (S.A. Hayes et al., 2018).

4.2.10.3. Status

The Short-Beaked Common Dolphin is not listed as threatened or endangered under the ESA and the Western North Atlantic Stock of the Short-Beaked Common Dolphins is not considered Strategic.

4.2.11. Common Bottlenose Dolphin (*Tursiops truncatus truncatus*)

Bottlenose Dolphins are one of the most well-known and widely distributed species of marine mammals. These dolphins reach 2–4 m (6–12.5 ft) in length and are light gray to black in color (NOAA Fisheries, 2018e). Bottlenose Dolphins are commonly found in groups of two to 15 individuals, though aggregations in the hundreds are occasionally observed (NOAA Fisheries, 2018e). They are considered generalist feeders and consume a wide variety of organisms, including fish, squid, and shrimp and other crustaceans (T.A Jefferson et al., 2008).

4.2.11.1. Distribution

The Common Bottlenose Dolphin is a cosmopolitan species that occurs in temperate and tropical waters worldwide. Two distinct morphotypes of Bottlenose Dolphin, coastal and offshore, occur along the eastern coast of the US (Curry & Smith, 1997; Hersh & Duffield, 1990; Mead & Potter, 1995; Rosel, Hansen, & Hohn, 2009). The offshore morphotype inhabits outer continental slope and shelf edge regions from Georges Bank to the Florida Keys, and the coastal morphotype is continuously distributed along the Atlantic Coast from south of New York to the Florida Peninsula (Sean A. Hayes et al., 2017). Offshore Common Bottlenose Dolphin sightings occur from Cape Hatteras to the eastern end of Georges Bank (Robert D. Kenney, 1990). There are 17 coastal, offshore, bay, and estuarine stocks of Common Bottlenose Dolphins in the US Atlantic EEZ. Those encountered in the WDA would likely belong to the Western North Atlantic Offshore Stock (S.A. Hayes et al., 2018). However, it is possible that a few animals could be from the North Atlantic Northern Migratory Coastal Stock, but they generally do not range farther north than New Jersey.

NEFSC observed Common Bottlenose Dolphins four times in the WDA during three of the AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). Two observations were in the fall of 2012 during an aerial survey; one observation was in the summer of 2013 during a shipboard survey; and one observation was during the summer of 2014 during a shipboard survey (NEFSC & SEFSC 2012, 2014a, 2014b). S. D. Kraus et al. (2016) observed Common Bottlenose Dolphins during all seasons within the RI/MA & MA WEAs. Common Bottlenose Dolphins were the second most commonly observed small cetacean species and exhibited little seasonal variability in abundance. They were observed in the MA WEA in all seasons, and observed in the Lease Area in fall and winter. One sighting of Common Bottlenose Dolphins in the S. D. Kraus et al. (2016) study included calves, and one sighting involved mating behavior. It is possible that the Northeast Large Whale Pelagic Survey may have underestimated the abundance of Common Bottlenose Dolphins because this survey was designed to target large cetaceans and the majority of small cetaceans were not identified to species (S. D. Kraus et al., 2016). Common Bottlenose Dolphins were not observed visually or detected acoustically during the 2016 or 2017 surveys in the Lease Area, but 12 visual observations and 10 acoustic detections of marine mammals during the 2016 G&G survey and one visual observation during the 2017 G&G survey were classified as “unidentified” dolphin or porpoise (Vineyard Wind, 2016, 2017).

4.2.11.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 97,476 Common Bottlenose Dolphins in the US Atlantic EEZ. The best available population estimate for the Western North Atlantic Offshore Stock of Bottlenose Dolphins is 77,532 (Sean A. Hayes et al., 2017). This estimate is from summer 2011 surveys covering waters from central Florida to the lower Bay of Fundy (Sean A. Hayes et al., 2017). The best available estimate for the North Atlantic Northern Migratory Coastal Stock is 6,639 (S.A. Hayes et al., 2018).

4.2.11.3. Status

Common Bottlenose Dolphins of the western North Atlantic are not federally listed as threatened or endangered under the ESA. The Western North Atlantic Offshore Stock is not considered Strategic (Sean A. Hayes et al., 2017). However, the western North Atlantic Northern Migratory Coastal stock of Common Bottlenose Dolphins is considered Strategic by NOAA Fisheries because it is listed as depleted under the MMPA (S.A. Hayes et al., 2018).

4.2.12. Harbor Porpoise (*Phocoena phocoena*)

The Harbor Porpoise is the only porpoise species found in the Atlantic. It is a small, stocky cetacean with a blunt, short-beaked head, dark gray back, and white underside (NOAA Fisheries, 2018h). It reaches a maximum length of 1.8 m (6 ft) and feeds on a wide variety of small fish and cephalopods (R. D. Kenney & Vigness-Raposa, 2010; R. R. Reeves & Read, 2003). Most Harbor Porpoise groups are small, usually between five and six individuals, although they aggregate into large groups for feeding or migration (T.A Jefferson et al., 2008).

4.2.12.1. Distribution

The Harbor Porpoise is usually found in shallow waters of the continental shelf, although they occasionally travel over deeper offshore waters. They are commonly found in bays, estuaries, harbors, and fjords less than 200 m (650 ft) deep (NOAA Fisheries, 2018h). S.A. Hayes et al. (2018) report that Harbor Porpoises are generally concentrated along the continental shelf within the northern Gulf of Maine and southern Bay of Fundy region during summer months (July through September). During fall (October through December) and spring (April through June), they are more widely dispersed from New Jersey to Maine. During winter (January through March), they range from New Brunswick, Canada, to North Carolina (S.A. Hayes et al., 2018). There are four distinct populations of Harbor Porpoise in the Western Atlantic: Gulf of Maine/Bay of Fundy, Gulf of St. Lawrence, Newfoundland, and Greenland (S.A. Hayes et al., 2018). Harbor Porpoises observed in the US Atlantic EEZ are considered part of the Gulf of Maine/Bay of Fundy stock.

NEFSC observed Harbor Porpoises four times in the WDA during two of the AMAPPS surveys (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). Three observations were in the spring of 2012 during an aerial survey; and one observation was in the spring of 2014 during a shipboard survey (NEFSC & SEFSC 2012, 2014b). S. D. Kraus et al. (2016) indicate that Harbor Porpoises occur within the RI/MA & MA WEAs in fall, winter, and spring. Harbor Porpoises were observed in groups ranging in size from three to 15 individuals and were primarily observed in the S. D. Kraus et al. (2016) study area from November through May, with very few sightings during June through September. It is possible that the Northeast Large Whale Pelagic Survey may have underestimated the abundance of Bottlenose Dolphins because this survey was designed to target large cetaceans and the majority of small cetaceans were not identified to species (S. D. Kraus et al., 2016). This species was not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 G&G surveys for the Project, but 12 visual observations and 10 acoustic detections of marine mammals during the 2016 G&G survey and one visual observation during the 2017 G&G survey were classified as “unidentified” dolphin or porpoise (Vineyard Wind, 2016).

4.2.12.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 17,651 Harbor Porpoise in the US Atlantic EEZ during winter (November to May) and 45,089 during summer (June to October) months. The best current abundance estimate of the Gulf of Maine/Bay of Fundy Harbor Porpoise stock is 79,883 individuals, based upon data collected during a 2011 line-transect sighting survey (S.A. Hayes et al., 2018).

4.2.12.3. Status

Harbor Porpoise are not listed as threatened or endangered under the ESA and is not listed under the MA ESA. The Gulf of Maine/Bay of Fundy Stock of Harbor Porpoises is not considered Strategic. The total annual estimated average human-caused mortality is 307 (S.A. Hayes et al., 2018).

4.3. Pinnipeds

Three species of pinnipeds occur in the Atlantic Ocean near the Offshore Project Area: the Harbor Seal, Gray Seal, and Harp Seal. All three pinniped species are most likely to occur in the region during winter and early spring.

4.3.1. Harbor Seal (*Phoca vitulina vitulina*)

The Harbor Seal is found throughout coastal waters of the Atlantic Ocean and adjoining seas above 30°N and is the most abundant pinniped in the US Atlantic EEZ (S.A. Hayes et al., 2018). This species is approximately 2 m (6 ft) in length and has a blue-gray back with light and dark speckling ((NOAA Fisheries, 2018i). Harbor Seals complete both shallow and deep dives during hunting, depending on the availability of prey (Tollit, Thompson, & Greenstreet, 1997). This species consumes a variety of prey, including fish, shellfish, and crustaceans (Bigg, 1981; Burns, 2002; T.A Jefferson et al., 2008; Randall R. Reeves, 1992). Harbor Seals commonly occur in coastal waters and on coastal islands, ledges, and sandbars (T.A Jefferson et al., 2008).

4.3.1.1. Distribution

Harbor Seals are year-round inhabitants of the coastal waters of eastern Canada and Maine (David T. Richardson & Rough, 1993) and occur seasonally along the southern New England to New Jersey coasts from September through late May (Barlas, 1999; Schneider & Payne, 1983; Schroeder, 2000). A general southward movement from the Bay of Fundy to southern New England waters occurs in fall and early winter (Barlas, 1999; Jacobs & Terhune, 2000; Rosenfeld, George, & Terhune, 1988; Whitman & Payne, 1990). A northward movement from southern New England to Maine and eastern Canada occurs prior to the pupping season, which takes place from mid-May through June along the Maine coast (M. K. Kenney, 1994; D. T. Richardson, 1976; Whitman & Payne, 1990; Wilson, 1978).

No Harbor Seals were observed in the WDA or OECC during AMAPPS surveys from 2010–2016 (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). S. D. Kraus et al. (2016) observed Harbor Seals in the RI/MA & MA WEAs and surrounding areas, but this survey was designed to target large cetaceans so locations and numbers of seal observations were not included in the study report (S. D. Kraus et al., 2016). Harbor Seals have five major haul-out sites in and near the RI/MA & MA WEAs: Monomoy Island, the northwestern side of Nantucket Island, Nomans Land, the north side of Gosnold Island, and the southeastern side of Naushon Island (Figure 10) (P. Michael Payne & Selzer, 1989). P. Michael Payne and Selzer (1989) conducted aerial surveys and found that for haul-out sites in Massachusetts and New Hampshire, Monomoy Island had approximately twice as many seals as any of the 13 other sites in the study (maximum count of 1,672 in March of 1986). Harbor Seals were not observed visually or detected acoustically in the Lease Area during the 2016 or 2017 G&G surveys for the Project, even though this survey overlapped with months seals would be expected to be present (October and November) (Vineyard Wind, 2016, 2017). Two seals visually observed during the 2017 G&G survey were classified as “unknown” (Vineyard Wind, 2017).

4.3.1.2. Abundance

Although the stock structure of the Western North Atlantic population is unknown, it is thought that Harbor Seals found along the eastern US and Canadian coasts represent one population that is termed the Western North Atlantic Stock (Andersen & Olsen, 2010; Temte & Wiig, 1991). The best estimate of abundance for Harbor Seals in the Western North Atlantic Stock is 75,834 (S.A. Hayes et al., 2018). This estimate was derived from a coast-wide survey along the Maine coast during May/June 2012.

4.3.1.3. Status

The Western North Atlantic Stock of Harbor Seals is not considered Strategic under the MMPA; this species is not listed as threatened or endangered under the ESA and is not listed under the MA ESA.

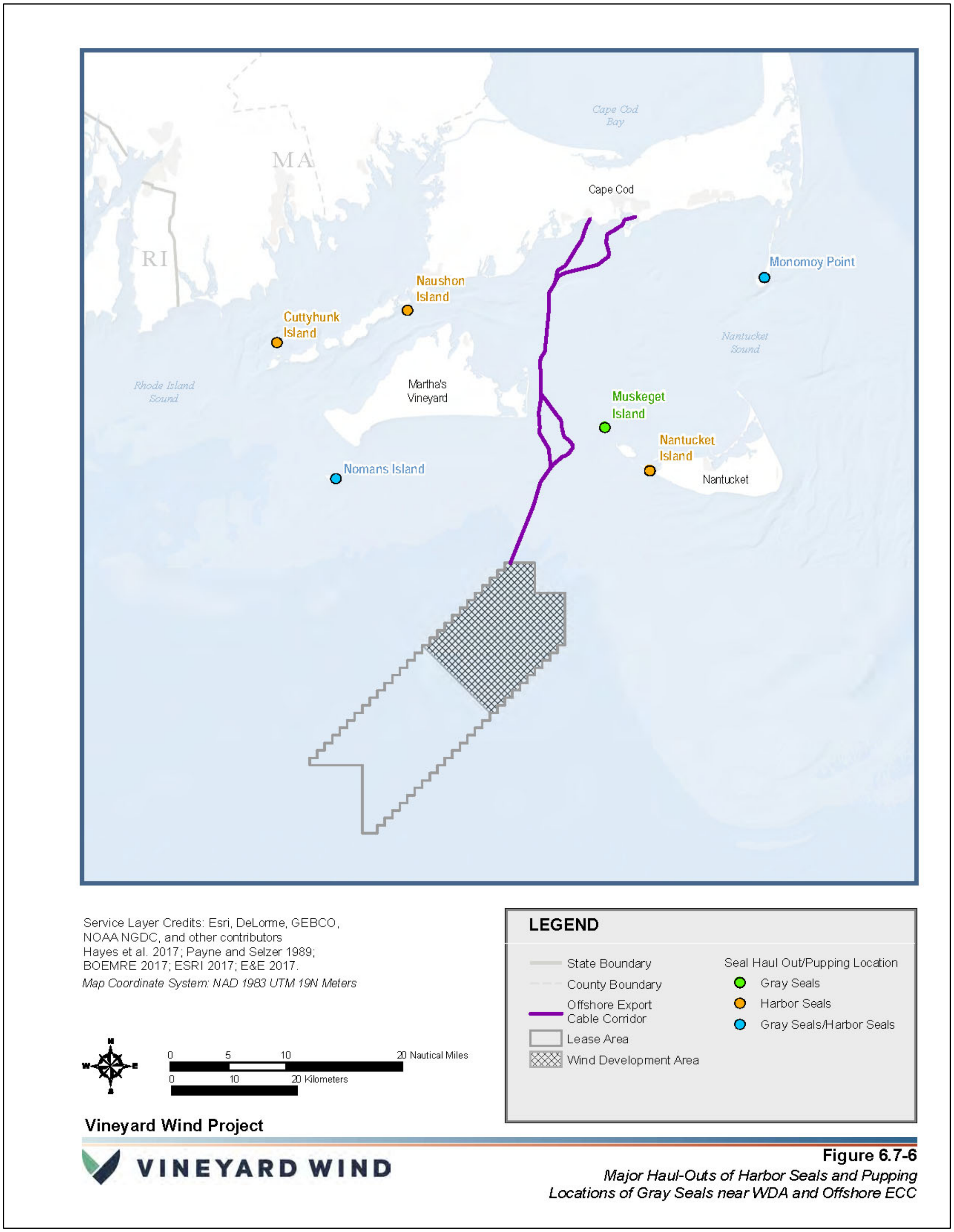

Figure 10. Major Haul-Outs of Harbor Seals and Pupping Locations of Gray Seals near WDA and OECC (Figure 6.7-6 of the Vineyard Wind Draft Construction and Operations Plan Volume I; Vineyard Wind, 2018).

4.3.2. Gray Seal (*Halichoerus grypus atlantica*)

Gray Seals are the second most common pinniped in the US Atlantic EEZ (T.A Jefferson et al., 2008). This species inhabits temperate and sub-arctic waters and lives on remote, exposed islands, shoals, and unstable sandbars (T.A Jefferson et al., 2008). Gray Seals are large, reaching 2–3 m (7.5–10 ft) in length, and have a silver-gray coat with scattered dark spots (NOAA Fisheries, 2018g). These seals are generally gregarious and live in loose colonies while breeding (T.A Jefferson et al., 2008). Though they spend most of their time in coastal waters, Gray Seals can dive to depths of 300 m (984 ft), and frequently forage on the OCS (T.A Jefferson et al., 2008; Veronique Lesage & Hammill, 2001). These opportunistic feeders primarily consume fish, crustaceans, squid, and octopus (W. N. Bonner, 1971; T.A Jefferson et al., 2008; Randall R. Reeves, 1992). They often co-occur with Harbor Seals because their habitat and feeding preferences overlap (NOAA Fisheries, 2018g).

4.3.2.1. Distribution

The eastern Canadian population of Gray Seals ranges from New Jersey to Labrador and is centered at Sable Island, Nova Scotia (Davies, 1957; Veronique Lesage & Hammill, 2001; Mansfield, 1966; David T. Richardson & Rough, 1993). There are three breeding concentrations in eastern Canada: Sable Island, the Gulf of St. Lawrence, and along the east coast of Nova Scotia (Lavigueur & Hammill, 1993). In US waters, Gray Seals currently pup at four established colonies from late December to mid-February: Muskeget and Monomoy Islands in Massachusetts, and Green and Seal Islands in Maine (Center for Coastal Studies, 2017; S.A. Hayes et al., 2018). Pupping was also observed in the early 1980s on small islands in Nantucket-Vineyard Sound and more recently at Nomans Island (Figure 10) (S.A. Hayes et al., 2018). Following the breeding season, Gray Seals may spend several weeks ashore in the late spring and early summer while undergoing a yearly molt. Gray Seals are expected to occur year-round in at least the OECC, with seasonal occurrence in the WDA from September to May (S.A. Hayes et al., 2018).

No Gray Seals were observed in the WDA or OECC during AMAPPS surveys from 2010–2016 (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). S. D. Kraus et al. (2016) observed Gray Seals in the RI/MA & MA WEAs and surrounding areas, but this survey was designed to target large cetaceans so locations and numbers of seal observations were not included in the study report (S. D. Kraus et al., 2016). Gray Seals were observed on two occasions during the 2016 survey and two additional occasions in the 2017 survey in the Lease Area (Vineyard Wind, 2016, 2017).

4.3.2.2. Abundance

Gray Seals form three populations in the Atlantic: Eastern Canada, Northwestern Europe, and the Baltic Sea (David T. Richardson & Rough, 1993). The Western North Atlantic Stock is equivalent to the Eastern Canada population. Available data are insufficient to estimate the size of the entire Eastern Canada Gray Seal population, but estimates are available for portions of the stock for certain time periods (S.A. Hayes et al., 2018). Gray Seal pup production for the three Canadian herds (Gulf of St Lawrence, Nova Scotia Eastern Shore, and Sable Island) in 2016 totaled 101,500 animals. The total population size for these areas was estimated at 424,300 for 2016 (DFO, 2017). For US waters alone, S.A. Hayes et al. (2018) estimated an abundance of 27,131.

4.3.2.3. Status

Gray seals are not considered Strategic under the MMPA, are not listed as threatened or endangered under the ESA, and are not listed under the MA ESA.

4.3.3. Harp Seal (*Pagophilus groenlandicus*)

The Harp Seal is found throughout the North Atlantic and Arctic Oceans (Lavigne & Kovacs, 1988); Ronald & Healey, 1981). This species is approximately 1.7 m (5.6 ft) in length and has light gray fur with a black face and a horseshoe-shaped black saddle on its back (NOAA Fisheries, 2018j) Harp Seals complete shallower dives relative to other pinnipeds (Schreer & Kovacs, 1997). This species consumes a variety of species of finfish and invertebrates, mainly capelin, cod (Gadidae), and krill ((NOAA Fisheries, 2018j).

4.3.3.1. Distribution

Harp Seals are year-round inhabitants of the coastal waters off eastern Canada and occur seasonally in the northeastern US. Harp Seals begin their seasonal shift south toward US waters following summer feeding in the more northern Canadian waters (Lavigne & Kovacs, 1988; David E. Sergeant, 1965). The most southerly point of observation for this species has been New Jersey, from January through May (D. E. Harris, Lelli, & Jakush, 2002). Sightings of Harp Seals this far south have been increasing since the early 1990s. The number of sightings and strandings from January to May have also increased off the east coast of the US (NOAA Fisheries, 2018j).

No Harp Seals were observed during AMAPPS surveys from 2010–2016 (NEFSC & SEFSC, 2011a; 2011b, 2012, 2014a, 2014b, 2015, 2016). S. D. Kraus et al. (2016) did not observe Harp Seals in the RI/MA & MA WEAs and surrounding areas (S. D. Kraus et al., 2016). Harp Seals were not observed visually or detected acoustically in the Lease Area during the 2016 G&G survey for the Project (Vineyard Wind, 2016).

4.3.3.2. Abundance

The world's Harp Seal population is divided into three separate stocks, with the Front/Gulf stock equivalent to the Western North Atlantic stock (W. Nigel Bonner, 1990; Lavigne & Kovacs, 1988). The best estimate of abundance for Harp Seals in the Western North Atlantic stock is 7.4 million (S.A. Hayes et al., 2018).

4.3.3.3. Status

The Harp Seal is not considered Strategic under the MMPA, not listed as threatened or endangered under the ESA, and not listed under the MA ESA.

5. Type of Incidental Taking Authorization Requested

5.1. Statement of Request

Vineyard Wind is requesting an IHA pursuant to section 101(a)(5)(D) of the MMPA for incidental take by both Level A and Level B harassment of small numbers of marine mammals during impact pile driving activities described in Section 1.0. Although exposure estimates predicted from modeling results indicate that Level A takes are zero or negligible when sound attenuation mitigation is employed; Level A takes are being requested as a precaution in the unlikely scenario that a marine mammal enters the zone of ensonification after pile driving has begun, and it is not feasible from an operational and safety perspective to cease the pile driving activity. In that case, the operator will power down the hammer energy, if feasible.

The mitigation measures described in Section 11.0 below are designed to minimize the likelihood that Level A takes of any marine mammal species will occur. In particular, noise attenuation technology will be used that reduces sound levels by a target of up to approximately 12 dB. Additional mitigation measures focused on ensuring no Level A harassment of a NARW will occur include, restricting pile driving to the months when NARWs are unlikely to be present in the Offshore Project Area and significant NARW monitoring efforts.

6. Numbers of Marine Mammals that May be Taken

6.1. Acoustic Impact Analysis Methods Overview

To estimate the potential effects (i.e., Level A and Level B harassment) of noise generated during the Project to marine mammals, JASCO performed the following modeling steps:

1. Modeled the spectral and temporal characteristics of the sound output from the proposed pile-driving activities using the industry-standard GRLWEAP (wave equation analysis of pile driving) model and JASCO's Pile Driving Source Model ("PDSM"). Source model set-up and initialization data were based on pile-driving operational parameters provided by Vineyard Wind.
2. Acoustic propagation modeling using JASCO's Marine Operations Noise Model ("MONM") and Full Wave Range Dependent Acoustic Model ("FWRAM") that combined the outputs of the source model with the spatial and temporal environmental context (e.g., location, oceanographic conditions, seabed type) to estimate sound fields (converted to exposure radii for monitoring and mitigation). The lower frequency bands were modeled using MONM-RAM, which is based on the parabolic equation method of acoustic propagation modeling, and the higher frequencies were modeled using MONM-Bellhop, which is a Gaussian-beam ray-theoretic acoustic propagation model.
3. Animal movement modeling integrated the estimated sound fields with species-typical behavioral parameters (e.g., dive patterns), in the JASCO Animal Simulation Model Including Noise Exposure (JASMINE) model to estimate received sound and exposure levels for the animals that may occur in the operational area.
4. Estimated the number of potential Level A and Level B acoustic exposures based on pre-defined acoustic thresholds/criteria (NMFS 2018a).

6.2. Acoustic Modeling: Scope and Assumptions

As described in Section 1, two types of foundations may be utilized and were therefore considered in the acoustic modeling study:

- Monopile foundations varying in size with a maximum of 10.3 m (33.8 ft) diameter piles, and
- Jacket-style foundations using 3 m (9.8 ft) diameter (pin) piles.

The 10.3 m (33.8 ft) monopile foundation is the largest potential pile diameter proposed for the Project and represents the maximum design envelope for monopile foundations. Piles for monopile foundations will be constructed for specific locations with maximum diameters ranging from ~8–10.3 m (26.2–33.8 ft) and an expected median diameter < 9 m (29.5 ft). Jacket foundations each require the installation of three to four jacket securing piles, known as jacket piles, of 3 m (9.8 ft) diameter. The piles for the monopile foundations are all 95 m (311.7 ft) in length and will be driven to a penetration depth of 20–45 m (65.6–147.6 ft) (mean penetration depth 30 m [98.4 ft]), the 3 m (9.8 ft) jacket piles for the jacket foundations are 65 m (213.3 ft) in length and will be driven to a penetration depth of 30–60 m (98.4–196.6 ft) (mean penetration depth of 45 m [147.6 ft]) (Vineyard Wind, 2018). An IHC S-4000 hammer was modeled for driving piles for the monopile foundations and an IHC S-2500 hammer was modeled for driving the 3 m (9.8 ft) jacket piles. Representative hammering schedules of increasing hammer energy with increasing penetration depth were modeled resulting in, generally, higher intensity sound fields as the hammer energy and penetration increased. Appendix A provides the complete Acoustic Modeling Report.

Two installation scenarios were considered: 1) the Maximum Design scenario consisting of 90 10.3 m (33.8 ft) WTG monopile foundations, 10 WTG jacket foundations, and two ESP jacket foundations; and 2) the Most Likely scenario, which is the maximum of the Most Likely installation configuration consisting of one hundred 10.3 m (33.8 ft) WTG monopile foundations and two ESP jacket foundations (Table 1). Both scenarios assumed four piles for each jacket.

Both scenarios were modeled assuming the installation of one foundation per day and two foundations per day distributed across the same calendar period. One jacket foundation per day (four piles) was assumed for both scenarios. It was also assumed that no concurrent pile driving would be performed. The pile-driving schedules for modeling were created based on the number of expected suitable weather days available per month in which pile driving may occur to better understand when the majority of pile driving is likely to occur throughout the year. The number of suitable weather days per month was obtained from historical weather data. The modeled pile-driving schedule for the Maximum Design scenario is show in Table 2.

The modeled source spectra are provided in Figures 11 and 12. For both pile diameters, the dominant energy over all hammer energies is below 100 Hz. The source levels of the 10.3 m (33.8 ft) pile installation contain more energy at lower frequencies than for the smaller 3 m (9.8 ft) piles. The acoustic modelling report in Appendix A has greater detail on the acoustic modelling process and results.

[redacted]

[redacted]

[redacted]

6.3. Acoustic Criteria – Level A and Level B Harassment

The MMPA (16 U.S.C. 1362) prohibits the take of marine mammals. MMPA defines the term "take" as: to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal. MMPA Regulations define harassment in two categories relevant to pile driving operations. These are:

- Level A: any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild, and
- Level B: any act of pursuit, torment or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing a disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild (16 U.S.C. 1362).

To assess the potential impacts of the Project-associated pile driving noise, it is necessary to first establish acoustic exposure criteria at which takes could result. In 2016, NOAA Fisheries issued a Technical Guidance document that provides acoustic thresholds for onset of permanent threshold shift (PTS) in marine mammal hearing for most sound sources, which was then updated in 2018 (NMFS, 2016; NMFS 2018a). NOAA Fisheries also provided guidance on the use of weighting functions when applying Level A harassment criteria. The Guidance recommends the use of a dual criterion for assessing Level A exposures, including a peak (unweighted/flat) sound level metric (PK) and a cumulative sound exposure level (SEL) metric with frequency weighting. Both acoustic criteria and weighting function application are divided into functional hearing groups (low-, mid-, and high-frequency) that species are assigned to, based on their respective hearing ranges.

The publication of ISO 18405 Underwater Acoustics – Terminology (ISO 2017) provided a dictionary of underwater bioacoustics (previous standards: ANSI S1.1-2013, R2013). The JASCO modeling follows the definitions and conventions of ISO (2017) except where stated otherwise (Table 4).

Table 4. Summary of relevant acoustic terminology used by US regulators and in the modeling report.

Metric	NMFS (2018a)	ISO (2017)	
		Main text/Tables	Equations
Sound pressure level	n/a	SPL	L_p
Peak pressure level	PK	PK	L_{pk}
Cumulative sound exposure level	SEL_{cum}	SEL	L_E

The SEL metric as used by NOAA Fisheries describes the sound energy received by a receptor over a period of 24 hours. Accordingly, following the ISO standard, this will hereafter be denoted as SEL, with the exception of tables and equations where L_E will be used alongside SEL to account for its use in mathematical equations.

6.3.1. Marine mammal hearing groups

Current data and predictions show that marine mammal species differ in their hearing capabilities, in absolute hearing sensitivity as well as frequency band of hearing (Whitlow W. L. Au & Hastings, 2008; W. J. Richardson, Greene, Malme, & Thomson, 1995; Southall et al., 2007; D. Wartzok & Ketten, 1999). While hearing measurements are available for a small number of species based on captive animal studies, direct measurements of many odontocetes and all mysticetes do not exist. As a result, hearing ranges for many odontocetes are grouped with similar species, and predictions for mysticetes are based on other methods, including: anatomical studies and modeling (Cranford & Krysl, 2015; Houser, Helweg, & Moore, 2001; Susan E. Parks, Clark, & Tyack, 2007; Tubelli, Zosuls, Ketten, & Mountain, 2012), vocalizations (Whitlow W. L. Au & Hastings, 2008; see reviews in W. J. Richardson et al., 1995; D. Wartzok & Ketten, 1999), taxonomy, and behavioral responses to sound (Marilyn E. Dahlheim & Ljungblad, 1990; see review in Reichmuth, Mulsow, Finneran, Houser, & Supin, 2007). In 2007, Southall and colleagues proposed that marine mammals be divided into hearing groups. This division was updated in 2016 and 2018 by NOAA Fisheries using more recent best available science (Table 5).

Table 5. Marine mammal hearing groups (NMFS 2018a; Sills, Southall, & Reichmuth, 2014).

Hearing group	Generalized hearing range*
Low-frequency (LF) cetaceans (mysticetes or baleen whales)	7 Hz to 35 kHz
Mid-frequency (MF) cetaceans (odontocetes: delphinids, beaked whales)	150 Hz to 160 kHz
High-frequency (HF) cetaceans (other odontocetes)	275 Hz to 160 kHz
Phocid pinnipeds in water (PPW)	50 Hz to 86 kHz
Phocid pinnipeds in air (PPA)†	50 Hz to 36 kHz

* The generalized hearing range is for all species within a group. Individual hearing will vary.
† Based on the distance from shore (23 km [14 mi] offshore of Martha's Vineyard and Nantucket), sound will not reach NOAA thresholds for behavioral disturbance of seals in air (90 dB root mean square [rms] re 20 µPa for Harbor Seals and 100 dB [rms] re 20 µPa for all other seal species) at land-based sites where seals may spend time out of the water and thus in-air hearing is not considered further.

6.3.2. Marine mammal auditory weighting functions

The potential for anthropogenic sounds to impact marine mammals is largely dependent on whether the sound occurs at frequencies that an animal can hear well, unless the sound pressure level is so high that it can cause physical tissue damage regardless of frequency. Auditory (frequency) weighting functions reflect an animal's ability to hear a sound (Nedwell & Turnpenny, 1998; J. R. Nedwell et al., 2007).

Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS thresholds expressed in metrics that consider what is known about marine mammal hearing (e.g., SEL [L_E]) (Erbe, McCauley, & Gavrilov, 2016; Finneran, 2016; Southall et al., 2007). Marine mammal auditory weighting functions published by Finneran (2016) are included in the NOAA Fisheries (NMFS 2018a) Technical Guidance for use in conjunction with corresponding PTS onset (Level A harassment) acoustic criteria (Table 6).

The application of marine mammal auditory weighting functions emphasizes the importance of making measurements and characterizing sound sources in terms of their overlap with biologically important frequencies (e.g., frequencies used for environmental awareness, communication, or the detection of predators or prey), and not only the frequencies of interest or concern for the completion of the sound-producing activity (i.e., context of sound source; NMFS 2018a).

6.3.3. Level A harassment exposure criteria

Injury to the hearing apparatus of a marine mammal may result from a fatiguing stimulus measured in terms of SEL, which considers the sound level and duration of the exposure signal. Intense sounds may also damage the hearing apparatus independent of duration so an additional metric of peak pressure (PK) is needed to assess acoustic exposure injury risk. PTS is considered injurious but there are no published data on the sound levels that cause PTS in marine mammals. There are data that indicate the received sound levels at which temporary threshold shift ("TTS") occurs, so PTS onset is typically extrapolated from TTS onset level and an assumed growth function (Southall et al., 2007).
NOAA Fisheries (2018a) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy accumulated over 24 hours (SEL), or very loud, instantaneous peak sound pressure levels. These dual threshold criteria of SEL and PK are used to calculate marine mammal exposures (Table 6).

Table 6. Summary of relevant PTS onset acoustic thresholds (NMFS 2018a).

Hearing group	**PTS onset thresholds* (received level)**	
	Impulsive	Non-impulsive
Low-frequency (LF) cetaceans	$L_{pk, flat}$: 219 dB $L_{E, LF, 24h}$: 183 dB	$L_{E, LF, 24h}$: 199 dB
Mid-frequency (MF) cetaceans	$L_{pk, flat}$: 230 dB $L_{E, MF, 24h}$: 185 dB	$L_{E, MF, 24h}$: 198 dB
High-frequency (HF) cetaceans	$L_{pk, flat}$: 202 dB $L_{E, HF, 24h}$: 155 dB	$L_{E, HF, 24h}$: 173 dB
Phocid seals in water (PW)	$L_{pk, flat}$: 218 dB $L_{E, PW, 24h}$: 185 dB	$L_{E, PW, 24h}$: 201 dB

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
$L_{pk, flat}$–peak sound pressure is flat weighted or unweighted and has a reference value of 1 μPa
L_E - denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 $\mu Pa^2 s$
The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting.

6.3.4. Level B harassment exposure criteria

Numerous studies on marine mammal behavioral responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioral reactions. However, it is recognized that the context in which the sound is received affects the nature and extent of responses to a stimulus (Ellison & Frankel, 2012; Southall et al., 2007). Because of the complexity and variability of marine mammal behavioral responses to acoustic exposure, NOAA Fisheries has not recently updated technical guidance on behavioral thresholds for use in calculating animal exposures (NMFS 2018a). NOAA Fisheries currently uses a single step function to assess behavioral impact (NOAA, 2005). A 50% probability of inducing behavioral responses at a sound pressure level ("SPL") of 160 dB re 1 µPa was derived from the HESS (1999) report which, in turn, was based on the responses of migrating mysticete whales to airgun sounds (Malme, Miles, Clark, Tyack, & Bird, 1984; Malme, Miles, Clark, Tyak, & Bird, 1983). The HESS team recognized that behavioral responses to sound may occur at lower levels, but significant responses were only likely to occur above an SPL of 140 dB re 1 µPa. An extensive review of behavioral responses to sound was undertaken by Southall et al. (2007, their Appenidx B). They found varying responses for most marine mammals between an SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions. NOAA Fisheries currently considers marine mammals exposed above 160 dB re 1 µPa to have experienced a Level B behavior take.

6.4. Predicted Sound Fields

The sound a source produces is characterized in time, spectral content, and space, and as the sound travels away from the source it is shaped by interactions with the environment in which it propagates (see Appendix A). For this reason, the sound field produced by a source is specific to the source and the location. Understanding the potential for sound exposure to impact animals requires an understanding of the sound field to which they could be exposed. Sound fields produced during pile driving were modeled by first characterizing the sound signal produced during pile driving using the industry-standard GRLWEAP (wave equation analysis of pile driving) model and JASCO's Pile Driving Source Model (PDSM). The source signal was then propagated along radial planes using JASCO's parabolic equation models MONM and FWRAM, and radial planes assembled in to three-dimensional sound fields (see Appendix A). These three-dimensional, per-strike sound fields were then used with animal movement modeling (see below) to obtain estimates of animal exposure probability.

Two sites were selected to provide representative propagation and sound fields for the Project area (Table 7, Figure A-1 of Appendix A). Source locations were selected to span the region from shallow to deep water and varying distances to dominant bathymetric features (i.e., slope and shelf break). Water depth and environmental characteristics (e.g., bottom-type) are similar throughout the WDA (Vineyard Wind, 2016), and therefore minimal difference was found in sound propagation results for the two sites (Appendix A).

Table 7. Sites used in propagation modeling.

Site	Location (UTM Zone 19N)		Water depth (m)*	Sound source	Source type
	Easting	Northing			
P1	382452	4548026	38	Monopile, Jacketed pile	Impulsive
P2	365240	4542200	46		

*Vertical datum for water depth is Earth Gravitational Model 1996 (EGM96).

6.4.1. Noise attenuation

Noise attenuation systems, such as bubble curtains, are sometimes used to decrease the sound levels in the water near a source. Bubbles create a local impedance change that acts as a barrier to sound transmission. The size of the bubbles determines their effective frequency band, with larger bubbles needed for lower frequencies. There are a variety of bubble curtain systems, confined or unconfined bubbles, and some with encapsulated bubbles or panels. Attenuation levels also vary by type of system, frequency band, and location. Small bubble curtains have been measured to reduce sound levels from ~10 dB to more than 20 dB but are highly dependent on depth of water, current, and configuration and operation of the curtain (M. Austin, S. L. Denes, J. T. MacDonnell, & G. A. Warner, 2016; Koschinski & Lüdemann, 2013). Larger bubble curtains tend to perform a bit better and more reliably, particularly when deployed with two rings (Bellmann, 2014; Koschinski & Lüdemann, 2013; Nehls, Rose, Diederichs, Bellmann, & Pehlke, 2016).

Encapsulated bubble systems, e.g., Hydro Sound Dampers (HSDs), are effective within their targeted frequency ranges, e.g., 100–800 Hz, and when used in conjunction with a bubble curtain appear to create the greatest attenuation, up to 30 dB (Elmer & Savery, 2014). A California Department of Transportation (CalTrans) study tested several systems and found that the best attenuation systems resulted in 10–15 dB of attenuation (Buehler et al., 2015). Similarly, M. Dähne, Tougaard, Carstensen, Rose, and Nabe-Nielsen (2017) found that single bubble curtains that reduced sound levels by 7 to 10 dB reduced the overall sound level by ~12 dB when combined as a double bubble curtain for 6 m steel monopiles in the North Sea. In the modeling study, we included hypothetical broadband attenuation levels of 6 and 12 dB to gauge the effects on the ranges to thresholds given these levels of attenuation can be achieved.

6.4.2. Distances to exposure thresholds

Though not directly used for exposure estimates, ranges to exposure criteria thresholds are often reported and useful for informing monitoring and mitigation zones. For each sound level threshold, two statistical estimates are calculated: the maximum range (R_{max}), and the 95% range ($R_{95\%}$). The R_{max} is simply the distance to the farthest modeled occurrence of the threshold level, at any depth. The $R_{95\%}$ for a given sound level is the radius of a circle, centered on the source, encompassing 95% of the modeled sound field at levels above threshold. Use of $R_{95\%}$ reduces the sensitivity to extreme outlying values (the farthest 5% of ranges) so is helpful in estimating ranges used for monitoring and mitigation purposes (see detailed description in Appendix A).

6.4.2.1. Level A harassment criteria radii

Table 8 lists the radial distances to SEL and PK level threshold criteria using NMFS (2018a) frequency weighting for marine mammals. For the PK level, the greatest distances expected are shown, typically occurring at the highest hammer energies. The distances to SEL thresholds are calculated using the hammer energy schedules for driving one monopile or four jacket piles (Appendix A).

Table 8. Radii distances ($R_{95\%}$ in meters) to Level A harassment thresholds (NMFS 2018a) at two modeling sites for marine mammal functional hearing groups estimated for each scenario foundation type. The largest mean radii are shown with 0, 6, and 12 dB sound attenuation.

Foundation type	Hearing group	Level A harassment (L_{pk})			Level A harassment (L_{E},24hr)		
		No attenuation	6 dB	12 dB	No attenuation	6 dB	12 dB
10.3 m (33.8 ft) monopile	LFC	34	17	8.5	5,443	3,191	1,599
	MFC	10	5	2.5	56	43	0
	HFC	235	119	49	101	71	71
	PPW	38	19	10	450	153	71
Four, 3 m (9.8 ft) jacket piles	LFC	7.5	4	2.5	12,975	7,253	3,796
	MFC	2.5	1	0.5	71	71	56
	HFC	51	26	13.5	1,389	564	121
	PPW	9	5	2.5	2,423	977	269

6.4.2.2. Level B harassment criteria radii

The NOAA (2005) behavioral threshold for all hearing groups is an unweighted 160 dB SPL. Acoustic propagation was modeled at two representative sites in the WDA (Appendix A). The radii distances shown in Table 9 are the maximum distance from piles averaged between the two modeled locations, obtained using the maximum hammer energy for the NOAA (2005) criteria. Two levels of attenuation, 6 and 12 dB, were modeled for the Project (Appendix A). Table 9 includes no attenuation, and sound reductions of 6 dB and 12 dB.

Table 9. Radii distances ($R_{95\%}$ in meters) to sound pressure level behavioral thresholds for marine mammals based on NOAA (2005). Ranges are calculated using the average maximum hammer energy at two modeling sites for marine mammal functional hearing groups estimated for each scenario foundation type with 0, 6 dB, and 12 dB sound reduction.

Foundation type	**Hearing group**	**Level B unweighted (NOAA, 2005)**		
		No attenuation	6 dB	12 dB
10.3 m (33.8 ft) monopile	LFC	6,316	4,121	2,739
	MFC			
	HFC			
	PW			
Four, 3 m (9.8 ft) jacket piles	LFC	4,104	3,220	2,177
	MFC			
	HFC			
	PW			

6.4.2.3. Effects of noise attenuation

As an illustration of the effect of sound attenuating technology on acoustic exposure radii calculations, percentage reductions are shown in Table 10.

Table 10. Percentage reduction in ranges to marine mammal exposure criteria with attenuation.

Metric	**Percentage range reduction (%)**	
	6 dB	12 dB
Level A (PK (L_{pk}))	49	73
Level A (SEL (L_E))	45	68
Level B (SPL (L_P))	49	75

6.5. Marine Mammal Occurrence Used in Take Estimation

6.5.1. Marine mammal densities

Marine mammal density estimates (animals/km^2) used in this assessment were obtained using the Duke University Marine Geospatial Ecological Laboratory model results (Roberts et al., 2016; Roberts, Mannocci, Schick, & Halpin, 2018). Jason Roberts supplied an unpublished model that provides updated densities for the Fin Whale, Humpback Whale, Minke Whale, NARW, Sei Whale, Sperm Whale, Pilot Whales, and Harbor Porpoise (Roberts et al., 2017). This model incorporates more sighting data than Roberts et al. (2016), including sightings from AMAPPS 2010–2014 surveys, which included some aerial surveys over the RI/MA & MA WEAs (NEFSC & SEFSC, 2011b, 2012, 2014a, 2014b, 2015, 2016). Density estimates for pinnipeds were calculated using Roberts et al. (2018) density data.

Visual survey studies conducted in the Offshore Project Area were reviewed to assess agreement with the Roberts et al. (2016); Roberts et al. (2017), and Roberts et al. (2018) density estimates for NARW and other cetacean species (S. D. Kraus et al., 2016). Notably, there were no observations of NARWs for the months of May to October, and only four sightings in December. There are no pile driving activities planned for the Project during January to April, when most of the sightings occurred in that study. Based on a review of the S. D. Kraus et al. (2016) survey information, it was determined that no changes were needed to the Roberts et al. (2015, 2016, 2017) density estimates for use in this modeling effort.

Mean monthly densities for all animals were calculated using a 13 km (8 mi) buffered polygon around the WDA perimeter and overlaying it on the density maps from Roberts et al. (2015), Roberts et al. (2016), Roberts et al. (2017), and Roberts et al. (2018) (Figure 13). The 13 km (8 mi) buffer defines the maximum area around the WDA with the potential to result in behavioral disturbance for the 10.3 m (33.8 ft) monopile installation using (Wood, Southall, & Tollit, 2012) threshold criteria. This buffer encompasses and extends well beyond the range of behavioral disturbance for all hearing groups using the (NOAA, 2005) unweighted thresholds.

The mean density for each month was determined by calculating the unweighted mean of all 10 x 10 km (6.2 x 6.2 mi) grid cells partially or fully within the buffer zone polygon. Densities were computed for the months of May to December to coincide with planned pile driving activities. In cases where monthly densities were unavailable, annual (Pilot Whales) and seasonal (seals) mean densities were used instead. Table 11 shows the monthly marine mammal density estimates for each species evaluated in the acoustic analysis.

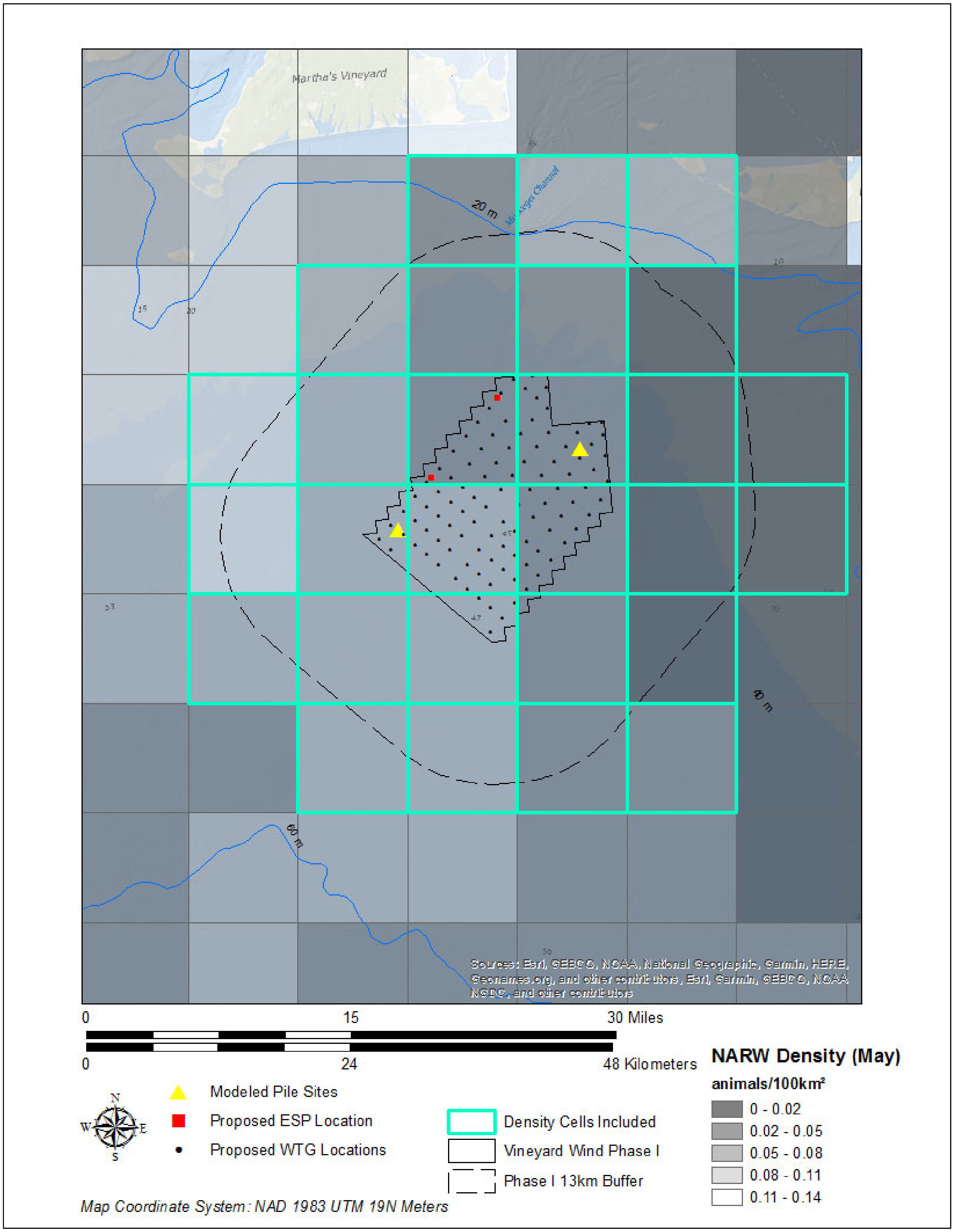

Figure 13. Density map showing Roberts et al. (2015), Roberts et al. (2016), Roberts et al. (2017), Roberts et al. (2018) _ENREF_312 grid cells. Highlighted cells indicate those used to calculate mean monthly species estimates in the vicinity of the Project.

Table 11. Mean monthly marine mammal density estimates for the Offshore Project Area from Roberts et al. (2015), Roberts et al. (2016), Roberts et al. (2017), Roberts et al. (2018).

Species of interest	Monthly densities (animals/100 km²)‡												Annual	May to Dec
Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Mean
Fin whale*	0.151	0.115	0.122	0.234	0.268	0.276	0.260	0.248	0.197	0.121	0.120	0.131	0.187	0.203
Humpback whale	0.033	0.018	0.034	0.204	0.138	0.139	0.199	0.109	0.333	0.237	0.078	0.049	0.131	0.160
Minke whale	0.052	0.064	0.063	0.136	0.191	0.171	0.064	0.051	0.048	0.045	0.026	0.037	0.079	0.079
North Atlantic right whale*	0.205	0.309	0.543	0.582	0.287	0.308	0.002	0.002	0.006	0.001	0.001	0.267	0.209	0.109
Sei whale*	0.001	0.002	0.001	0.033	0.029	0.012	0.003	0.002	0.003	0.001	0.002	0.001	0.007	0.007
Atlantic white sided dolphin	1.935	0.972	1.077	2.088	4.059	3.742	2.801	1.892	1.558	1.950	2.208	3.281	2.297	2.686
Bottlenose dolphin	0.382	0.011	0.007	0.497	0.726	2.199	5.072	3.603	4.417	4.460	2.136	1.216	2.061	2.979
Pilot whales†	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
Risso's dolphin	0.006	0.003	0.001	0.001	0.005	0.005	0.010	0.020	0.016	0.006	0.013	0.018	0.009	0.012
Short beaked dolphin	7.734	1.260	0.591	1.613	3.093	3.153	3.569	6.958	12.200	12.727	9.321	16.831	6.588	8.482
Sperm whale*	0.001	0.001	0.001	0.001	0.003	0.006	0.029	0.033	0.012	0.012	0.008	0.001	0.009	0.013
Harbor porpoise	3.939	6.025	12.302	6.959	3.904	1.332	0.910	0.784	0.717	0.968	2.609	2.686	3.595	1.739
Gray seal	6.844	8.291	8.621	15.170	19.123	3.072	0.645	0.372	0.482	0.687	0.778	3.506	5.633	3.583
Harbor seal	6.844	8.291	8.621	15.170	19.123	3.072	0.645	0.372	0.482	0.687	0.778	3.506	5.633	3.583
Harp seal	6.844	8.291	8.621	15.170	19.123	3.072	0.645	0.372	0.482	0.687	0.778	3.506	5.633	3.583

* Listed as Endangered under the ESA.
† Long- and Short-finned Pilot Whales are grouped together.
‡ Density estimates are from habitat-based density modeling of the entire Atlantic EEZ from Roberts et al. (2016).

6.5.2. Marine mammal mean group size

Density estimates inherently account for group size because the mean group size is a factor in the density estimate calculation. However, density surfaces, like those produced by Roberts et al. (2016); Roberts et al. (2015); Roberts et al. (2017), and Roberts et al. (2018) used to calculate mean densities in the project area, spread individuals out in space as if they did not occur in groups. When calculating takes, in cases where the exposure estimate was less than the average group size, we assumed that if one group member were to be exposed, it is likely that all animals in the same group would receive a similar exposure level. Thus, for the requested takes, we increased the value from the exposure modeling results to equal one mean group size, rounded up to the nearest integer, for species with predicted exposures of less than one mean group size. The one exception to this was the NARW (see below).

Mean group sizes for species were derived from S. D. Kraus et al. (2016), where available, as the best representation of expected group sizes within the RI/MA & MA WEAs (Table 12). These were calculated as the number of individuals sighted, divided by the number of sightings summed over the four seasons (from Tables 5 and 19 in S. D. Kraus et al., 2016). Sightings for which species identification was considered either definite or probable were used in the S. D. Kraus et al. (2016) data. For species that were observed very rarely during the Kraus et al. (2016) study (i.e., Sperm Whales and Risso's Dolphins) or observed but not analyzed (i.e., pinnipeds), data derived from AMAPPS surveys (Palka et al., 2017) were used to evaluate mean group size. For Sperm Whales and Risso's Dolphins, the number of individuals divided by the number of groups observed during 2010–2013 AMAPPS NE summer shipboard surveys and NE aerial surveys during all seasons was used (Appendix I of Palka et al., 2017). Though pinnipeds congregate in large numbers on land, at sea they are generally foraging alone or in small groups. For Harbor and Gray Seals, Palka et al. (2017) report sightings of seals at sea during 2010–2013 spring, summer, and fall NE AMAPPS aerial surveys. Those sightings include both Harbor Seals and Gray Seals, as well as unknown seals, and thus a single group size estimate was calculated for these two species. Harp Seals are occasionally recorded south of the RI/MA & MA WEAs on Long Island, New York, and in the nearshore waters, usually in groups of one or two individuals. During 2002–2018, the Coastal Research and Education Society of Long Island (CRESLI) reported seven sightings of Harp Seals (CRESLI, 2018). Five of these were of single individuals and two were of two animals.

Table 12. Mean group size of species that could be present in the Offshore Project Area.

Species	Mean group size
Fin Whale*	1.8
Humpback Whale	2.0
Minke Whale	1.2
North Atlantic Right Whale*	2.4
Sei Whale*	1.6
Atlantic White-Sided Dolphin	27.9
Common Bottlenose Dolphin	7.8
Pilot whales$	8.4
Risso's Dolphin	5.3
Short-Beaked Common Dolphin	34.9
Sperm Whale*	1.5
Harbor Porpoise	2.7
Gray Seal	1.4
Harbor Seal	1.4
Harp Seal	1.3

* Listed as Endangered under the ESA.
$ Kraus et al. (2016) report sightings of Long- and Short-Finned Pilot Whales combined.

6.6. Animal Movement and Exposure Modeling

The JASMINE model was used to predict the probability of exposure of animals to sound arising from the Project pile driving operations. Sound exposure models like JASMINE use simulated animals (animats) to sample the predicted 3D sound fields using movement rules derived from animal observations. The output of the simulation is the exposure history for each animat within the simulation. The precise location of animals (and their pathways) are not known prior to a project, therefore a repeated random sampling technique (Monte Carlo) is used to estimate exposure probability with many animats and randomized starting positions. The output of the simulation is the exposure history for each animat within the simulation, and the combined history of all animats gives a probability density function of exposure during the Project. Scaling the probability density function by the real-world density of animals results in the mean number of animals expected to be exposed during the Project. Due to the probabilistic nature of the process, fractions of animals may be predicted to exceed threshold. If, for example, 0.1 animals are predicted to exceed threshold in the model, that is interpreted as a 10% chance that one animal will exceed threshold during the Project, or equivalently, if the simulation were re-run ten times, one of the ten simulations would result in an animal exceeding threshold. Similarly, a mean number prediction of 33.11 animals can be interpreted as re-running the simulation where the number of animals exceeding threshold may differ in each simulation but the mean number of animals over all of the simulations is 33.11. A portion of an animal cannot be taken during a project, so it is common practice to round mean number animal exposure values to integers using standard rounding methods. However, for low-probability events it is more precise to provide the actual values. For this reason mean number values are not rounded (Section 6.6.1).

Sound fields are input into JASMINE and animats are programmed to behave like the marine animals that may be present in the Offshore Project Area. The parameters that may be used for forecasting realistic behaviors (e.g., diving, foraging, aversion, surface times, etc.) are determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. An individual animat's sound exposure levels are summed over a specified duration, such as 24 hours, to determine its total received energy, and then compared to the threshold criteria described above.

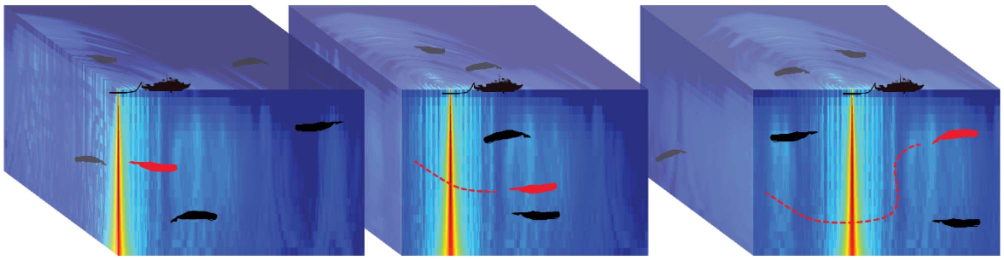

Figure 14. Depiction of animats in an environment with a moving sound field. Example animat (red) shown moving with each time step. The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

6.6.1. Exposure estimates

The exposure estimates shown in Table 13 - Table 16, and Table 19 (with aversion) represent the mean number of animals exposed to underwater sounds exceeding Level A and Level B harassment thresholds resulting from JASMINE analysis.

6.6.1.1. Scenario 1 – Maximum Design (90 monopiles, 12 jacket foundations)

The numbers of individual cetaceans potentially exposed above the threshold criteria (NMFS, 2018a; NOAA, 2005) for pile driving operations (limited to the months of May through December) using the Maximum Design scenario summarized in Table 1 with attenuation levels of 6 dB and 12 dB, are shown in Tables 13 and 14 for the scenarios of one pile being driven per day and two piles being driven per day, respectively. Estimated exposures assuming the targeted sound reduction of up to 12 dB are highlighted in the tables.

Table 13. The mean number of marine mammals‡ estimated to experience sound levels above exposure threshold criteria for the Project (NMFS 2018a; NOAA, 2005) using the Maximum Design scenario parameters and one foundation per day with 6 and 12 dB of sound attenuation.

Species	**6 dB Attenuation**			**12 dB Attenuation**		
	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)
Fin Whale*	0.10	4.13	33.11	0.02	0.29	21.78
Humpback Whale	0.03	9.01	30.10	0.01	1.00	19.66
Minke Whale	0.04	0.22	12.21	0.00	0.07	7.90
North Atlantic Right Whale*	0.03	1.36	13.25	0.00	0.09	8.74
Sei Whale*	0.00	0.14	1.09	0.00	0.01	0.74
Atlantic White-Sided Dolphin	0.00	0.00	449.20	0.00	0.00	277.82
Common Bottlenose Dolphin	0.00	0.00	96.21	0.00	0.00	62.21
Pilot Whales	0.00	0.00	0.00	0.00	0.00	0.00
Risso's Dolphin	0.00	0.00	1.61	0.00	0.00	1.04
Short-Beaked Common	0.10	0.00	1059.97	0.10	0.00	703.81
Sperm Whale*	0.00	0.00	0.00	0.00	0.00	0.00
Harbor Porpoise	4.23	0.17	150.13	1.54	0.00	91.96
Gray Seal	0.11	0.30	196.40	0.04	0.07	118.06
Harbor Seal	0.36	0.21	214.04	0.33	0.07	136.33
Harp Seal	0.73	0.87	217.35	0.00	0.04	132.91

‡ A portion of an animal cannot be taken during a project, so it is common practice to round mean number animal exposure values to integers using standard rounding methods. However, for low-probability events it is more precise to provide the actual values. For this reason mean number values are not rounded (Section 6.6.1).

* Listed as Endangered under the ESA.

Table 14. The mean number of marine mammals estimated to experience sound levels above exposure threshold criteria for the Project (NMFS 2018a) using the Maximum Design scenario parameters and two foundations per day with 6 and 12 dB of sound attenuation.

Species	6 dB Attenuation			12 dB Attenuation		
	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)
Fin Whale*	0.10	4.49	29.71	0.00	0.41	20.57
Humpback Whale	0.03	9.59	27.23	0.00	1.09	18.48
Minke Whale	0.03	0.23	11.52	0.00	0.05	7.76
North Atlantic Right Whale*	0.02	1.39	11.75	0.01	0.10	7.96
Sei Whale*	0.00	0.14	0.93	0.00	0.01	0.65
Atlantic White-Sided Dolphin	0.13	0.00	428.23	0.00	0.00	272.67
Common Bottlenose Dolphin	0.00	0.00	67.71	0.00	0.00	43.87
Pilot Whales	0.00	0.00	0.00	0.00	0.00	0.00
Risso's Dolphin	0.00	0.00	1.38	0.00	0.00	0.95
Short-Beaked Common Dolphin	0.44	0.00	897.91	0.10	0.00	622.78
Sperm Whale*	0.00	0.00	0.00	0.00	0.00	0.00
Harbor Porpoise	4.23	0.17	125.23	1.85	0.06	82.28
Gray Seal	0.29	0.47	145.20	0.04	0.25	96.41
Harbor Seal	1.01	0.86	164.48	0.16	0.39	110.25
Harp Seal	0.38	0.53	162.03	0.17	0.04	108.19

* Listed as Endangered under the ESA.

6.6.1.2. Scenario 2 – Most Likely (100 monopiles, 2 jacket foundations)

The estimated mean number of individual cetaceans potentially exposed above the threshold criteria (NMFS 2018a; NOAA, 2015) for pile driving operations (limited to the months of May through December) using the Most Likely scenario summarized in Table 1 with no attenuation, and with attenuation levels of 6 dB and 12 dB, are shown in Tables 15 and 16 for the scenarios of one pile being driven per day and two piles being driver per day, respectively. Estimated exposures assuming the targeted sound reduction of 12 dB are highlighted in the tables.

Table 15. The mean number of marine mammals estimated to experience sound levels above the exposure threshold criteria for the Project (NMFS 2018a; NOAA, 2005) using the Most Likely scenario parameters and one foundation per day with 6 and 12 dB of sound attenuation.

Species	6 dB Attenuation			12 dB Attenuation		
	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)
Fin Whale*	0.11	2.84	29.85	0.02	0.23	19.43
Humpback Whale	0.04	6.54	26.27	0.01	0.83	17.08
Minke Whale	0.04	0.13	10.28	0.00	0.06	6.77
North Atlantic Right Whale*	0.04	0.72	10.82	0.00	0.04	7.09
Sei Whale*	0.00	0.09	0.95	0.00	0.01	0.65
Atlantic White-Sided Dolphin	0.00	0.00	380.82	0.00	0.00	236.77
Common Bottlenose Dolphin	0.00	0.00	98.56	0.00	0.00	64.19
Pilot Whales	0.00	0.00	0.00	0.00	0.00	0.00
Risso's Dolphin	0.00	0.00	1.48	0.00	0.00	0.94
Short-Beaked Common Dolphin	0.01	0.00	941.41	0.01	0.00	617.01
Sperm Whale*	0.00	0.00	0.00	0.00	0.00	0.00
Harbor Porpoise	3.86	0.14	134.88	1.38	0.00	80.89
Gray Seal	0.00	0.01	176.92	0.00	0.00	104.60
Harbor Seal	0.34	0.01	191.06	0.34	0.00	120.64
Harp Seal	0.72	0.72	193.65	0.00	0.00	116.13

* Listed as Endangered under the ESA.

Table 16. The mean number of marine mammals estimated to experience sound levels above exposure threshold criteria for the Project (NMFS 2018a; NOAA, 2005) using the Most Likely scenario parameters and two foundations per day with 6 and 12 dB of sound attenuation.

Species	6 dB Attenuation			12 dB Attenuation		
	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)
Fin Whale*	0.11	3.24	26.07	0.00	0.36	18.08
Humpback Whale	0.04	7.18	23.09	0.00	0.93	15.77
Minke Whale	0.03	0.15	9.53	0.00	0.04	6.62
North Atlantic Right Whale*	0.02	0.76	9.21	0.01	0.06	6.25
Sei Whale*	0.00	0.09	0.78	0.00	0.01	0.55
Atlantic White-Sided Dolphin	0.14	0.00	357.71	0.00	0.00	231.09
Common Bottlenose Dolphin	0.00	0.00	66.75	0.00	0.00	43.72
Pilot Whales	0.00	0.00	0.00	0.00	0.00	0.00
Risso's Dolphin	0.00	0.00	1.22	0.00	0.00	0.84
Short-Beaked Common Dolphin	0.39	0.00	761.48	0.01	0.00	527.04
Sperm whale*	0.00	0.00	0.00	0.00	0.00	0.00
Harbor Porpoise	3.86	0.14	107.61	1.72	0.07	70.29
Gray Seal	0.19	0.19	123.97	0.00	0.18	82.23
Harbor Seal	1.01	0.68	139.82	0.17	0.34	93.67
Harp Seal	0.36	0.36	136.45	0.18	0.00	90.56

* Listed as Endangered under the ESA.

6.6.2. Aversion

Aversion is a common response of animals to sound, particularly at relatively high sound exposure levels (Ellison, Southall, Clark, & Frankel, 2012). As received sound level generally decreases with distance from a source, this aspect of natural behavior can strongly influence the estimated maximum sound levels an animal is predicted to receive and significantly affects the probability of more pronounced direct or subsequent behavioral effects. Additionally, animals are less likely to respond to sound levels distant from a source, even when those same levels elicit response at closer ranges; both proximity and received levels are important factors in aversive responses (Rebecca A. Dunlop et al., 2017). As a supplement to this modeling study for comparison purposes only, parameters determining aversion at specified sound levels were implemented for the NARW in recognition of their highly endangered status, and Harbor Porpoise, a species that has demonstrated a strong aversive response to pile driving sounds in multiple studies. Aversion was not input as a model parameter when estimating Level A or Level B takes in Table 20.

Aversion is implemented in JASMINE by defining a new behavioral state that an animat may transition in to when a received level is exceeded. There are very few data on which modeling of aversive behavior can be based. Because of the dearth of information and to be consistent within this report, aversion probability is based on the Wood et al. (2012) step function that was used to estimate potential behavioral disruption. Animats are assumed to avert by changing their headings by a fixed amount away from the source, with higher received levels associated with a greater deflection (Tables 17 and 18). Aversion thresholds for marine mammals are based on the Wood et al. (2012) step function. Animats remain in the aversive state for a specified amount of time, depending on the level of exposure that triggered aversion (Tables 17 and 18). During this time, travel parameters are recalculated periodically as with normal behaviors. At the end of the aversion interval, the animat once again applies the parameters in Tables 17 and 18 and, depending on the current level of exposure, either begins another aversion interval or transitions to a non-aversive behavior; while aversion begins immediately, transition to a regular behavior occurs at the end of the next surface interval, consistent with regular behavior transitions.

Table 17. Aversion parameters for the animal movement simulation of North Atlantic right whales based on Wood et al. (2012) behavioral response criteria.

Probability of aversion	Received sound level (SPL, dB re 1 µPa)	Change in course (°)	Duration of aversion(s)
10%	140	10	300
50%	160	20	60
90%	180	30	30

Table 18. Aversion parameters for the animal movement simulation of Harbor porpoise based on Wood et al. (2012) behavioral response criteria.

Probability of aversion	Received sound level (SPL, dB re 1 µPa)	Change in course (°)	Duration of aversion(s)
50%	120	20	60
90%	140	30	30

6.6.2.1. Effect of Aversion

The exposure estimate tables above do not account for aversion or the implementation of mitigation measures other than sound attenuation (e.g., pile driving shut-down or power down). Some marine mammals are well known for their aversive responses to anthropogenic sound (e.g., Harbor Porpoise), although it is assumed that most species will avert from noise. The Wood et al. (2012) step function includes a probability of response that is based primarily on observed aversive behavior in field studies. Additional exposure estimates that included aversion in the animal movement model, based on the Wood et al. (2012) response probabilities, were calculated for both the Harbor Porpoise and the NARW for all modeling scenarios contemplated in this study. The most conservative exposure results are associated with the unattenuated Maximum Design scenario, installing two foundations per day. For comparative purposes only, the results are shown with and without aversion (Table 19).

Table 19. Comparison of mean exposure estimates for Harbor Porpoise and NARW when aversion is included in animal movement models relative to models without aversion.

Species	No attenuation – no aversion			No attenuation – with aversion		
	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)	Level A harassment (L_{pk})	Level A harassment (L_E)	Behavior max. SPL ($L_{p,24hr}$)
Harbor Porpoise	8.24	0.33	183.1	0.12	0	10.68
North Atlantic Right Whale	0.08	6.47	20.12	0	0.40	8

6.7. Number of Takes Requested

With the inclusion of more jacket foundations, and therefore more pile driving in the WDA, exposure estimates for the Maximum Design scenario (Tables 13 and 14) are higher than the Most Likely scenario (Tables 15 and 16). In all scenarios, the maximum number of jacket foundations modeled per day was one (four jacket piles). Whether one monopile foundation is installed per day or two makes little difference with respect to projected Level A exposures (Table 13 versus Table 14, and Table 15 versus Table 16). The same total amount of pile driving is conducted during the Project’s construction, whether one monopile or two is installed per day, so the finding that potential Level A exposures are similar indicates that animals are primarily exposed to sound by just one piling event per day, even when two occur. For behavioral (Level B) disruptions, exposure estimates for one monopile foundation per day are somewhat higher than for two monopiles foundations per day (Table 13 versus Table 14, and Table 15 versus Table 16). With two monopile foundations per day, there are half as many days of pile driving so there is likewise a reduced number of overall predicted behavioral response exposures for the Project. To allow some flexibility in the final design and during installation operations, exposure estimates from the scenario resulting in the largest number of potential exposures, the Maximum Design scenario with one pile driven per day and 12 dB of sound attenuation, were selected as the basis for requesting Level A and Level B takes (Table 20).

In all cases, the modeled Level A takes were extremely low, zero to less than one animal. Although the exposure modeling suggests that the likelihood of Level A takes for all species is very small, we are requesting Level A takes for most species as a precautionary measure, using a conservative approach based on the mean group size as described in Section 6.5.2. Although Level A takes are theoretically possible based on the exposure modeling performed, the modeling methods did not account for likely aversive responses or the implementation of mitigation measures. Based on the example modeling that did account for aversion (Table 19), the probability of Level A takes even without any sound attenuation is very low. It is also unlikely that a large cetacean would remain undetected by PSOs within the zone where Level A acoustic exposure could occur for long enough to accumulate the required sound energy.

Thus, although a request for Level A takes is included here, it is very unlikely that such takes would actually occur.

Table 20. Number of Level A and Level B takes requested. For species included in the exposure modeling the values are based on the scenario with the highest estimated mean exposures - Maximum Design scenario with one pile installed per day, 12 dB sound attenuation, and without aversion (Table 13). The modeling results are shown for reference.

Species	**Modeled Exposures (with 12 dB attenuation)**		**Requested Takes**			
	Level A Harassment (*L*E)	Level B Max. SPL (L_p,24hr)	Level A Harassment	Level B Harassment	Stock Abundance	Level B Request as Percentage of Stock
Fin Whale*	0.29	21.78	2	9	4,859	0.2
Humpback Whale	1.00	19.66	2	56	1,773†	3.2
Minke Whale	0.07	7.90	2	98	3,014†	3.2
North Atlantic Right Whale*	0.09	8.74	0	20	394†	5.0
Sei Whale*	0.01	0.74	2	4	453†	0.9
Atlantic White-Sided Dolphin	0.00	277.82	28	1,107	54,800	3.0
Common Bottlenose Dolphin	0.00	62.21	8	68	75,664	0.1
Pilot Whales	0.00	0.00	9	91	27,597	0.3
Risso's Dolphin	0.00	1.04	6	12	11,483	0.2
Short-Beaked Common Dolphin	0.00	703.81	35	4,646	108,376	5.4
Sperm Whale*	0.00	0.00	2	5	4,199	0.1
Harbor Porpoise	0.00	91.96	3	5	60,281†	0.0
Gray Seal	0.07	118.06	2	414	27,131‡	1.5
Harbor Seal	0.07	136.33	2	64	75,834‡	0.1
Harp Seal	0.04	132.91	2	4	7,400,000‡	0.0

Take estimates are based on the scenario resulting in the largest Level B takes, i.e., the Maximum Design scenario and 12 dB of sound attenuation.
Abundance numbers are from Roberts et al. (2016); Roberts et al. (2017); Roberts et al. (2018) except for pinnipeds.
*Listed as endangered under the ESA.
†Maximum seasonal abundance
‡ Seal abundance estimates are from S.A. Hayes et al. (2018). Harp Seal estimate is for western North Atlantic Harp Seals in Canadian waters
$ Roberts et al. (2017) combine Long-Finned and Short-Finned Pilot Whales. It is likely that most of the animals affected by the Project in this genus will be Long-Finned Pilot Whales.

Low-frequency cetaceans are more likely to exceed the SEL exposure threshold. This occurs because the hearing frequency of this group overlaps with the highest energy frequency bands produced during pile driving. However, the numbers of potential exposures are still quite small. For all baleen whales, less than one individual is predicted to receive Level A harassment sound exposure for the Maximum Design scenario with 12 dB of noise attenuation and no other mitigation measures. As a precautionary measure, however, we are requesting two Level A takes each for the Fin Whale, Humpback Whale, Minke Whale, and Sei Whale based on mean group size. Because of NARW-specific mitigation and monitoring, there are no Level A takes requested for this species. These enhanced mitigation measures, focused on NARW, include a voluntary restriction on pile driving from January 1 to April 30, and a requirement that PSOs monitor the RWSAS regularly during the project to be informed of the location of any NARW sighting in the vicinity of planned pile driving activities. The 2011-2015 NLPSC aerial surveys of the RI/MA & MA WEAs logged no sightings of NARW during May through November (S. D. Kraus et al., 2016), so the piling restriction alone is likely to all but eliminate any NARW takes. NARWs were sighted during December in the NLPSC surveys, however, the sighting rate for that month was more than two and a half times lower than the January sighting rate and more than five times lower than the highest monthly sighting rate, which occurred during March. Additionally, historical weather data suggest there will be fewer good weather days this time of the year.

Fewer than one individual from each odontocete and pinniped species is predicted to receive Level A harassment sound exposure, assuming 12 dB of noise attenuation and no aversive behavior. When aversion was included in the Harbor Porpoise modeling, zero animals were predicted to received sound above Level A harassment thresholds. As a precautionary approach, we are requesting Level A takes equal to one average group size for all odontocete and pinniped species.

In requesting Level B takes, we examined PSO data from the 2016–2018 site characterization surveys for the Project and calculated a daily sighting rate (individuals per day) for each species in each year. To estimate a conservative number of potential Level B exposures, we multiplied the maximum sighting rate from the three years by the number of pile driving days under the Maximum Design scenario (i.e., 102 days). This calculation assumes that the largest average group size from the three years for each species may be present during piling on each day. We used this conservative estimate for all species that were recorded by PSOs during the 2016–2018 surveys. For Sei whales, this approach resulted in the same number of estimated Level B takes as Level A takes (two), so the Level A value was doubled to arrive at the requested Level B takes. Risso's Dolphins and Harp Seals were not sighted by PSOs during those surveys, so this request includes Level B takes equal to two average group sizes for those species.

7. Anticipated Impact of the Activity

7.1. Characteristics of Pile Driving Sounds

Impact pile driving produces impulsive sounds with peak levels typically above L_{pk} 200 dB re 1 µPa near the source (Tougaard, Madsen, & Wahlberg, 2008). Pile driving generates sounds that are relatively broadband (Peter T. Madsen, Wahlberg, Tougaard, Lucke, & Tyack, 2006). Measurements have shown that most energy occurs from 10–2,000 Hz, with some energy up to 10 kHz near the source (Bailey et al., 2010; S.B. Blackwell, 2005). The dominant frequency range of pile driving is most likely related to differences in the size, shape, and thickness of the piles. These pulsed sounds are typically high energy with fast rise times and sharp peaks, which can result in both Level B and Level A sound exposures, depending on proximity to the sound source and a variety of environmental and biological conditions (Dahl et al., 2015; J. R Nedwell et al., 2007). Appendix A provides a detailed description of the pile driving sounds expected to be produced during the Project and used as a basis for modeling potential impacts.

7.2. Potential Effects of Pile Driving on Marine Mammals

All marine mammals use sound as a critical way to carry out life-sustaining functions, such as foraging, navigating, communicating, and avoiding predators. Marine mammals also use sound to learn about their surrounding environment by gathering information from other marine mammals, prey species, phenomena such as wind, waves, and rain, or from seismic activity (W. J. Richardson et al., 1995). The effects of sounds from pile driving could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, temporary or permanent hearing impairment (TTS or PTS), or non-auditory physical or physiological effects (Nowacek, Thorne, Johnston, & Tyack, 2007; W. J. Richardson et al., 1995; Southall et al., 2007).

7.2.1. Masking

Masking is the obscuring of sounds of interest by interfering sounds, generally at similar frequencies. Introduced underwater sound will, through masking, reduce the effective listening area and/or communication distance of a marine mammal species if the frequency of the source is close to that used as a signal by the marine mammal, and if the anthropogenic sound is present for a significant fraction of the time (Clark et al., 2009; Erbe, Reichmuth, Cunningham, Lucke, & Dooling, 2016; Gervaise, Simard, Roy, Kinda, & Menard, 2012; Hatch, Clark, Van Parijs, Frankel, & Ponirakis, 2012; Jensen et al., 2009; Rice et al., 2014; W. J. Richardson et al., 1995; Tennessen & Parks, 2016). Conversely, if little or no overlap occurs between the introduced sound and the frequencies used by the species, communication is not expected to be disrupted. Also, if the introduced sound is present only infrequently, communication is not expected to be disrupted much, if at all. In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter, Bakhtiari, Trickey, & Finneran, 2016; Branstetter, Trickey, Aihara, Finneran, & Liberman, 2013; Finneran & Branstetter, 2013; Sills, Southall, & Reichmuth, 2017). The biological repercussions of a loss of listening area or communication space, to the extent that this occurs, are unknown.

Although masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, there are few specific studies on this related to impact pile driving. Low-frequency cetaceans such as baleen whales are likely to be more susceptible to masking by the low-frequency noise produced by pile driving (W. J. Richardson et al., 1995); however, to date, most studies have considered impacts from a different impulsive source, seismic airguns. Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between the seismic pulses (e.g., Bröker, Durinck, Vanman, & Martin, 2013; Cerchio, Strindberg, Collins, Bennett, & Rosenbaum, 2014;

Dunn & Hernandez, 2009; C. R. Greene, Jr., Altman, & Richardson, 1999; Greene Jr, Altman, & Richardson, 1999; Holst et al., 2011; Holst et al., 2006; Meike Holst, Mari A. Smultea, W. R. Koski, & B. Haley, 2005; M. Holst, M.A. Smultea, W.R. Koski, & B. Haley, 2005; McDonald, Hildebrand, & Webb, 1995; Sharon L. Nieukirk et al., 2012; W. John Richardson, Würsig, & Greene, 1986; Sciacca et al., 2016; Smultea, Holst, Koski, & Stoltz, 2004; Thode et al., 2012). However, some of these studies found evidence of reduced calling (or at least reduced call detection rates) in the presence of seismic pulses. One report indicates that calling Fin Whales distributed in a part of the North Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark & Gagnon, 2006). It is not clear from that paper whether the whales ceased calling because of masking, or whether this was a behavioral response not directly involving masking. Also, Bowhead Whales (*Balaena mysticetus*) in the Beaufort Sea apparently decrease their calling rates in response to seismic operations, although movement out of the area also contributes to the lower call detection rate (Susanna B. Blackwell et al., 2013; Susanna B. Blackwell et al., 2015). In contrast, Di Iorio and Clark (2009) found that Blue Whales in the St. Lawrence Estuary increased their call rates during operations by a lower-energy seismic source. The sparker used during the study emitted frequencies of 30–450 Hz with a relatively low source level of 193 dB re 1 $\mu Pa_{pk\text{-}pk}$. There is some evidence that Fin Whale song notes recorded in the Mediterranean had lower bandwidths during periods with, versus without, airgun sounds (Castellote, Clark, & Lammers, 2012).

Among the odontocetes, there has been one report that Sperm Whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles, Smultea, Würsig, DeMaster, & Palka, 1994). However, more recent studies of Sperm Whales found that they continued calling in the presence of seismic pulses (Holst et al., 2011; Holst et al., 2006; Jochens et al., 2008; P.T. Madsen, Møhl, Nielsen, & Wahlberg, 2002; Sharon L. Nieukirk et al., 2012; Smultea et al., 2004; P. Tyack, Johnson, & Miller, 2003). P. T. Madsen et al. (2006) noted that airgun sounds would not be expected to cause significant masking of Sperm Whale calls given the intermittent nature of airgun pulses. Dolphins and porpoises are also commonly heard calling while airguns are operating (Gordon et al., 2003; Holst et al., 2011; Meike Holst et al., 2005; M. Holst et al., 2005; Potter et al., 2007; Smultea et al., 2004). Masking effects of impact pile driving are expected to be negligible in the case of the smaller odontocetes, given the intermittent nature of the pulses plus the fact that sounds important to them occur predominantly at much higher frequencies than the dominant components of airgun and pile driving sounds. For example, the Harbor Porpoise produces echolocation clicks of 110–150 kHz (Møhl & Andersen, 1973; Teilmann et al., 2002) with source levels of 135–177 dB re 1 μPa at 1 m and the Common Bottlenose Dolphin produces echolocation clicks of 110–130 kHz with source levels of 218–228 dB re 1 μPa (reviewed by W. J. Richardson et al., 1995).

Some cetaceans are known to increase the source levels of their calls, shift their peak frequencies, or otherwise modify their vocal behavior in response to increased noise (Whitlow W.L. Au, 1993; also Bittencourt et al., 2017; Castellote et al., 2012; M. Dahlheim & Castellote, 2016; Marilyn Elayne Dahlheim, 1987; Di Iorio & Clark, 2009; Hanser, Doyle, Szabo, Sharpe, & McCowan, 2009; Heiler, Elwen, Kriesell, & Gridley, 2016; Holt, Noren, Veirs, Emmons, & Veirs, 2009; Véronique Lesage, Barrette, Kingsley, & Sjare, 1999; Luís, Couchinho, & dos Santos, 2014; Martins, Rossi-Santos, & Silva, 2016; McKenna, 2011; Melcon et al., 2012; S. L. Nieukirk, Mellinger, Hildebrand, McDonald, & Dziak, 2005; O'Brien et al., 2016; Papale, Gamba, Perez-Gil, Martin, & Giacoma, 2015; Susan E. Parks et al., 2007; Susan E. Parks, Cusano, Bocconcelli, Friedlaender, & Wiley, 2016; Susan E. Parks, Groch, Flores, Sousa-Lima, & Urazghildiiev, 2016; S. E. Parks, Johnson, Nowacek, & Tyack, 2010; Susan E. Parks, Johnson, Nowacek, & Tyack, 2012; Susan E Parks, Urazghildiiev, & Clark, 2009; Rako Gospić & Picciulin, 2016; reviewed by W. J. Richardson et al., 1995; Risch, Corkeron, Ellison, & Van Parijs, 2012; Sairanen, 2014; Scheifele et al., 2005; Terhune, 1999; P. L. Tyack & Janik, 2013). Holt, Noren, Dunkin, and Williams (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. It is not known how often these types of vocal responses occur upon exposure to airgun sounds. If cetaceans exposed to airgun sounds sometimes respond by changing their vocal behavior, this adaptation, along with directional hearing and preadaptation to tolerate some masking by natural sounds (W. J. Richardson et al., 1995), would all reduce the importance of masking by seismic pulses.

Given the higher duty cycle of impact pile driving (one strike every ~two seconds) compared to most airgun surveys (one pulse every ~10 seconds), there may be a somewhat greater potential for masking to occur during pile driving. However, in this project, pile driving is not expected to occur for more than approximately three hours at one time. Compared to the 24 hour per day operation of airguns during most seismic surveys, the total time during which masking might occur would be much reduced. Peter T. Madsen et al. (2006) argued that significant masking effects would be unlikely during impact pile driving given the intermittent nature of these sounds and short signal duration.

7.2.2. Behavioral Disturbance

Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. In some cases, behavioral responses to sound may in turn reduce the overall exposure to that sound (e.g., Finneran et al., 2015; Wensveen et al., 2015).

Detailed data on reactions of marine mammals to anthropogenic sounds are limited to relatively few species and situations (see reviews in Gordon et al., 2003; Nowacek et al., 2007; W. J. Richardson et al., 1995; Southall et al., 2007). Marine mammals' behavioral responses to noise range from no response, to mild aversion, to panic and flight (Southall et al., 2007). Behavioral reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Ellison et al., 2012; W. J. Richardson et al., 1995; Southall et al., 2007; Douglas Wartzok, Popper, Gordon, & Merrill, 2003). If a marine mammal reacts to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al., 2013).

Given the many uncertainties in predicting the quantity and types of impacts of sound on marine mammals, it is common practice to estimate how many mammals would be present within a particular distance of human activities and/or exposed to a particular level of anthropogenic sound (see Section 6). In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner. One of the reasons for this is that the selected distances/isopleths are based on limited studies indicating that some animals exhibited short-term reactions at this distance or sound level, whereas the calculation assumes that all animals exposed to this level would react in a biologically significant manner. Additionally, the calculations and modeling assume numerous conservative inputs.

Similar to masking studies, there is little information available on behavioral responses of baleen whales to impact pile driving sounds, but a number of studies have considered impacts from seismic airguns. Baleen whales generally tend to avoid impulsive sounds from operating airguns, but avoidance radii vary greatly among species, locations, whale activities, oceanographic conditions affecting sound propagation, etc. (see reviews in Gordon et al., 2003; W. J. Richardson et al., 1995). Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong sound pulses from airguns often react by moving away from and/or around the sound source. Some of the major studies and reviews on this topic are Gordon et al. (2003); Johnson et al. (2007); Ljungblad, Wursig, Swartz, and Keene (1988); Malme et al. (1984); Malme, Miles, Tyack, Clark, and Bird (1985); Malme, Würsig, Bird, and Tyack (1988); McCauley, Jenner, Jenner, McCabe, and Murdoch (1998); Robert D McCauley et al. (2000); R.D. McCauley et al. (2000); G. W. Miller, Elliott, Koski, Moulton, and Richardson (1999); G. W. Miller et al. (2005); Moulton and Holst (2010); Nowacek et al. (2007); W. John Richardson et al. (1986); W. J. Richardson et al. (1995); W. John Richardson, Miller, and Greene (1999); W. J. Richardson and Malme (1993); C. J. Stone (2015); Carolyn J. Stone and Tasker (2006); and Weir (2008). Although baleen whales often show only slight overt responses to operating airgun arrays (C. J. Stone, 2015; Carolyn J. Stone & Tasker, 2006; Weir, 2008), strong avoidance reactions by several species of mysticetes have been observed. Experiments with a single airgun (327.7–1,638 cubic centimeters [20–100 cubic inches] in size) showed that Bowhead, Humpback, and Gray Whales (*Eschrichtius robustus*) all showed localized avoidance (Malme et al., 1984; Malme et al., 1985; Malme, Würsig, Bird, & Tyack, 1986; Malme et al., 1988; Robert D McCauley et al., 2000; R.D. McCauley et al., 2000; McCauley, Jenner, Jenner, McCabe, et al., 1998; W. John Richardson et al., 1986).

Studies of Bowhead, Humpback, and Gray Whales have shown that seismic pulses with received levels of 160–170 dB re 1 µPa SPL seem to cause obvious avoidance behavior in a substantial portion of the animals exposed (W. J. Richardson et al., 1995). More recent studies have shown that some species of baleen whale (Bowhead and Humpback Whales in particular) at times show strong avoidance at received levels lower than 160–170 dB re 1 µPa SPL. The largest avoidance radii involved migrating Bowhead Whales, which avoided an operating seismic vessel by 20–30 km (65.6–98.4 mi) (G. W. Miller et al., 1999; W. John Richardson et al., 1999). In the cases of migrating Bowhead (and Gray) Whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme & Miles, 1985; Malme et al., 1984; W. J. Richardson et al., 1995). Feeding Bowhead Whales, in contrast to migrating whales, show much smaller avoidance distances (R. E. Harris, Elliott, & Davis, 2007; G. W. Miller et al., 2005), presumably because moving away from a food concentration has greater cost to the whales than does a course deviation during migration. Since the Offshore Project Area is not located in an important feeding area, such as the Gulf of Maine for NARW, most responses to the planned impact pile driving are expected to be more similar those observed for migrating animals, where they simply avoided the area around the activity and continued on their migratory path, and result in little overall impact to individual animals. As with masking, because the relative time of pile driving is short, the temporal exposure when animals may interact with the acoustics from piling is also very short, therefore further limiting the overall impact.

Most studies of behavioral responses of marine mammals to noise from offshore wind developments have been conducted on Harbor Porpoise (e.g., Bailey et al., 2010; Brandt et al., 2011; Michael Dähne et al., 2013; M. Dähne et al., 2017) and Harbor and Gray Seals (Edrén et al., 2010). These studies showed some avoidance during periods of construction activity, but then continued use of the area after construction activities were completed. Similarly, studies near the United Kingdom, Newfoundland and Angola, in the Gulf of Mexico, off Central America, and Alaska have shown localized avoidance of seismic surveys by these species, although, dolphins, porpoises and seals are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). Overall, odontocete and pinniped reactions to impulsive sounds from large arrays of airguns are variable and, at least for delphinids and some porpoises, seem to be confined to a smaller radius than has been observed for some mysticetes. Thus, avoidance responses by these species are expected to be relatively minor and temporary, resulting in minimal overall impacts.

7.2.3. Hearing Impairment

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Finneran, 2015; Southall et al., 2007). However, there has been no specific documentation of TTS, nor permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to anthropogenic sounds during realistic field conditions.

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter, 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. It is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or “injury” (Le Prell, Henderson, Fay, & Popper, 2012; Southall et al., 2007). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. However, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa & Liberman, 2009; Liberman, 2014). These findings have raised some questions as to whether TTS should continue to be considered a non-injurious effect (Tougaard, Wright, & Madsen, 2015; Tougaard, Wright, & Madsen, 2016; Weilgart, 2014).

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter, 1985). Physical damage to a mammal’s hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times. Rise time is the time interval required for sound pressure to increase from the baseline pressure to peak pressure. Permanent damage can also occur from the accumulation of sound energy over time.

The criteria used in the exposure modeling (Section 6.3) (NMFS, 2018a) reflect the most recent scientific review and conclusions of NOAA Fisheries regarding sound levels that could cause PTS. Based on the exposure modeling results (Tables 13 and 16), the number of marine mammals that may experience hearing impairment is quite small, even when planned mitigation measures are not considered. Taking those criteria into account, the likelihood of the Project causing PTS in a marine mammal is negligible.

7.3. Population Level Effects

NOAA Fisheries provides best available estimates of abundance (N_{best}) for all marine mammal stocks under their jurisdiction in their annual Stock Assessment Reports (SARs; S.A. Hayes et al., 2018). In some cases, NOAA Fisheries considers these to be underestimates because the full known range of the stock was not surveyed, the estimate did not include availability-bias correction for submerged animals, or there may be uncertainty regarding population structure (Sean A. Hayes et al., 2017). Marine mammal abundance estimates are also available from Duke University Marine Geospatial Ecological Laboratory habitat-based models Roberts et al. (2016); Roberts et al. (2017). These models provide estimates of abundance for the entire US EEZ and hence are often larger than the SAR abundance estimates. The densities used in the acoustic modeling study to estimate potential exposures were derived from Roberts et al. (2016); Roberts et al. (2015); Roberts et al. (2017) data, and therefore it is most appropriate to use the abundance estimates from that same source when calculating the percent of population or stock potentially exposed (Table 20). Thus, the Roberts et al. (2016), Roberts et al. (2017) abundance estimates were used to calculate the percentage of each population or stock that could potentially receive Level A or Level B sound exposures for the two scenarios (Maximum Design envelope and Most Likely) and one or two foundations per day (Tables 21–24). Roberts et al. (2018) do not provide abundance estimates for individual seal species, so the N_{best} for pinnipeds used in take estimation are from NOAA Fisheries most recent SAR (S.A. Hayes et al., 2018).

Table 21. Estimated Level A and Level B harassment acoustic exposures as a percentage of species' abundance for the Maximum Design scenario and one foundation per day with 6 and 12 dB of sound attenuation.

Species	Number of Exposures as a Percentage of Abundance					
	6 dB Attenuation			12 dB Attenuation		
	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)
Fin Whale*	0.00	0.09	0.68	0	0.01	0.45
Humpback Whale	0.00	0.51	1.70	0	0.06	1.11
Minke Whale	0.00	0.01	0.40	0	0	0.26
North Atlantic Right Whale*	0.01	0.34	3.36	0	0.02	2.22
Sei Whale*	0.00	0.03	0.24	0	0	0.16
Atlantic White-Sided Dolphin	0.00	0.00	0.84	0	0	0.51
Common Bottlenose Dolphin	0.00	0.00	0.13	0	0	0.08
Pilot Whales	0.00	0.00	0.00	0	0	0.00
Risso's Dolphin	0.00	0.00	0.01	0	0	0.01
Short-Beaked Common Dolphin	0.00	0.00	0.97	0	0	0.65
Sperm Whale*	0.00	0.00	0.00	0	0	0.00
Harbor Porpoise	0.01	0.00	0.25	0	0	0.15
Gray Seal	0.00	0.00	0.72	0	0	0.44
Harbor Seal	0.00	0.00	0.28	0	0	0.18
Harp Seal	0.00	0.00	0.00	0	0	0.00

* Listed as endangered under the ESA

Table 22. Estimated Level A and Level B harassment acoustic exposures as a percentage of species' abundance for the Maximum Design scenario and two foundations per day with 6 and 12 dB of sound attenuation.

Species	Number of Exposures as a Percentage of Abundance					
	6 dB Attenuation			12 dB Attenuation		
	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)
Fin Whale*	0.00	0.09	0.61	0	0.01	0.42
Humpback Whale	0.00	0.54	1.54	0	0.06	1.04
Minke Whale	0.00	0.01	0.38	0	0	0.26
North Atlantic Right Whale*	0.00	0.35	2.98	0	0.03	2.02
Sei Whale*	0.00	0.03	0.21	0	0	0.14
Atlantic White-Sided Dolphin	0.00	0.00	0.78	0	0	0.50
Common Bottlenose Dolphin	0.00	0.00	0.09	0	0	0.06
Pilot Whales	0.00	0.00	0.00	0	0	0.00
Risso's Dolphin	0.00	0.00	0.01	0	0	0.01
Short-Beaked Common Dolphin	0.00	0.00	0.82	0	0	0.57
Sperm Whale*	0.00	0.00	0.00	0	0	0.00
Harbor Porpoise	0.01	0.00	0.21	0	0	0.14
Gray Seal	0.00	0.00	0.54	0	0	0.36
Harbor Seal	0.00	0.00	0.22	0	0	0.15
Harp Seal	0.00	0.00	0.00	0	0	0.00

* Listed as endangered under the ESA

Table 23. Estimated Level A and Level B harassment acoustic exposures as a percentage of species' abundance for the Most Likely scenario and one foundation per day with 6 and 12 dB of sound attenuation.

Species	Number of Exposures as a Percentage of Abundance					
	6 dB Attenuation			12 dB Attenuation		
	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)
Fin Whale*	0	0.06	0.61	0	0	0.40
Humpback Whale	0	0.37	1.48	0	0.05	0.96
Minke Whale	0	0	0.34	0	0	0.22
North Atlantic Right Whale*	0.01	0.18	2.75	0	0.01	1.80
Sei Whale*	0	0.02	0.21	0	0	0.14
Atlantic White-Sided Dolphin	0	0	0.69	0	0	0.44
Common Bottlenose Dolphin	0	0	0.13	0	0	0.09
Pilot Whales	0	0	0.00	0	0	0.00
Risso's Dolphin	0	0	0.01	0	0	0.01
Short-Beaked Common Dolphin	0	0	0.86	0	0	0.57
Sperm Whale*	0	0	0.00	0	0	0.00
Harbor Porpoise	0.01	0	0.22	0	0	0.13
Gray Seal	0	0	0.65	0	0	0.39
Harbor Seal	0	0	0.25	0	0	0.16
Harp Seal	0	0	0.00	0	0	0.00

* Listed as endangered under the ESA

Table 24. Estimated Level A and Level B harassment acoustic exposures as a percentage of species' abundance for the Most Likely scenario and two foundations per day with 6 and 12 dB of sound attenuation.

Species	Number of Exposures as a Percentage of Abundance					
	6 dB Attenuation			12 dB Attenuation		
	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)
Fin Whale*	0.00	0.07	0.54	0	0.01	0.37
Humpback Whale	0.00	0.40	1.30	0	0.05	0.89
Minke Whale	0.00	0	0.32	0	0.00	0.22
North Atlantic Right Whale*	0.00	0.19	2.34	0	0.01	1.59
Sei Whale*	0.00	0.02	0.17	0	0.00	0.12
Atlantic White-Sided Dolphin	0.00	0	0.65	0	0.00	0.42
Common Bottlenose Dolphin	0.00	0	0.09	0	0.00	0.05
Pilot Whales	0.00	0	0.00	0	0.00	0.00
Risso's Dolphin	0.00	0	0.01	0	0.00	0.01
Short-Beaked Common Dolphin	0.00	0	0.70	0	0.00	0.48
Sperm Whale*	0.00	0	0.00	0	0.00	0.00
Harbor Porpoise	0.01	0	0.18	0	0.00	0.12
Gray Seal	0.00	0	0.46	0	0.00	0.30
Harbor Seal	0.00	0	0.18	0	0.00	0.12
Harp Seal	0.00	0	0.00	0	0.00	0.00

* Listed as endangered under the ESA

Overall, the estimated exposures expressed as percentages of species populations indicate very low potential for impacts — regardless of the scenario, number of piles driven per day, and for both Level A and Level B harassment (Tables 21–24). In the Maximum Design scenario with one foundation installed per day and 6 dB of attenuation, the predicted percentage of species abundance is very low—0.41% for Minke Whale, 0.68% for Fin Whale, 0.24% for Sei Whale, and 1.7% for Humpback Whale. Population percentages for other species are all equally small. These numbers are reduced even further with 12 dB sound attenuation, so that percentage of species abundance is zero, or negligible, for all species.

Low-frequency cetaceans are more likely to exceed the SEL exposure threshold. This occurs because the hearing frequency of this group overlaps with the highest energy frequency bands produced during pile driving. However, the percentages of these species' populations that could potentially receive Level A harassment sound exposures are all less than 1%, assuming 6 dB of sound attenuation. For mid- and high frequency cetaceans, as well as pinnipeds, the percentages of populations are also less than 1% or zero. Based on this approach to assessing potential exposures in the context of marine mammal population or stock sizes, impacts to the species present in the region are expected to be negligible.

8. Anticipated Impacts on Subsistence Uses

NOAA Office of Protected Resources defines "subsistence" as the use of marine mammals taken by Alaskan Natives for food, clothing, shelter, heating, transportation, and other uses necessary to maintain the life of the taker or those who depend upon the taker to provide them with such subsistence. There are no traditional subsistence hunting areas in the Vineyard Wind WDA. As such, there are no relevant subsistence uses of marine mammals implicated by this action.

9. Anticipated Impacts on Habitat

Vineyard Wind has thoroughly analyzed impacts to habitat from the Project in its site characterization and impact assessment. These are summarized in Volume III of the COP. Under the Maximum Design scenario of 90 monopiles and 12 jacket foundations, the total footprint of the Project is only 0.03 km^2 (7.75 acres) of the 675 km^2 (166,886 acre) Lease Area. The WTGs and ESPs will add structure to the water column with spacing of 1.4–1.9 km (0.76–1.0 nm).

10. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals

10.1. Short-Term Habitat Alterations

In order to assess the impacts of cable-laying activities, a set of computer simulation models was used. Details of these models are provided in Appendix II-A of the COP, Volume III. The model results indicate that most of the suspended sediment mass would settle out quickly and would not be transported for significant distances by the currents. Thus, potential impacts from suspended sediments resulting from cable laying are not expected to result in takes of marine mammals.

The altered soundscape resulting from pile driving is likely to have the greatest impact on the marine mammal community. Modeling of pile driving installation activities indicates that there is potential for both marine mammals and the fish and invertebrates that they prey upon to experience sound exposure at levels that may cause behavioral response, including aversion and avoidance. Expected habitat displacement or avoidance of construction activities during WTG and ESP installation is based on modeled sound levels and studies of other wind energy projects. This model prediction is consistent with research data that indicate significant avoidance behavior and displacement during pile driving (Bailey, Brookes, & Thompson, 2014; Bergström et al., 2014; Brandt et al., 2011; Brasseur et al., 2010; Carstensen, Henriksen, & Teilmann, 2006; Michael Dähne et al., 2013; W. J. Richardson et al., 1995; Tougaard, Carstensen, Teilmann, Skov, & Rasmussen, 2009).

Research suggests that this displacement is temporally limited to the construction phase (Bergström et al., 2014). The proposed Project configuration of WTGs and ESPs includes a minimum 1.4 km (0.76 nm) spacing between structures, allowing access and transit through the WDA during construction. Based on the results of other wind energy project monitoring studies, re-occupation of habitat in the Project area is expected to occur at levels equivalent to or higher than the region around the Project post-construction and during operation.

10.2. Longer-Term Habitat Alterations

Longer-term habitat alterations resulting from the Project include the creation of hard substrate around WTG and ESP installations, loss of habitat from the footprint of the installations and the introduction of structures into the water column. These are intended to remain in place throughout the life of the Project. As discussed in Section 9, the overall footprint of the Project is very small relative to the Lease area. Further, there is abundant similar habitat in adjacent areas that is available to marine mammals and their prey.

There are few studies that have measured the responses of marine mammals to habitat modification resulting from offshore wind farm construction and operation, and none have yet assessed longer term impacts at the population level (Bailey et al., 2014). Researchers have concluded, from the limited studies that do exist, that the most significant negative impacts of offshore wind farm construction are likely to occur as a result of avoidance of construction noise or structures rather than direct mortality (Bailey et al., 2014).

Creation of hard bottom and introduction of structures into the water column may benefit marine mammals by increasing prey availability. Offshore wind energy projects may benefit fish by acting as artificial reefs, increasing fish aggregation and productivity and improving prey species abundance and diversity during long-term operation (Bailey et al., 2014; Inger et al., 2009; Lindeboom et al., 2011; Petersen & Malm, 2006; Scheidat et al., 2011; Wilhelmsson, Malm, & Öhman, 2006). This artificial reef phenomenon is fairly well document around oil and gas platforms off California and in the Gulf of Mexico, which are considered to have rich fish assemblages (e.g., Ajemian, Wetz, Shipley-Lozano, Shively, &

Stunz, 2015; Claisse et al., 2014; Love, Nishimoto, Clark, & Bull, 2015). Fujii (2015, 2016) observed that feeding habits of major fish species were closely associated with an offshore oil platform in the North Sea.

Increased prey is not limited to fish aggregation and production. Offshore platforms may generate sufficient illumination to affect the local distribution of phototaxic prey invertebrates including zooplankton (Keenan, Benfield, & Blackburn, 2007; McConnell, Routledge, & Connors, 2010). Bergström et al. (2014) summarized probable impacts of wind energy project construction and operation on marine mammals, fish, and benthos, and concluded that there is a moderate level of certainty of significant positive habitat gain for fish arising from wind energy project habitat modification. Other studies suggest that there are little to no differences in species' presence inside and outside wind farms post-construction and during operation (Tougaard & Henrikson, 2009).

There are data to suggest that marine mammals could be attracted to the Project infrastructure. Russell et al. (2014) conducted a tagging study of Harbor and Grey Seals living near two active wind energy project areas on the British and Dutch coasts of the North Sea. The tag data strongly suggested that the associated wind energy structures were used for foraging, and the directed movements showed that animals could effectively navigate to and between structures (Russell et al., 2014). Studies of Harbor Porpoise activity within operational wind farms showed that relatively more porpoises were found in the wind farm area compared to reference sites, with statistically positive linkage to the wind energy project (Todd, Lepper, & Todd, 2007). Where certain vessels and/or vessel-based activities are excluded from portions of the area for periods of time, the Project may provide shelter for marine mammals (e.g., Scheidat et al., 2011).

A negative effect of habitat gain may emerge if the infrastructure functions as introduction habitat for invasive species (Bulleri & Airoldi, 2005; Page, Dugan, Culver, & Hoesterey, 2006). The opportunistic use of artificial substrata (oil and gas platforms) by non-indigenous coral species in the Gulf of Mexico is well documented, with growing concern related to a spread of these species to the Atlantic as marine infrastructure increases (Sammarco, Porter, & Cairns, 2010). Over the lifetime of the Project's operation, more structurally complex habitats that might develop in artificial infrastructure are likely to have greater species diversity and abundance.

11. Mitigation Measures

Mitigation measures implemented during Project construction can decrease the potential impacts to marine mammals by reducing the zone of potential exposure and therefore the likelihood of Level B and Level A sound exposures. Vineyard Wind will comply with all applicable monitoring and mitigation regulations and any permit conditions placed on the Project by regulatory agencies. In addition to regulatory compliance, Vineyard Wind is applying various enhanced mitigation measures to the Project to reduce the potential for negative impacts to marine mammals during construction. The selection of appropriate mitigation techniques will consider safety, practical application, and effectiveness for the Project. Table 25 details the suite of planned monitoring activities and mitigation measures. Additional details are provided in Appendix C, Vineyard Wind Draft Monitoring Framework. While protection of marine mammals is a top priority, environmental and human health and safety is the very highest priority in working in the offshore environment; therefore, exceptions to mitigation may be made under certain circumstances.

Clearance zones in Table 25 are based on modeled distances to the NMFS Level A harassment thresholds (both PK and SEL). Visual observation capability, practical and safe offshore implementation, and practicability of the mitigation measures in concert are also considered. The proposed distances are shorter than the SEL Level A harassment radii shown in Table 8 because, in order for a marine mammal to experience Level A exposure at those distances, the animal would need to remain within the indicated distance for the entire duration of pile driving within a 24 hour period. Large mysticete whales generally avoid areas of strong anthropogenic sounds (Rebecca A. Dunlop et al., 2017; Gordon et al., 2003; Nowacek et al., 2007; W. J. Richardson et al., 1995; Southall et al., 2007; Southall, Nowaceck, Miller, & Tyack, 2016), so it is very unlikely that individual whales would remain within the 1.6 km distance for that long. Also, the natural movement patterns of most marine mammals mean the clearance zones assume longer than expected exposure durations for the SELcum criteria.

As described in Section 6.4.1 above, noise attenuation systems, such as bubble curtains, are sometimes used to decrease the sound levels in the water near a source. Bubbles create a local impedance change that acts as a barrier to sound transmission. The size of the bubbles determines their effective frequency band, with larger bubbles needed for lower frequencies. There are a variety of bubble curtain systems, confined or unconfined bubbles, and some with encapsulated bubbles or panels. Encapsulated bubble systems, e.g., Hydro Sound Dampers (HSDs), are effective within their targeted frequency ranges, e.g., 100–800 Hz, and when used in conjunction with a bubble curtain appear to create the greatest attenuation, up to 30 dB (Elmer & Savery, 2014). The exact noise attenuation system to be used for mitigation is yet to be determined. However, a suitable system that achieves the target sound reduction of up to approximately 12 dB will be selected and will be used at all times when pile driving is underway. Vineyard Wind will deploy the selected noise attenuation system whenever pile driving is underway and have a second back-up system on hand to be implemented pending results of the sound field verification.

Several mitigation measures are in place to minimize the potential for vessel strikes using guidelines described in the NOAA Fisheries (NOAA Fisheries, 2018m) and NMFS Northeast Regional whale watching guidelines (NOAA, 2012). These mitigation measures, supplemented with additional mitigation measures specific to NARW, are show in Table 25.

In addition to the measures listed below, Vineyard Wind allocated $3 million to research that will advance marine mammal protections as the offshore wind industry develops along the East Coast. The Whales and Wind Fund will support development and demonstration of innovative methods and technologies to enhance protections for marine mammals as the Massachusetts and US offshore wind industry continues to grow.

Table 25. Proposed monitoring and mitigation plans during Project construction.

Monitoring & mitigation measure	Description	Anticipated regulatory requirement	Enhanced mitigation	Additional information
Mitigation for All Marine Mammals				
Seasonal Restrictions	▪ Vineyard Wind will establish a restriction on pile driving between January 1 and April 30[1]	—	✓	▪ No pile driving activities January - April
Sound Reduction Technology	▪ Vineyard Wind will implement attenuation mitigation to reduce sound levels by a target of up to approximately 12 dB - A noise attenuation technology will be implemented (e.g., Noise Mitigation System [NMS], Hydro-sound Damper [HSD], Noise Abatement System [AdBm], bubble curtain, or similar), and a second back-up attenuation technology (e.g. bubble curtain or similar) will be on-hand, if needed pending results of sound field verification.	—	✓	▪ Integrated equipment dampening methods ▪ External sound dampening
Sound Field Verification	▪ Sound levels will be recorded for each of the pile types for comparison with model results	✓	✓	▪ One each of the monopiles and jacket piles will be recorded and characterized
Low Visibility Construction Operations	▪ Pile driving will not be initiated when the clearance zone cannot be visually monitored, i.e., the PSO is unable to see the full extent of the clearance zone due to reduced visibility	—	✓	▪ As determined by the lead PSO on duty
Protected Species Observers (PSOs)	▪ A minimum of two PSOs will maintain watch during daylight hours when pile driving is underway ▪ PSOs may not perform another duty while on watch ▪ PSOs may not exceed four consecutive watch hours; must have a minimum two hour break between watches; and may not exceed a combined watch schedule of more than 12 hours in a 24-hour period ▪ All PSOs will have training certificates that meet or exceed BOEM/BSEE criteria or have NMFS approval, or will be pre-approved by NMFS ▪ PSOs will be deployed on the installation vessel ▪ PSOs will check the NMFS Sighting Advisory System for NARW activity ▪ Clearance and monitoring zones will be monitored around the pile center for marine mammals ▪ PSOs will record behavioral activity of animals observed	✓	✓	n/a

Monitoring & mitigation measure	Description	Anticipated regulatory requirement	Enhanced mitigation	Additional information
Clearance Zones (radius from pile center)	▪ Monopile and Jacket Installation: - Mysticete Whales: 500 m - Odontocetes and Pinnipeds: 50 m	✓	✓	▪ Proposed clearance zones are based on modeled distances to the NMFS Level A harassment thresholds (both PK and SEL), visual observation capability, and practical offshore implementation. ▪ Clearance zone distances assume longer than expected exposure durations for SEL criteria.
Monitoring Zones (radius from pile center)	▪ PSOs will monitor to the extent practicable - During Monopile Installation: 2,750 m - During Jacket Installation: 2,200 m	✓	✓	▪ Monitoring zones are based on the NMFS Level B harassment criteria (160 dB SPL) and reflect the average distance of two modeled sites.
Pre-piling Clearance Timing	▪ Clearance zone(s) must be clear for the following time period prior to pile driving - Mysticete whales for 30 minutes - Odontocetes and Pinnipeds for 15 minutes	✓	✓	▪ Use reticle binoculars and/or range sticks
Soft-start	▪ Soft-start will be implemented during pile driving. ▪ The soft start process shall consist of 3 single hammer strikes at less than 40 percent hammer energy followed by at least one minute delay before the subsequent hammer strikes. This process shall be conducted a total of 3 times (e.g. 3 single strikes, delay, 3 single strikes, delay, 3 single strikes, delay).	✓	✓	n/a
Passive Acoustic Monitoring (PAM)	▪ A PAM system will be utilized – the system will be identified prior to construction and in consultation with BOEM and NOAA Fisheries ▪ The PAM system will not be located on the installation vessel to avoid interference ▪ A team of trained PAM operators will monitor for acoustic detections ▪ The system will be in operation in accordance with the pre-piling clearance timing	—	✓	n/a

Monitoring & mitigation measure	Description	Anticipated regulatory requirement	Enhanced mitigation	Additional information
Shut downs	▪ If a marine mammal is observed approaching the clearance zone, the PSO will request a temporary cessation of pile driving. Where shut-down is not possible to maintain installation feasibility, reduced hammer energy will be requested and implemented where practicable ▪ After shut down, piling can be initiated once the clearance zone is clear for the minimum species-specific time period, or if required to maintain installation feasibility	✓	—	n/a
Vessel Strike Avoidance	▪ 100 m (328 feet) will be maintained between all transiting vessels and whales ▪ If a whale is observed within 100 m (328 feet), the transiting vessel will shift engine to neutral and will not re-engage engines until the whale has moved out of the vessel path and beyond 100 m (328 feet) ▪ Transiting vessels will maintain a separation distance of 50 m (164 feet) from pinnipeds and dolphins, except for bow-riding dolphins and voluntarily approaching pinnipeds ▪ Vineyard Wind will report sightings of injured or dead protected species			n/a
Additional Pile Driving Mitigation for NARW				
May 1 to May 14	▪ An extended PAM clearance zone of 10 km (radius from pile center) will be implemented for NARW ▪ PAM will be operated 24/7 ▪ Prior to piling, an aerial or boat survey will be conducted across the extended 10 km clearance zone - Aerial surveys will not begin until the lead PSO on duty determines adequate visibility and at least 1 hour after sunrise (on days with sun glare) - Boat surveys will not begin until the lead PSO on duty determines there is adequate visibility - If a NARW is sighted during the survey, piling operations will not be conducted that day unless an additional survey is conducted to confirm the zone is clear of NARW	—	✓	n/a
May 1 to December 31	▪ 60 minute pre-piling monitoring time period ▪ Clearance zone: Minimum 1000 m	—	✓	n/a
November 1 to December 31	▪ An extended PAM clearance zone of 10 km (radius from pile center) will be implemented for NARW ▪ An aerial survey, as described above, may also be utilized to confirm zone is clear ▪ PAM will be operated 24/7	—	✓	n/a
Additional Vessel Speed Mitigation for NARW				
November 1 to May 14	▪ Vessels will travel at less than 10 knots within the WDA ▪ When transiting to or from the WDA (this will not apply to any transiting in Nantucket Sound, which has been demonstrated by best available science to not provide consistent habitat for NARW) Vineyard Wind will either travel at less than 10 knots or will implement visual surveys or PAM to ensure the transit corridor is clear of NARW	—	✓	n/a

Monitoring & mitigation measure	Description	Anticipated regulatory requirement	Enhanced mitigation	Additional information
DMA	▪ Vineyard Wind will reduce speeds within a temporary DMA to 10 knots unless visual surveys or PAM are conducted, which demonstrate that NARW are not present in the transit corridor, or the animals can be avoided.	—	✓	n/a
Year-round	▪ An observer who has undergone marine mammal training will be stationed on vessels transiting to and from the WDA if traveling over 10 knots ▪ 500 m (1640 feet) will be maintained between all transiting vessels and NARW	—	✓	n/a

[1] This restriction is intended to minimize the amount of pile driving that occurs when the migratory NARW is likely to be in the Offshore Project Area and thus limit sound exposure for this endangered species. Density data from Roberts et al. (2016) and survey data (both visual and acoustic) from Kraus et al. (2016) suggest that the highest density of NARWs in the WDA occurs annually in March. Over 93% of the sightings in the Kraus et al. (2016) study occurred from January through April, with no NARWs sighted from May through August.

12. Arctic Plan of Cooperation

Not applicable.

The Project will take place off the US northeast coast in the Atlantic Ocean, and no activities will take place in or near a traditional Arctic subsistence hunting area. Therefore, there are no relevant subsistence uses of marine mammals implicated by this action.

13. Monitoring and Reporting

The suite of planned monitoring activities is detailed below and summarized in Table 25 above.

13.1. Sound Field Verification

Exposure estimates indicate that mitigation measures achieving a sound attenuation of 6 dB are protective for species of concern, including the NARW. Vineyard Wind has committed to mitigative technologies capable of reducing sound levels by up to approximately 12 dB. To assess the efficacy of mitigation measures and to determine the distance to pre-defined acoustic thresholds, Vineyard Wind proposes to conduct a sound field verification (SFV) when construction commences. Sound levels will be measured at distances from the pile at one monopile location and one jacket pile location. The results of the *in situ* SFV will be compared to the modeling results presented in this report. These results will also inform Project mitigation measure implementation for the remainder of the construction, such as determining clearance and monitoring zones. Specific details on equipment type and deployment strategy will be provided to BOEM and NOAA in advance of the SFV.

13.2. Visual Monitoring

When a marine mammal sighting is made, the PSO will record:

- Species, group size, age/size/sex categories (if determinable);
- Behavior when first sighted and after initial sighting;
- Heading (if consistent), bearing, and distance from the observer;
- Apparent reaction to activities (e.g., none, avoidance, approach, paralleling, etc.), and closest point of approach; and
- Time, location, speed, and activity of the vessel, sea state, and visibility.

The vessel's position and speed, water depth, sea state, and visibility will also be recorded at the start and end of each observation watch, and whenever there is a change in any of those variables that materially effects sighting conditions.

13.3. Passive Acoustic Monitoring

The exact specifications of the PAM system, the software to be used, and the monitoring protocol will be identified prior to construction and in consultation with BOEM and NOAA Fisheries.

13.4. Reporting

A final marine mammal sighting and detection report will be provided to NOAA Fisheries and other federal agencies as required by permit/authorization stipulations.

Sightings of any NARW will be reported to the RWSAS as soon as it is practical to do so. Sightings of any injured, distressed, or dead marine mammals will be reported by a PSO to NOAA Fisheries as soon as it is practical to do so.

14. Suggested Means of Coordination

In addition to the monitoring and reporting measures discussed in this application, Vineyard Wind has committed Vineyard Wind has allocated $3 million to helping advance marine mammal protections as the offshore wind industry develops along the East Coast (see Section 11). The specific goals and monitoring activities will be determined in collaboration with a panel of experts in marine mammal populations in the WDA and Lease Area, regional stakeholders, and Federal and State agencies through a process currently being developed.

As described in Section 13, marine species sightings data will be collected during the PSO monitoring and acoustic detection data will be collected during PAM. These data will be shared with BOEM and NOAA Fisheries, thereby contributing to the knowledge on these protected species, which may provide insights for future projects.

15. Literature Cited

[BOEM] Bureau of Ocean Energy Management. (2014a). Atlantic OCS Proposed Geological and Geophysical Activities Mid-Atlantic and South Atlantic Planning Area Final Programmatic Environmental Impact Statement. Retrieved from http://www.boem.gov/BOEM-2014-001-v1/

[BOEM] Bureau of Ocean Energy Management. (2014b). *Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic Outer Continental Shelf Offshore Massachusetts: Revised Environmental Assessment* 2014-603). U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. https://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/State_Activities/BOEM%20RI_MA_Revised%20EA_22May2013.pdf.

[CeTAP] Cetacean and Turtle Assessment Program, University of Rhode Island. (1982). *A Characterization of marine mammals and turtles in the mid- and North Atlantic aeas of the US Outer Continental Shelf, final report*. Contract AA551-CT8-48. Bureau of Land Management. Washington, DC.

[CRESLI] Coastal Research and Education Society of Long Island. (2018). CRESLI seal sightings. Retrieved from http://cresli.org/cresli/seals/seal_sightings.html#2012-2013-sightings

[DFO] Fisheries and Oceans Canada. (2017). *Stock Assessment of Canadian Northwest Atlantic Grey Seals (Halichoerus Grypus): Quebec and Maritimes Regions* 2017/045). http://waves-vagues.dfo-mpo.gc.ca/Library/40646749.pdf.

50 CFR Part 224: Endangered Fish and Wildlife; Final Rule To Implement Speed Restrictions to Reduce the Threat of Ship Collisions With North Atlantic Right Whales, 60173-60187 (2008).

50 CFR Part 223 and 224: Endangered and Threatened Species; Identification of 14 Distinct Population Segments of the Humpback Whale (*Megaptera novaeangliae*) and Revision of Species-Wide Listing; Final Rule, 62260-62320 (2016a).

50 CFR Part 226: Endangered and Threatened Species; Critical Habitat for Endangered North Atlantic Right Whale; Final Rule, 4838-4874 (2016b).

[HESS] High Energy Seismic Survey. (1999). *High Energy Seismic Survey Review Process and Interim Operational Guidelines for Marine Surveys Offshore Southern California*. Prepared for the California State Lands Commission and the United States Minerals Management Service Pacific Outer Continental Shelf Region by the High Energy Seismic Survey Team. Camarillo, CA.

[ISO] International Organization for Standardization. (2017). ISO 18405:2017. Underwater Acoustics – Terminology. In (pp. 51). Geneva.

[NAVO] Naval Oceanography Office (US). (2003). *Database description for the Generalized Digital Environmental Model (GDEM-V) (U)* MS 39522-5003). Oceanographic Data Bases Division, Stennis Space Center.

[NEFSC] Northeast Fisheries Science Center, & [SEFSC] Southeast Fisheries Science Center. (2011a). *2010 Annual report to the inter-agency agreement M10PG00075/0001: A comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the western North Atlantic Ocean*. Retrieved from https://www.nefsc.noaa.gov/psb/AMAPPS/docs/Final_2010AnnualReportAMAPPS_19Apr2011.pdf

[NEFSC] Northeast Fisheries Science Center, & [SEFSC] Southeast Fisheries Science Center. (2011b). *2011 Annual report to the inter-agency agreement M10PG00075/0001: A comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the western North Atlantic Ocean*. Retrieved from https://www.nefsc.noaa.gov/psb/AMAPPS/docs/NMFS_AMAPPS_2011_annual_report_final_BOEM.pdf

[NEFSC] Northeast Fisheries Science Center, & [SEFSC] Southeast Fisheries Science Center. (2012). *2012 Annual report to the inter-agency agreement M10PG00075/0001: A comprehensive assessment of marine mammal,* *marine turtle, and seabird abundance and spatial distribution in US waters of the western North Atlantic Ocean*. Retrieved from https://www.nefsc.noaa.gov/psb/AMAPPS/docs/NMFS_AMAPPS_2012_annual_report_FINAL.pdf

[NEFSC] Northeast Fisheries Science Center, & [SEFSC] Southeast Fisheries Science Center. (2014a). *2013 Annual report to the inter-agency agreement M10PG00075/0001: A comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the western North Atlantic Ocean*.

[NEFSC] Northeast Fisheries Science Center, & [SEFSC] Southeast Fisheries Science Center. (2014b). *2014 Annual report to the inter-agency agreement M10PG00075/0001: A comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the western North Atlantic Ocean*. Retrieved from https://www.nefsc.noaa.gov/psb/AMAPPS/docs/NMFS_AMAPPS_2014_annual_report_Final.pdf

[NEFSC] Northeast Fisheries Science Center, & [SEFSC] Southeast Fisheries Science Center. (2015). *2015 Annual report to the inter-agency agreement M10PG00075/0001: A comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the western North Atlantic Ocean. - AMAPPS II*.

[NEFSC] Northeast Fisheries Science Center, & [SEFSC] Southeast Fisheries Science Center. (2016). *Annual report of a comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the western North Atlantic Ocean – AMAPPS II*. Retrieved from https://www.nefsc.noaa.gov/psb/AMAPPS/docs/Annual%20Report%20of%202016%20AMAPPS_final.pdf

[NMFS] National Marine Fisheries Northeast Region. (1991). *Final Recovery Plan for the Humpback Whale (Megaptera novaeangliae)*. Report prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service. Silver Spring, MA. https://repository.library.noaa.gov/view/noaa/15993.

[NMFS] National Marine Fisheries Service. (2009). Non-Competitive Leases for Wind Resource Data Collection on the Northeast Outer Continental Shelf, May 14, 2009. Letter to Dr. James Kendall, Chief, Environmental Division, Minerals Management Service, and Mr. Frank Cianfrani, Chief – Philadelphia District, U.S. Army Corps of Engineers. In.

[NMFS] National Marine Fisheries Service. (2016). *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55

[NMFS] National Marine Fisheries Service. (2018a). *2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59 Retrieved from https://www.fisheries.noaa.gov/webdam/download/75962998

[NMFS] National Marine Fisheries Service. (2018b). *Takes of marine mammals incidental to specified activities; Taking marine mammals incidental to marine site characterization surveys off of Delaware*. Federal Register. 4 Apr 2018

[NOAA] National Oceanic and Atmospheric Administration. (2005). *Notice of Public Scoping and Intent to Prepare an Environmental Impact Statement*.

[NOAA] National Oceanic and Atmospheric Administration. (2012). Northeast Regional Whale Whatching Guidelines for Commercial & Recreational Whale Watchers from Maine through Virginia. In.

[NOAA] National Oceanic and Atmospheric Administration. (2013, December 2013). *Draft guidance for assessing the effects of anthropogenic sound on marine mammals: Acoustic threshold levels for onset of permanent and temporary threshold shifts*, Silver Spring, MA: NMFS Office of Protected Resources.

[NOAA] National Oceanic and Atmospheric Administration. (2015, July 2015). *Draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset* *of permanent and temporary threshold shifts*, 180 pp. Silver Spring, Maryland: NMFS Office of Protected Resources.

[USFWS] U.S. Fish and Wildlife Service. (2014). *West Indian manatee (Trichechus manatus) Florida stock (Florida subspecies, Trichechus manatus latirostris)*. https://www.fws.gov/northflorida/manatee/SARS/20140123_FR00001606_Final_SAR_WIM_FL_Stock.pdf.

Abend, A., G., & Smith, T., D. (1999). *Review of the distribution of the long-finned pilot whale (Globicephala melas) in the North Atlantic and Mediterranean*. NOAA Technical Memorandum NMFS-NE-117 Retrieved from www.nefsc.noaa.gov/nefsc/publications/tm/tm117/tm117.pdf

Acevedo-Gutiérrez, A., Croll, D. A., & Tershy, B. R. (2002). High feeding costs limit dive time in the largest whales. *Journal of Experimental Biology, 205*(12), 1747-1753.

Aerts, L., Blees, M., Blackwell, S., Greene, C., Kim, K., Hannay, D. E., & Austin, M. (2008). *Marine mammal monitoring and mitigation during BP Liberty OBC seismic survey in Foggy Island Bay, Beaufort Sea, July-August 2008: 90-day report* LGL Report P1011-1). Report by LGL Alaska Research Associates Inc., LGL Ltd., Greeneridge Sciences Inc. and JASCO Applied Sciences for BP Exploration Alaska. http://www.nmfs.noaa.gov/pr/pdfs/permits/bp_liberty_monitoring.pdf.

Aguilar, A. (1986). A review of old Basque whaling and its effect on the right whales (*Eubalaena glacialis*) of the North Atlantic. *Report of the International Whaling Commission, 10*, 191-199.

Ajemian, M. J., Wetz, J. J., Shipley-Lozano, B., Shively, J. D., & Stunz, G. W. (2015). An Analysis of Artificial Reef Fish Community Structure along the Northwestern Gulf of Mexico Shelf: Potential Impacts of "Rigs-to-Reefs" Programs. *PLoS ONE, 10*(5), e0126354. doi:10.1371/journal.pone.0126354

Alves, F., Dinis, A., Cascão, I., & Freitas, L. (2010). Bryde's whale (*Balaenoptera brydei*) stable associations and dive profiles: New insights into foraging behavior. *Marine Mammal Science, 26*(1), 202-212.

Amano, M., & Yoshioka, M. (2003). Sperm whale diving behavior monitored using a suction-cup-attached TDR tag. *Marine Ecology Progress Series, 258*, 291-295.

American Cetacean Society. (2018). Pilot Whale. Retrieved from https://www.acsonline.org/index.php?option=com_content&view=article&id=65:pilot-whale&catid=20:site-content

Andersen, L., & Olsen, M. T. (2010). Distribution and population structure of North Atlantic harbour seals (*Phoca vitulina*). *NAMMCO Scientific Publications, 8*, 15-35.

ANSI S12.7-1986. (R2006). American National Standard Methods for Measurements of Impulse Noise. In. New York: American National Standards Institute.

ANSI S1.1-1994. (R2004). American National Standard Acoustical Terminology. In. New York: American National Standards Institute.

ANSI S1.1-2013. (R2013). American National Standard Acoustical Terminology. In. New York: American National Standards Institute.

Aoki, K., Amano, M., Yoshioka, M., Mori, K., Tokuda, D., & Miyazaki, N. (2007). Diel diving behavior of sperm whales off Japan. *Marine Ecology Progress Series, 349*, 277-287.

Au, W. W. L. (1993). *The sonar of dolphins*. New York: Springer-Verlag.

Au, W. W. L., & Hastings, M. C. (2008). *Principles of Marine Bioacoustics*: Springer.

Austin, M., Denes, S., MacDonnell, J., & Warner, G. (2016). *Hydroacoustic Monitoring Report: Anchorage Port Modernization Project Test Pile Program*. Version 3.0. Technical report by JASCO Applied Sciences for Anchorage Port Modernization Project Test Pile Program

Anchorage, AK.

Austin, M., Denes, S. L., MacDonnell, J. T., & Warner, G. A. (2016). *Hydroacoustic Monitoring Report: Anchorage Port Modernization Project Test Pile Program*. Version 3.0. Technical report by JASCO Applied Sciences for the Port of Anchorage. Anchorage, AK.

Bailey, H., Brookes, K. L., & Thompson, P. M. (2014). Assessing environmental impacts of offshore wind farms: Lessons learned and recommendations for the future. *Aquatic Biosystems, 10*(1), 8. doi:10.1186/2046-9063-10-8

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

Baird, R. W., Borsani, J. F., Hanson, M. B., & Tyack, P. L. (2002). Diving and night-time behavior of long-finned pilot whales in the Ligurian Sea. *Marine Ecology Progress Series, 237*, 301-305.

Baird, R. W., & Stacey, P. J. (1991). Status of Risso's dolphin, *Grampus griseus*, in Canada. *Canadian Field-Naturalist, 105*(2), 233-242.

Barlas, M. E. (1999). *The distribution and abundance of harbor seals (Phoca vitulina concolor) and gray seals (Halichoerus grypus) in southern New England, winter 1998-summer 1999.* (PhD), Boston University,

Baugmartner, M. F., & Mate, B. R. (2003). Summertime foraging ecology of North Atlantic right whales. *Marine Ecology Progress Series, 264*, 123-135.

Baumgartner, M. F., & Mate, B. R. (2005). Summer and fall habitat of North Atlantic right whales (*Eubalaena glacialis*) inferred from satellite telemetry. *Canadian Journal of Fisheries and Aquatic Sciences, 62*(3), 527-543.

Bearzi, G., Reeves, R. R., Remonato, E., Pierantonio, N., & Airoldi, S. (2011). Risso's dolphin *Grampus griseus* in the Mediterranean Sea. *Mammalian Biology, 76*(4), 385-400.

Beck, C. A., Bowen, W. D., McMillan, J. I., & Iverson, S. J. (2003). Sex differences in the diving behaviour of a size-dimorphic capital breeder: The grey seal. *Animal Behaviour, 66*(4), 777-790.

Becker, J. J., Sandwell, D. T., Smith, W. H. F., Braud, J., Binder, B., Depner, J., . . . Weatherall, P. (2009). Global Bathymetry and Elevation Data at 30 Arc Seconds Resolution: SRTM30_PLUS. *Marine Geodesy, 32*(4), 355-371.

Bellmann, M. A. (2014). *Overview of existing noise mitigation systems for reducing pile-driving noise*. Paper presented at the Inter-noise2014, Melbourne, Australia. https://www.acoustics.asn.au/conference_proceedings/INTERNOISE2014/papers/p358.pdf

Bergström, L., Kautsky, L., Malm, T., Rosenberg, R., Wahlberg, M., Capetillo, N. Å., & Wilhelmsson, D. (2014). Effects of offshore wind farms on marine wildlife—a generalized impact assessment. *Environmental Research Letters, 9*(3), 12.

Betke, K. (2008). *Measurement of Wind Turbine Construction Noise at Horns Rev II* (1256-08-a-KB)(Technical report by Institut für technische und angewandte Physik GmbH (ITAP) for BioConsultSH. Husun, Germany. https://tethys.pnnl.gov/sites/default/files/publications/Betke-2008.pdf.

Bigg, M. A. (1981). Harbour seal, *Phoca vitulina* and *Phoca largha*. In S. H. Ridgeway & R. J. Harrison (Eds.), *Hangbook of Marine Mammals. Volume 2: Seals* (pp. 1-28). New York: Academic Press.

Bittencourt, L., Lima, I. M. S., Andrade, L. G., Carvalho, R. R., Bisi, T. L., Lailson-Brito, J., & Azevedo, A. F. (2017). Underwater noise in an impacted environment can affect Guiana dolphin communication. *Marine Pollution Bulletin, 114*(2), 1130-1134. doi:https://doi.org/10.1016/j.marpolbul.2016.10.037

Blackwell, S. B. (2005). *Underwater Measurements of Pile driving Sounds during the Port MacKenzie Dock Modifications, 13-16 August 2004*. Report from Greeneridge Sciences, Inc., and LGL Alaska Research Associates, Inc., in association with HDR Alaska, Inc. for Knik Arm Bridge and Toll Authority, Department of Transportation and Public Facilities, and Federal Highway Administration.

Blackwell, S. B., Nations, C. S., McDonald, T. L., Greene, C. R., Thode, A. M., Guerra, M., & Michael Macrander, A. (2013). Effects of airgun sounds on bowhead whale calling rates in the Alaskan Beaufort Sea. *Marine Mammal Science, 29*(4), E342-E365. doi:doi:10.1111/mms.12001

Blackwell, S. B., Nations, C. S., McDonald, T. L., Thode, A. M., Mathias, D., Kim, K. H., . . . Macrander, A. M. (2015). Effects of Airgun Sounds on Bowhead Whale Calling Rates: Evidence for Two Behavioral Thresholds. *PLoS ONE, 10*(6), e0125720.

Blix, A. S., & Folkow, L. P. (1995). Daily energy expenditure in free living minke whales. *Acta Physiologica, 153*(1), 61-66. doi:doi:10.1111/j.1748-1716.1995.tb09834.x

Bloch, D., Heide-Jorgensen, M. P., Stefansson, E., Mikkelsen, B., Ofstad, L. H., Dietz, R., & Andersen, L. W. (2003). Short-term movements of long-finned pilot whales *Globicephala melas* around the Faroe Islands. *Wildlife Biology, 9*(1), 47-58.

Bonner, W. N. (1971). Grey seal *Halichoerus grypus fabricus*. In S. H. Ridgway & H. J. Harrison (Eds.), *Handbook of Marine Mammals*. London: Academic Press, Inc.

Bonner, W. N. (1990). *The natural history of seals*. New York: Facts of File Publications.

Bowles, A. E., Smultea, M., Würsig, B., DeMaster, D. P., & Palka, D. (1994). Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island Feasibility Test. *Journal of the Acoustical Society of America, 96*(4), 2469-2484. doi:10.1121/1.410120

Brandt, M. J., Diederichs, A., Betke, K., & Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series, 421*, 205-216.

Branstetter, B. K., Bakhtiari, K. L., Trickey, J. S., & Finneran, J. J. (2016). Hearing Mechanisms and Noise Metrics Related to Auditory Masking in Bottlenose Dolphins (*Tursiops truncatus*). In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II* (pp. 109-116). New York: Springer.

Branstetter, B. K., Trickey, J. S., Aihara, H., Finneran, J. J., & Liberman, T. R. (2013). Time and frequency metrics related to auditory masking of a 10 kHz tone in bottlenose dolphins (*Tursiops truncatus*). *Journal of the Acoustical Society of America, 134*(6), 4556-4565.

Brasseur, S., van Polanen Petel, T., Aarts, G., Meesters, E., Dijkman, E., & Reijnders, P. (2010). *Grey seals (Halichoerus grypus) in the Dutch North sea: Population ecology and effects of wind farms* C137/10). Report by IMARES Wageningen UR for Wea @ Sea. http://edepot.wur.nl/260049.

Breed, G. A., Jonsen, I. D., Myers, R. A., Bowen, W. D., & Leonard, M. L. (2009). Sex-specific, seasonal foraging tactics of adult grey seals (*Halichoerus grypus*) revealed by state–space analysis. *Ecology, 90*(11), 3209-3221.

Bröker, K., Durinck, J., Vanman, C., & Martin, B. (2013). *Monitoring of marine mammals and the sound scape during a seismic survey in two license blocks in the Baffin Bay, West Greenland, in 2012*. Paper presented at the Abstracts of the 20th Biennial Conference on the Biology of Marine Mammals, Dunedin, New Zealand.

Brown, M. W., Fenton, D., Smedbol, K., Merriman, C., Robichaud-Leblanc, K., & Conway, J. D. (2009). *Recovery Strategy for the North Atlantic Right Whale (Eubalaena glacialis) in Atlantic Canadian Waters [Final]*. Fisheries and Oceans Canada.

Buckingham, M. J. (2005). Compressional and shear wave properties of marine sediments: Comparisons between theory and data. *Journal of the Acoustical Society of America, 117*(1), 137-152.

Buehler, D., Oestman, R., Reyff, J., Pommerenck, K., & Mitchell, B. (2015). *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* (CTHWANP-RT-15-306.01.01)(California Department of Transportation (CALTRANS), Division of Environmental Analysis. http://www.dot.ca.gov/hq/env/bio/files/bio_tech_guidance_hydroacoustic_effects_110215.pdf.

Bulleri, F., & Airoldi, L. (2005). Artificial marine structures facilitate the spread of a non-indigenous green alga, *Codium fragile* ssp. *tomentosoides*, in the north Adriatic Sea. *Journal of Applied Ecology, 42*(6), 1063-1072. doi:doi:10.1111/j.1365-2664.2005.01096.x

Burns, J. J. (2002). Harbour seal and spotted seal, *Phoca vitulina* and *P. largha*. In W. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopaedia of Marine Mammals* (pp. 552-560). San Diego, CA: Academic Press.

Carstensen, J., Henriksen, O. D., & Teilmann, J. (2006). Impacts of offshore wind farm construction on harbour porpoises: Acoustic monitoring of echolocation activity using porpoise detectors (T-PODs). *Marine Ecology Progress Series, 321*, 295-308. doi:10.3354/meps321295

Castellote, M., Clark, C. W., & Lammers, M. O. (2012). Acoustic and behavioural changes by fin whales (*Balaenaptera physalus*) in response to shipping and airgun noise. *Biological Conservation, 147*(1), 115-122.

Center for Coastal Studies. (2017). Cape Cod seals. Retrieved from http://coastalstudies.org/sealresearch/cape-cod-seals/

Cerchio, S., Strindberg, S., Collins, T., Bennett, C., & Rosenbaum, H. (2014). Seismic Surveys Negatively Affect Humpback Whale Singing Activity off Northern Angola. *PLoS ONE, 9*(3), e86464. doi:10.1371/journal.pone.0086464

Cipriano, F. (2002). Atlantic white-sided dolphin. In W. F. Perrin, B. Wursig, & J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (pp. 49-51). San Diego, CA: Academic Press.

Claisse, J. T., Pondella, D. J., Love, M., Zahn, L. A., Williams, C. M., Williams, J. P., & Bull, A. S. (2014). Oil platforms off California are among the most productive marine fish habitats globally. *Proceedings of the National Academy of Sciences, 111*(43), 15462-15467. doi:10.1073/pnas.1411477111

Clapham, P. J., & Mayo, C. A. (1987). Reproduction and recruitment of individually identified humpback whales, *Megaptera novaeangliae*, observed in Massachusetts Bay, 1979–1985. *Canadian Journal of Zoology, 65*(12), 2853-2863. doi:10.1139/z87-434

Clark, C. W., Ellison, W. T., Southall, B. L., Hatch, L., Van Parijs, S. M., Frankel, A., & Ponirakis, D. (2009). Acoustic masking in marine ecosystems: Intuitions, analysis, and implication. *Marine Ecology Progress Series, 395*, 201-222.

Clark, C. W., & Gagnon, G. C. (2006). Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. *International Whaling Commission Scientific Committee Document SC/58 E, 9*.

Collins, M. D. (1993). A split-step Padé solution for the parabolic equation method. *Journal of the Acoustical Society of America, 93*(4), 1736-1742.

Collins, M. D., Cederberg, R. J., King, D. B., & Chin-Bing, S. (1996). Comparison of algorithms for solving parabolic wave equations. *Journal of the Acoustical Society of America, 100*(1), 178-182.

Cranford, T. W., & Krysl, P. (2015). Fin whale sound reception mechanisms: Skull vibration enables low-frequency hearing. *PLoS ONE, 10*(1), e0116222.

Croll, D. A., Acevedo-Gutiérrez, A., Tershy, B. R., & Urbán-Ramírez, J. (2001). The diving behavior of blue and fin whales: Is dive duration shorter than expected based on oxygen stores? *Comparative Biochemistry and Physiology Part A, 129*(4), 797-809.

Curry, B. E., & Smith, J. (1997). Phylogeographic structure of the bottlenose dolphin (*Tursiops truncatus*): Stock identification and implications for management. *Molecular genetics of marine mammals, 3*, 327-247.

Dahl, P. H., de Jong, C. A. F., & Popper, A. N. (2015). The Underwater Sound Field from Impact Pile Driving and Its Potential Effects on Marine Life. *Acoustics Today, 11*(2), 18-25.

Dahlheim, M., & Castellote, M. (2016). Changes in the acoustic behavior of gray whales *Eschrichtius robustus* in response to noise. *Endangered Species Research, 31*, 227-242. doi:10.3354/esr00759

Dahlheim, M. E. (1987). *Bio-acoustics of the gray whale (Eschrichtius robustus).* (PhD), University of British Columbia, Vancouver, BC.

Dahlheim, M. E., & Ljungblad, D. K. (1990). Preliminary hearing study on gray whales (*Eschrichtius robustus*) in the field. In J. Thomas & R. Kastelein (Eds.), *Sensory abilities of cetaceans* (Vol. 196, pp. 335-346): Springer US.

Dähne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Krügel, K., . . . Siebert, U. (2013). Effects of pile-driving on harbour porpoises (*Phocoena phocoena*) at the first offshore wind farm in Germany. *Environmental Research Letters, 8*(2).

Dähne, M., Tougaard, J., Carstensen, J., Rose, A., & Nabe-Nielsen, J. (2017). Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. *Marine Ecology Progress Series, 580*, 221-237.

Daoust, P. Y., Couture, E. L., Wimmer, T., & Bourque, L. (2017). *Incident report: North Atlantic right whale mortality event in the Gulf of St. Lawrence, 2017*. Collaborative report by Canadian Wildlife Health Cooperative, Marine Animal Response Society, and Fisheries and Oceans Canada.

Davies, J. L. (1957). The Geography of the Gray Seal. *Journal of Mammalogy, 38*(3), 297-310.

Di Iorio, L., & Clark, C. W. (2009). Exposure to seismic survey alters blue whale acoustic communication. *Biology Letters, 6*(1), 51-54.

Doksæter, L., Olsen, E., Nøttestad, L., & Fernö, A. (2008). Distribution and feeding ecology of dolphins along the Mid-Atlantic Ridge between Iceland and the Azores. *Deep Sea Research Part II, 55*(1), 243-253. doi:https://doi.org/10.1016/j.dsr2.2007.09.009

Dolphin, W. F. (1987). Dive behavior and estimated energy expenditure of foraging humpback whales in southeast Alaska. *Canadian Journal of Zoology, 65*(2), 354-362.

Donovan, G. P. (1991). A review of IWC stock boundaries. *Reports of the International Whaling Commission (Special Issue), 13*, 39-68.

Dufault, S., Whitehead, H., & Dillon, M. (1999). An examination of the current knowledge on the stock structure of sperm whales (*Physeter macrocephalus*) worldwide. *Journal of Cetacean Research and Management, 1*(1), 1-10.

Dunlop, R. A., Noad, M. J., Cato, D. H., Kniest, E., Miller, P. O., Smith, J. N., & Stokes, M. D. (2013). Mutivariate analysis of behavioural response experiments in humpback whales (*Megaptera novaeangliae*). *Journal of Experimental Biology, 216*, 759-770.

Dunlop, R. A., Noad, M. J., McCauley, R. D., Scott-Hayward, L., Kniest, E., Slade, R., . . . Cato, D. H. (2017). Determining the behavioural dose–response relationship of marine mammals to air gun noise and source proximity. *Journal of Experimental Biology, 220*(16), 2878-2886. doi:10.1242/jeb.160192

Dunn, R. A., & Hernandez, O. (2009). Tracking blue whales in the eastern tropical Pacific with an ocean-bottom seismometer and hydrophone array. *Journal of the Acoustical Society of America, 126*(3), 1084-1094. doi:10.1121/1.3158929

Edrén, S. M. C., Andersen, S. M., Teilmann, J., Carstensen, J., Harders, P. B., Dietz, R., & Miller, L. A. (2010). The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. *Marine Mammal Science, 26*(3), 614-634. doi:doi:10.1111/j.1748-7692.2009.00364.x

Ellison, W. T., Clark, C. W., & Bishop, G. C. (1987). *Potential use of surface reverberation by bowhead whales, Balaena mysticetus, in under-ice navigation: Preliminary considerations*.

Ellison, W. T., & Frankel, A. S. (2012). A common sense approach to source metrics. In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life* (pp. 433-438). New York: Springer.

Ellison, W. T., Southall, B. L., Clark, C. W., & Frankel, A. S. (2012). A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds. *Conservation Biology, 26*(1), 21-28. doi:10.1111/j.1523-1739.2011.01803.x

Elmer, K.-H., & Savery, J. (2014). *New Hydro Sound Dampers to reduce piling underwater noise.* Paper presented at the INTER-NOISE and NOISE-CON Congress and Conference Proceedings.

Erbe, C. (2009). Underwater noise from pile driving in Moreton Bay, Qld. *Acoustics Australia, 37*(3), 87-92.

Erbe, C., McCauley, R., & Gavrilov, A. (2016). Characterizing marine soundscapes. In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II* (pp. 265-271). New York: Springer.

Erbe, C., Reichmuth, C., Cunningham, K., Lucke, K., & Dooling, R. (2016). Communication masking in marine mammals: A review and research strategy. *Marine Pollution Bulletin, 103*(1), 15-38.

Finneran, J. J. (2015). *Auditory weighting functions and TTS/PTS exposure functions for cetaceans and marine carnivores*. Technical report by SSC Pacific. San Diego, CA.

Finneran, J. J. (2016). *Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise*. Technical Report for Space and Naval Warfare Systems Center Pacific. San Diego, CA. http://www.dtic.mil/dtic/tr/fulltext/u2/1026445.pdf.

Finneran, J. J., & Branstetter, B. K. (2013). Effects of noise on sound perception in marine mammals. In H. Brumm (Ed.), *Animal communication and noise* (Vol. 2, pp. 273-308). Berlin, Heidelberg: Springer.

Finneran, J. J., Schlundt, C. E., Branstetter, B. K., Trickey, J. S., Bowman, V., & Jenkins, K. (2015). Effects of multiple impulses from a seismic air gun on bottlenose dolphin hearing and behavior. *Journal of the Acoustical Society of America, 137*(4), 1634-1646.

Folkow, L. P., Nordøy, E. S., & Blix, A. S. (2004). Distribution and diving behaviour of harp seals (*Pagophilus groenlandicus*) from the Greenland Sea stock. *Polar Biology, 27*(5), 281-298.

Frankel, A. S., Ellison, W. T., & Buchanan, J. (2002). *Application of the acoustic integration model (AIM) to predict and minimize environmental impacts*. Paper presented at the OCEANS'02 MTS/IEEE.

Funk, D., Hannay, D. E., Ireland, D., Rodrigues, R., & Koski, W. (Eds.). (2008). *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–November 2007: 90-day report*: LGL Report P969-1. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for Shell Offshore Inc., National Marine Fisheries Service (U.S.), and U.S. Fish and Wildlife Service.

Gervaise, C., Simard, Y., Roy, N., Kinda, B., & Menard, N. (2012). Shipping noise in whale habitat: Characteristics, sources, budget, and impact on belugas in Saguenay–St. Lawrence Marine Park hub. *Journal of the Acoustical Society of America, 132*(1), 76-89.

Gjertz, I., Lydersen, C., & Wiig, Ø. (2001). Distribution and diving of harbour seals (*Phoca vitulina*) in Svalbard. *Polar Biology, 24*(3), 209-214.

Goldbogen, J. A., Calambokidis, J., Oleson, E., Potvin, J., Pyenson, N. D., Schorr, G., & Shadwick, R. E. (2011). Mechanics, hydrodynamics and energetics of blue whale lunge feeding: efficiency dependence on krill density. *Journal of Experimental Biology, 214*, 131-146.

Goldbogen, J. A., Calambokidis, J., Shadwick, R. E., Oleson, E. M., Mcdonald, M. A., & Hildebrand, J. A. (2006). Kinematics of foraging dives and lunge-feeding in fin whales. *Journal of Experimental Biology, 209*(7), 1231-1244. doi:10.1242/jeb.02135

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M. P., Swift, R., & Thompson, D. (2003). A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal, 37*(4), 16-34. doi:10.4031/002533203787536998

Gowans, S., & Whitehead, H. (1995). Distribution and habitat partitioning by small odontocetes in the Gully, a submarine canyon on the Scotian Shelf. *Canadian Journal of Zoology, 73*(9), 1599-1608.

Greene, C. R., Jr. (1997). Physical acoustics measurements. In W. J. Richardson (Ed.), *Northstar Marine Mammal Monitoring Program, 1996: Marine Mammal and Acoustical Monitoring of a Seismic Program in the Alaskan Beaufort Sea* (pp. 3-1 to 3-63): LGL Rep. 2121-2. Report by LGL Ltd. and Greeneridge Sciences Inc. for BP Exploration (Alaska) Inc. and National Marine Fisheries Services.

Greene, C. R., Jr., Altman, N. S., & Richardson, W. J. (1999). Bowhead whale calls. In W. J. Richardson (Ed.), *Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998* (pp. 6-1 to 6-23): Report by LGL Ltd. and Greeneridge Sciences Inc. for Western Geophysical and National Marine Fisheries Service. LGL Rep. TA2230-3.

Greene Jr, C. R., Altman, N. S., & Richardson, W. J. (1999). The influence of seismic survey sounds on bowhead whale calling rates. *Journal of the Acoustical Society of America, 106*(4), 2280-2280. doi:10.1121/1.427798

Hain, J. H. W., Ratnaswamy, M. J., Kenney, R. D., & Winn, H. E. (1992). The fin whale, *Balaenoptera physalus*, in waters of the northeastern United States continental shelf. *Reports of the International Whaling Commission, 42*, 653-669.

Hamazaki, T. (2002). Spatiotemporal prediction models of cetacean habitats in the mid-western North Atlantic Ocean (from Cape Hatteras, North Carolina, USA to Nova Scotia, Canada). *Marine Mammal Science, 18*(4), 920-939. doi:doi:10.1111/j.1748-7692.2002.tb01082.x

Hannay, D. E., & Racca, R. G. (2005). *Acoustic Model Validation* 0000-S-90-04-T-7006-00-E, Revision 02). Technical report by JASCO Research Ltd. for Sakhalin Energy Investment Company Ltd.

Hanser, S. F., Doyle, L. R., Szabo, A. R., Sharpe, F. A., & McCowan, B. (2009, October 2009). *Bubble-net feeding humpback whales in Southeast Alaska change their vocalization patterns in the presence of moderate vessel noise.* Paper presented at the Abstracts of the 18th Biennial Conference on the Biology of Marine Mammals, Quebec, Canada.

Harris, D. E., Lelli, B., & Jakush, G. (2002). Harp seal records from the Southern Gulf of Maine: 1997–2001. *Northeastern Naturalist, 9*(3), 331-340. doi:10.1656/1092-6194(2002)009[0331:HSRFTS]2.0.CO;2

Harris, R. E., Elliott, T., & Davis, R. A. (2007). *Results of mitigation and monitoring program, Beaufort Span 2-D marine seismic program, open-water season 2006* TA4319-1). Report by LGL Ltd. for GX Technology Corporation.

Hastie, G. D., Wilson, B., & Thompson, P. M. (2006). Diving deep in a foraging hotspot: Acoustic insights into bottlenose dolphin dive depths and feeding behaviour. *Marine Biology, 148*, 1181-1188.

Hatch, L. T., Clark, C. W., Van Parijs, S. M., Frankel, A. S., & Ponirakis, D. W. (2012). Quantifying loss of acoustic communication space for right whales in and around a U.S. National Marine Sanctuary. *Conservation Biology, 26*(6), 983-994. doi:http://dx.doi.org/10.1111/j.1523-1739.2012.01908.x

Hayes, S. A., Josephson, E., Maze-Foley, K., & Rosel, P. E. (2017). *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2016*. U.S. Department of Commerce, NOAA, NMFS NFSC. NOAA Technical Memorandum NMFS-NE-241. Woods Hole, Massachusetts. https://repository.library.noaa.gov/view/noaa/14864.

Hayes, S. A., Josephson, E., Maze-Foley, K., & Rosel, P. E. (Eds.). (2018). *U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—2017*. Woods Hole, MA: U.S. Dep. Commer., NOAA Technical Memo NMFS-NE-245.

Heide-Jorgensen, M. P., Bloch, D., Stefansson, E., Mikkelsen, B., Ofstad, L. H., & Dietz, R. (2002). Diving behaviour of long-finned pilot whales *Globicephala melas* around the Faroe Islands. *Wildlife Biology, 8*(4), 307-313.

Heiler, J., Elwen, S. H., Kriesell, H. J., & Gridley, T. (2016). Changes in bottlenose dolphin whistle parameters related to vessel presence, surface behaviour and group composition. *Animal Behaviour, 117*, 167-177. doi:https://doi.org/10.1016/j.anbehav.2016.04.014

Hersh, S. L., & Duffield, D. A. (1990). Distinction between northwest Atlantic offshore and coastal bottlenose dolphins based on hemoglobin profile and morphometry. In S. Leatherwood & R. Reeves (Eds.), *The bottlenose dolphin* (pp. 129-139). San Diego: Academic Press.

Herzing, D. L., & Elliser, C. R. (2016). Opportunistic sightings of cetaceans in nearshore and offshore waters of Southeast Florida. *Journal of Northwest Atlantic Fisheries and Science, 48*, 21-31.

Holst, M., Beland, J., Mactavish, B., Nicolas, J., Hurley, B., Dawe, B., . . . Pavan, G. (2011, 27 Nov to 2 Dec 2011). *Visual-acoustic survey of cetaceans during a seismic study near Taiwan, April-July 2009.* Paper presented at the Abstracts of the 19th Biennial Conference on the Biology of Marine Mammals, Tampa, FL.

Holst, M., Richardson, W. J., Koski, W. R., Smultea, M. A., Haley, B., Fitzgerald, M. W., & Rawson, M. (2006, 23-26 May 2006). *Effects of large and small-source seismic surveys on marine mammals and sea turtles.* Paper presented at the AGU Spring Meeting Abstracts, Baltimore, MD.

Holst, M., Smultea, M. A., Koski, W. R., & Haley, B. (2005). *Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific Ocean off Central America, November–December 2004.* (TA2822-30)(Report from LGL Ltd. for Lamont-Doherty Earth Observatory of Columbia University and National Marine Fisheries Service.

Holst, M., Smultea, M. A., Koski, W. R., & Haley, B. (2005). *Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's Marine Seismic Program off the Northern Yucatán Peninsula in the Gulf of Mexico, January-Feburary 2004* (TA2822 31)(Lamont-Doherty Earth Observatory of Columbia University. Palisades, NY.

Holt, M. M., Noren, D. P., Dunkin, R. C., & Williams, T. M. (2015). Vocal performance affects metabolic rate in dolphins: implications for animals communicating in noisy environments. *Journal of Experimental Biology, 218*(11), 1647-1654. doi:10.1242/jeb.122424

Holt, M. M., Noren, D. P., Veirs, V., Emmons, C. K., & Veirs, S. (2009). Speaking up: Killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. *Journal of the Acoustical Society of America, 125*(1), EL27-EL32.

Hooker, S. K., Whitehead, H., & Gowans, S. (1999). Marine protected area design and the spatial and temporal distribution of cetaceans in a submarine canyon. *Conservation Biology, 13*(3), 592-602.

Houser, D. S. (2006). A method for modeling marine mammal movement and behavior for environmental impact assessment. *IEEE Journal of Oceanic Engineering, 31*(1), 76-81.

Houser, D. S., & Cross, M. J. (1999). *Marine Mammal Movement and Behavior (3MB): A Component of the Effects of Sound on the Marine Environment (ESME) Distributed Model*. Version 8.08, by BIOMIMETICA.

Houser, D. S., Dankiewicz -Talmadge, L. A., Stockard, T. K., & Ponganis, P. J. (2010). Investigation of the potential for vascular bubble formation in a repetitively diving dolphin. *Journal of Experimental Biology, 213*(1), 52-62.

Houser, D. S., Helweg, D. A., & Moore, P. W. B. (2001). A bandpass filter-bank model of auditory sensitivity in the humpback whale. *Aquatic Mammals, 27*(2), 82-91.

Illingworth & Rodkin, Inc. (2007). Appendix I. Compendium of pile driving sound data. In *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* (pp. 129). Sacramento, CA: Illingworth & Rodkin, Inc. for the California Department of Transportation, Sacramento, CA.

Inger, R., Attrill, M. J., Bearhop, S., Broderick, A. C., James Grecian, W., Hodgson, D. J., . . . Godley, B. J. (2009). Marine renewable energy: Potential benefits to biodiversity? An urgent call for research. *Journal of Applied Ecology, 46*(6), 1145-1153. doi:doi:10.1111/j.1365-2664.2009.01697.x

Ireland, D. S., Rodrigues, R., Funk, D., Koski, W., & Hannay, D. E. (2009). *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–October 2008: 90-Day Report* LGL Report P1049-1).

Jacobs, S. R., & Terhune, J. M. (2000). Harbor seal (*Phoca vitulina*) numbers along the New Brunswick coast of the Bay of Fundy in the fall in relation to aquaculture. *Northeastern Naturalist, 7*(3), 289-296. doi:10.1656/1092-6194(2000)007[0289:HSPVNA]2.0.CO;2

Jefferson, T. A., Webber, M. A., & Pitman, R. L. (2008). *Marine Mammals of the World, A Comprehensive Guide to their Identification*. Amsterdam: Elsevier.

Jefferson, T. A., Weir, C. R., Anderson, R. C., Ballance, L. T., Kenney, R. D., & Kiszka, J. J. (2014). Global distribution of Risso's dolphin *Grampus griseus*: A review and critical evaluation. *Mammal Review, 44*(1), 56-68. doi:doi:10.1111/mam.12008

Jensen, F. H., Bejder, L., Wahlberg, M., Soto, N. A., Johnson, M., & Madsen, P. T. (2009). Vessel noise effects on delphinid communication. *Marine Ecology-Progress Series, 395*, 161-175. doi:10.3354/meps08204

Jessopp, M., Cronin, M., & Hart, T. (2013). Habitat-Mediated Dive Behavior in Free-Ranging Grey Seals. *PLoS ONE, 8*(5), e63720. doi:10.1371/journal.pone.0063720

Jochens, A. E., Biggs, D., Benoit-Bird, K., Engelhaupt, D., Gordon, J., Hu, C., . . . Johnson, M. (2008). *Sperm Whale Seismic Study in the Gulf of Mexico: Synthesis Report* OCS Study MMS 2008-006). US Dept. of Interior, Minerals Management Service, Gulf of Mexico OCS Region.

Johnson, S. R., Richardson, W. J., Yazvenko, S. B., Blokhin, S. A., Gailey, G., Jenkerson, M. R., . . . Egging, D. E. (2007). A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. *Environmental Monitoring and Assessment, 134*(1), 1. doi:10.1007/s10661-007-9813-0

Katona, S. K., & Beard, J. A. (1990). *Population size, migrations and feeding aggregations of the humpback whale (Megaptera novaeangliae) in the western North Atlantic Ocean*.

Keenan, S. F., Benfield, M. C., & Blackburn, J. K. (2007). Importance of the artificial light field around offshore petroleum platforms for the associated fish community. *Marine Ecology Progress Series, 331*, 219-231.

Kenney, M. K. (1994). *Harbor seal population trends and habitat use in Maine.* (M.Sc.), University of Maine, Orono, ME.

Kenney, R. D. (1990). Bottlenose dolphins off the north-eastern United States. In S. Leatherwood & R. R. Reeves (Eds.), *The bottlenose dolphin*. San Diego, CA: Academic Press.

Kenney, R. D., Hyman, M. A. M., Owen, R. E., Scott, G. P., & Winn, H. E. (1986). Estimation of prey densities required by western North Atlantic right whales. *Marine Mammal Science, 2*(1), 1-13. doi:doi:10.1111/j.1748-7692.1986.tb00024.x

Kenney, R. D., Scott, G. P., Thompson, T. J., & Winn, H. E. (1997). Estimates of prey consumption and trophic impacts of cetaceans in the USA northeast continental shelf ecosystem. *Journal of Northwest Atlantic fishery science, 22*, 155-171.

Kenney, R. D., & Vigness-Raposa, K. J. (2010). Marine mammals and sea turtles of Narragansett Bay, Block Island Sound, Rhode Island Sound, and nearby waters: An analysis of existing data for the Rhode Island Ocean Special Area Management Plan. In *RICRMC (Rhode Island Coastal Resources Management Council)*

Ocean Special Area Management Plan (SAMP). Appendix A: Technical Reports for the Rhode Island Ocean Special Area Management Plan (Vol. 2, pp. 705-1042).

Kenney, R. D., Winn, H. E., & Macaulay, M. C. (1995). Cetaceans in the Great South Channel, 1979–1989: Right whale (*Eubalaena glacialis*). *Continental Shelf Research, 15*(4), 385-414. doi:https://doi.org/10.1016/0278-4343(94)00053-P

Knowlton, A. R., & Kraus, S. D. (2001). Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. *Journal of Cetacean Research and Management (special issue), 2*, 193-208.

Koschinski, S., & Lüdemann, K. (2013). *Development of Noise Mitigation Measures in Offshore Wind Farm Construction*. Commissioned by the Federal Agency for Nature Conservation (Bundesamt für Naturschutz, BfN). Original report (in German) published Jul 2011, updated Feb 2013. Nehmten and Hamburg, Germany. https://www.bfn.de/fileadmin/MDB/documents/themen/meeresundkuestenschutz/downloads/Berichte-und-Positionspapiere/Mitigation-Measures-Underwater-Noise_2013-08-27_final.pdf.

Kraus, S. D., Brown, M. W., Caswell, H., Clark, C. W., Fujiwara, M., Hamilton, P. K., . . . Rolland, R. M. (2005). North Atlantic Right Whales in Crisis. *Science, 309*(5734), 561-562. doi:10.1126/science.1111200

Kraus, S. D., Leiter, S., Stone, K., Wikgren, B., Mayo, C., Hughes, P., . . . Tielens, J. (2016). *Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles*. US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2016-054. Sterling, Virginia.

Kryter, K. D. (1985). *The Effects of Noise on Man* (2nd ed.). Orlando, FL: Academic Press.

Kujawa, S. G., & Liberman, M. C. (2009). Adding insult to injury: Cochlear nerve degeneration after 'temporary' noise induced hearing loss. *Journal of Neuroscience, 29*(45), 14077-14086.

LaBrecque, E., Curtice, C., Harrison, J., Van Parijs, S. M., & Halpin, P. N. (2015). 2. Biologically Important Areas for cetaceans within U.S. waters - East coast region. *Biologically Important Areas for cetaceans within U.S. waters. Aquatic Mammals (Special Issue), 41*(1), 17-29.

Lafortuna, C., L., Jahoda, M., Azzellino, A., Saibene, F., & Colombini, A. (2003). Locomotor behaviours and respiratory pattern of the Mediterranean fin whale (*Balaenoptera physalus*). *European Journal of Applied Physiology, 90*(3-4), 387-395.

Lander, M. E., Harvey, J. T., Hanni, K. D., & Morgan, L. E. (2002). Behavior, movements, and apparent survival of rehabilitated and free-ranging harbor seal pups. *Journal of Wildlife Management, 66*(1), 19-28. doi:10.2307/3802867

Lavigne, D. M., & Kovacs, K. M. (1988). *Harps & hoods: Ice-breeding seals of the northwest Atlantic*. Waterloo, ON, Canada: University of Waterloo Press.

Lavigueur, L., & Hammill, M. O. (1993). Distribution and seasonal movements of grey seals, *Halichoerus grypus*, born in the Gulf of St. Lawrence and eastern Nova Scotia shore. *Canadian Field-Naturalist, 107*(3), 329-340.

Le Prell, C. G., Henderson, D., Fay, R. R., & Popper, A. N. (2012). *Noise-induced hearing loss: Scientific advances*. New York: Springer Science & Business Media.

Leatherwood, S., Caldwell, D. K., & Winn, H. E. (1976). *Whales, dolphins, and porpoises of the western North Atlantic. A guide to their identification*. NOAA Technical Report NMFS Circ. 396.

Lesage, V., Barrette, C., Kingsley, M. C., & Sjare, B. (1999). The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River estuary, Canada. *Marine Mammal Science, 15*(1), 65-84.

Lesage, V., & Hammill, M. O. (2001). The status of the grey seal, *Halichoerus grypus*, in the Northwest Atlantic. *Canadian Field-Naturalist, 115*(4), 653-662.

Lesage, V., Hammill, M. O., & Kovacs, K. M. (1999). Functional classification of harbor seal (*Phoca vitulina*) dives using depth profiles, swimming velocity, and an index of foraging success. *Canadian Journal of Zoology, 77*(1), 74-87.

Liberman, M. C. (2014). Noise-induced hearing loss: Permanent vs. temporary threshold shifts and the effects of hair-cell vs. neuronal degeneration. In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life, II* (pp. 567-570). New York: Springer.

Lindeboom, H. J., Kouwenhoven, H. J., Bergman, M. J. N., Bouma, S., Brasseur, S., Daan, R., . . . Scheidat, M. (2011). Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. *Environmental Research Letters, 6*(3), 1-13. doi:10.1088/1748-9326/6/3/035101

Lippert, S., Nijhof, M., Lippert, T., Wilkes, D., Gavrilov, A., Heitmann, K., . . . Theobald, P. (2016). COMPILE—A Generic Benchmark Case for Predictions of Marine Pile-Driving Noise. *IEEE Journal of Oceanic Engineering, 41*(4), 1061-1071. doi:10.1109/JOE.2016.2524738

Ljungblad, D. K., Wursig, B., Swartz, S. L., & Keene, J. M. (1988). Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. *Arctic, 41*(3), 183-194.

Longhurst, A. R. (1998). *Ecological geography of the sea* (2nd ed.): Elsevier Academic Press.

Lopez, B. D. (2009). The bottlenose dolphin *Tursiops truncatus* foraging around a fish farm: Effects of prey abundance on dolphin's behavior. *Current Zoology, 55*(4), 243-248.

Love, M. S., Nishimoto, M. M., Clark, S., & Bull, A. S. (2015). *Analysis of fish populations at platforms off Summerland, California* Report by Marine Science Institute for U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region. OCS Study 2015-019. https://www.boem.gov/2015-019/.

Lowry, L. F., Frost, K. J., Hoep, J. M., & Delong, R. A. (2001). Movements of satellite-tagged subadult and adult harbor seals in Prince William Sound, Alaska. *Marine Mammal Science, 17*(4), 835-861.

Luís, A. R., Couchinho, M. N., & dos Santos, M. E. (2014). Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. *Marine Mammal Science, 30*(4), 1417-1426. doi:10.1111/mms.12125

MacGillivray, A. O. (2014). A model for underwater sound levels generated by marine impact pile driving. *Proceedings of Meetings on Acoustics, 20*(1), 045008.

MacGillivray, A. O., & Chapman, N. R. (2012). Modeling underwater sound propagation from an airgun array using the parabolic equation method. *Canadian Acoustics, 40*(1), 19-25.

Madsen, P. T., Johnson, M., Miller, P. J. O., Aguilar Soto, N., Lynch, J., & Tyack, P. (2006). Quantitative measures of air-gun pulses recorded on sperm whales (*Physeter macrocephalus*) using acoustic tags during controlled exposure experiments. *Journal of the Acoustical Society of America, 120*(4), 2366-2379.

Madsen, P. T., Møhl, B., Nielsen, B. K., & Wahlberg, M. (2002). Male sperm whale behaviour during exposures to distant seismic survey pulses. *Aquatic Mammals, 28*(3), 231-240.

Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K., & Tyack, P. L. (2006). Wind turbine underwater noise and marine mammals: Implications of current knowledge and data needs. *Marine Ecology Progress Series, 309*, 279-295.

Malme, C. I., & Miles, P. R. (1985, Jan 1985). *Behavioral responses of marine mammals (gray whales) to seismic discharges.* Paper presented at the Proceedings of the Workshop on Effects of Explosives Use in the Marine Environment, Halifax, NS.

Malme, C. I., Miles, P. R., Clark, C. W., Tyack, P., & Bird, J. E. (1984). *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Phase II: January 1984 migration* (5586)(Report prepared by Bolt, Beranek and Newman Inc. for the U.S. Department of the

Interior, Minerals Management Service. Cambridge, MA (USA). https://www.boem.gov/BOEM-Newsroom/Library/Publications/1983/rpt5586.aspx.

Malme, C. I., Miles, P. R., Clark, C. W., Tyak, P., & Bird, J. E. (1983). *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior* (5366)(http://www.boem.gov/BOEM-Newsroom/Library/Publications/1983/rpt5366.aspx.

Malme, C. I., Miles, P. R., Tyack, P., Clark, C. W., & Bird, J. E. (1985). *Investigation of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Feeding Humpback Whale Behavior* Report No. NTIS PB86-218385). Report from BBN Labs Inc. for U.S. Minerals Management Service.

Malme, C. I., Würsig, B., Bird, J. E., & Tyack, P. L. (1986). *Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modeling* 56).

Malme, C. I., Würsig, B., Bird, J. E., & Tyack, P. L. (1988). Observations of feeding gray whale responses to controlled industrial noise exposure. In W. M. Sackinger, M. O. Jeffries, J. L. Imm, & S. D. Treacy (Eds.), *Port and ocean engineering under Arctic conditions* (Vol. 2). Fairbanks: University of Alaska, Geophysical Institute.

Mansfield, A. W. (1966). The grey seal in eastern Canadian waters. *Canadian Audubon Magazine, 28*, 161-166.

Martins, D. T. L., Rossi-Santos, M. R., & Silva, F. J. D. L. (2016). Effects of anthropogenic noise on the acoustic behaviour of *Sotalia guianensis* (Van Bénéden, 1864) in Pipa, North-eastern Brazil. *Journal of the Marine Biological Association of the United Kingdom, 98*(2), 1-8.

Mate, B. R., Lagerquist, B. A., Winsor, M., Geraci, J., & Prescott, J. H. (2005). Movements and dive habits of a satellite-monitored longfinned pilot whale (*Globicephala melas*) in the northwest Atlantic. *Marine Mammal Science, 21*(1), 136-144.

Mate, B. R., Stafford, K. M., Nawojchik, R., & Dunn, J. L. (1994). Movements and dive behavior of a satellite-monitored Atlantic white-sided dolphin (*Lagenorhynchus acutus*) in the Gulf of Maine. *Marine Mammal Science, 10*(1), 116-121.

Mayo, C. A., & Marx, M. K. (1990). Surface foraging behaviour of the North Atlantic right whale, *Eubalaena glacialis*, and associated zooplankton characteristics. *Canadian Journal of Zoology, 68*(10), 2214-2220. doi:10.1139/z90-308

McCauley, R. D., Fewtrell, J., Duncan, A. J., Jenner, C., Jenner, M.-N., Penrose, J. D., . . . McCabe, K. (2000). *Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid* (R99-15)(Prepared for Australian Petroleum Production Exploration Association by Centre for Maine Science and Technology. Western Australia. http://cmst.curtin.edu.au/publications/.

McCauley, R. D., Fewtrell, J., Duncan, A. J., Jenner, C., Jenner, M.-N., Penrose, J. D., . . . Mccabe, K. (2000). Marine seismic surveys: A study of environmental implications. *Australian Petroleum Production Exploration Association (APPEA) Journal, 40*(1), 692-708.

McCauley, R. D., Jenner, M.-N., Jenner, C., McCabe, K. A., & Murdoch, J. (1998). The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: Preliminary results of observations about a working seismic vessel and experimental exposures. *Australian Petroleum Production Exploration Association (APPEA) Journal, 38*(1), 692-707.

McCauley, R. D., Jenner, M. N., Jenner, C., & Cato, D. H. (1998). Observations of the movements of humpback whales about an operating seismic survey vessel near Exmouth, Western Australia. *Journal of the Acoustical Society of America, 103*, 2909-2909.

McConnell, A., Routledge, R., & Connors, B. M. (2010). Effect of artificial light on marine invertebrate and fish abundance in an area of salmon farming. *Marine Ecology Progress Series, 419*, 147-156.

McDonald, M. A., Hildebrand, J. A., & Webb, S. C. (1995). Blue and fin whales observed on a seafloor array in the Northeast Pacific. *Journal of the Acoustical Society of America, 98*(2), 712-721.

McKenna, M. F. (2011). *Blue whale response to underwater noise from commercial ships.* (Ph.D.), University of California, San Diego, CA.

Mead, J. G., & Potter, C. W. (1995). Recognizing two populations of the bottlenose dolphin (*Tursiops truncatus*) of the Atlantic coast of North America-morphologic and ecologic considerations. *International Biological Research Institute Reports, 5*, 31-43.

Melcon, M. L., Cummins, A. J., Kerosky, S. M., Roche, L. K., Wiggins, S. M., & Hildebrand, J. A. (2012). Blue whales respond to anthropogenic noise. *PLoS ONE, 7*(2), 1-6.

Meynecke, J. O., Vindenes, S., & Teixeira, D. (2013). Monitoring humpback whale (*Megaptera novaeangliae*) behaviour in a highly urbanised coastline: Gold Coast, Australia. In E. Moksness, E. Dahl, & J. Støttru (Eds.), *Global Challenges in Integrated Coastal Zone Management* (pp. 101-113).

Miller, G. W., Elliott, R. E., Koski, W. R., Moulton, V. D., & Richardson, W. J. (1999). Whales In W. J. Richardson (Ed.), *Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998* (pp. 5-1 to 5-109): Rep. TA2230-3. Report by LGL Ltd. and Greeneridge Sciences Inc. for Western Geophysical and National Marine Fisheries Service.

Miller, G. W., Moulton, V. D., Davis, R. A., Holst, M., Millman, P., MacGillivray, A. O., & Hannay, D. E. (2005). Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001-2002. In S. L. Armsworthy, P. J. Cranford, & K. Lee (Eds.), *Offshore oil and gas environmental effects monitoring/Approaches and technologies* (pp. 511-542). Columbus, OH: Battelle Press.

Miller, P. J. O., Aoki, K., Rendell, L. E., & Amano, M. (2008). Stereotypical resting behavior of the sperm whale. *Current Biology, 18*(1), R21-R23.

Miller, P. J. O., Johnson, M. P., Tyack, P. L., & Terray, E. A. (2004). Swimming gaits, passive drag and buoynacy of diving sperm whales *Physeter macrocephalus*. *Journal of Experimental Biology, 207*, 1953-1967.

Møhl, B., & Andersen, S. (1973). Echolocation: High-frequency component in the click frequency of the harbour porpoise (*Phocoena phocoena* L.). *Journal of the Acoustical Society of America, 54*, 1368-1372.

Moulton, V. D., & Holst, M. (2010). *Effects of seismic survey sound on cetaceans in the Northwest Atlantic* 182). Environmental Studies Research Funds.

Murase, H., Tamura, T., Otani, S., & Nishiwaki, S. (2015). Satellite tracking of Bryde's whales *Balaenoptera edeni* in the offshore western North Pacific in summer 2006 and 2008. *Fisheries Science, 82*(1), 35-45. doi:10.1007/s12562-015-0946-8

Nedwell, J. R., Parvin, S. J., Edwards, B., Workman, R., Brooker, A. G., & Kynoch, J. E. (2007). *Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters* 544R0738). Report prepared by Subacoustech for COWRIE Ltd. Newbury, UK.

Nedwell, J. R., & Turnpenny, A. W. (1998). *The use of a generic frequency weighting scale in estimating environmental effect*. Paper presented at the Workshop on Seismics and Marine Mammals, London, U.K.

Nedwell, J. R., Turnpenny, A. W. H., Lovell, J., Parvin, S. J., Workman, R., & Spinks, J. A. L. (2007). *A validation of the dB_{ht} as a measure of the behavioural and auditory effects of underwater noise* 534R1231). Report prepared by Subacoustech Ltd. for the UK Department of Business, Enterprise and Regulatory Reform under Project No. RDCZ/011/0004. http://www.subacoustech.com/wp-content/uploads/534R1231.pdf.

Nehls, G., Rose, A., Diederichs, A., Bellmann, M., & Pehlke, H. (2016). Noise mitigation during pile driving efficiently reduces disturbance of marine mammals. In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II* (2015/11/28 ed., Vol. 875, pp. 755-762). New York: Springer.

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., . . . Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology, 27*(2), 314-322.

Nieukirk, S. L., Mellinger, D. K., Hildebrand, J. A., McDonald, M. A., & Dziak, R. P. (2005). *Downward shift in the frequency of blue whale vocalizations*. Paper presented at the Abstracts of the 16th Biennial Conference on the Biology of Marine Mammals, San Diego, CA.

Nieukirk, S. L., Mellinger, D. K., Moore, S. E., Klinck, K., Dziak, R. P., & Goslin, J. (2012). Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999–2009. *Journal of the Acoustical Society of America, 131*(2), 1102-1112.

NOAA Fisheries. (1993). *Stellwagen Bank Management Plan and Final Environmental Impact Statement*. https://stellwagen.noaa.gov/management/1993plan/toc.html.

NOAA Fisheries. (2010). *Final recovery plan for the sperm whale (Physeter macrocephalus)*. National Marine Fisheries Service. Silver Spring, MD, USA.

NOAA Fisheries. (2018a, 30 Aug 2018). 2016-2018 Humpback Whale Unusual Mortality Event along the Atlantic Coast. Retrieved from https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2018-humpback-whale-unusual-mortality-event-along-atlantic-coast

NOAA Fisheries. (2018b, 30 Aug 2018). 2017-2018 Minke Whale unusual mortality event along the Atlantic Coast. Retrieved from https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2018-minke-whale-unusual-mortality-event-along-atlantic-coast

NOAA Fisheries. (2018c, 30 Aug 2018). 2017-2018 North Atlantic right whale unusual mortality event. Retrieved from https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2018-north-atlantic-right-whale-unusual-mortality-event

NOAA Fisheries. (2018d). Atlantic white-sided dolphin (*Lagenorhynchus acutus*) overview. Retrieved from https://www.fisheries.noaa.gov/species/atlantic-white-sided-dolphin

NOAA Fisheries. (2018e). Common bottlenose dolphin (*Tursiops truncatus*) overview. Retrieved from https://www.fisheries.noaa.gov/species/common-bottlenose-dolphin

NOAA Fisheries. (2018f). Fin whale (*Balaenoptera physalus*) overview. Retrieved from https://www.fisheries.noaa.gov/species/fin-whale

NOAA Fisheries. (2018g). Gray seal (*Halichoerus grypus atlantica*) overview. Retrieved from https://www.fisheries.noaa.gov/species/gray-seal

NOAA Fisheries. (2018h). Harbor porpoise (*Phocoena phocoena*) overview. Retrieved from https://www.fisheries.noaa.gov/species/harbor-porpoise

NOAA Fisheries. (2018i). Harbor seal (*Phoca vitulina*) overview. Retrieved from https://www.fisheries.noaa.gov/species/harbor-seal

NOAA Fisheries. (2018j). Harp seal (*Pagophilus groenlandicus*) overview. Retrieved from https://www.fisheries.noaa.gov/species/harp-seal

NOAA Fisheries. (2018k). Humpback whale (*Megaptera novaeangliae*) overview. Retrieved from https://www.fisheries.noaa.gov/species/humpback-whale

NOAA Fisheries. (2018l). Long-finned pilot whale (*Globicephala melas*) overview. Retrieved from https://www.fisheries.noaa.gov/species/long-finned-pilot-whale

NOAA Fisheries. (2018m). Marine Life Viewing Guidelines. Retrieved from https://www.fisheries.noaa.gov/topic/marine-life-viewing-guidelines#guidelines-&-distances

NOAA Fisheries. (2018n). Minke whale (*Balaenoptera acutorostrata*) overview. Retrieved from https://www.fisheries.noaa.gov/species/minke-whale

NOAA Fisheries. (2018o). North Atlantic right whale (*Eubalaena glacialis*) overview. Retrieved from https://www.fisheries.noaa.gov/species/north-atlantic-right-whale

NOAA Fisheries. (2018p). Risso's dolphin (*Grampus griseus*) overview. Retrieved from https://www.fisheries.noaa.gov/species/rissos-dolphin

NOAA Fisheries. (2018q). Sei Whale (*Balaenoptera borealis*) overview. Retrieved from https://www.fisheries.noaa.gov/species/sei-whale

NOAA Fisheries. (2018r). Short-beaked common dolphin (*Delphinus delphis*) overview. Retrieved from https://www.fisheries.noaa.gov/species/short-beaked-common-dolphin

NOAA Fisheries. (2018s). Short-finned pilot whale (*Globicephala macrorhynchus*) overview. Retrieved from https://www.fisheries.noaa.gov/species/short-finned-pilot-whale

NOAA Fisheries. (2018t). Sperm whale (*Physeter macrocephalus*) overview. Retrieved from https://www.fisheries.noaa.gov/species/sperm-whale

Nordøy, E. S., Folkow, L. P., Potelov, V., Prischemikhin, V., & Blix, A. S. (2008). Seasonal distribution and dive behaviour of harp seals (*Pagophilus groenlandicus*) of the White Sea–Barents Sea stock. *Polar Biology, 31*(9), 1119–1135.

Northridge, S. P., Tasker, M., Webb, A., & Williams, J. E. (1997). White-beaked *Lagenorhynchus albirostris* and Atlantic white-sided dolphin *L. acutus* distributions in northwest European and US North Atlantic waters. *Report of the International Whaling Commission, 47*, 797-805.

Nowacek, D. P., Thorne, L. H., Johnston, D. W., & Tyack, P. L. (2007). Responses of cetaceans to anthropogenic noise. *Mammal Review, 37*(2), 81-115.

O'Neill, C., Leary, D., & McCrodan, A. (2010). Sound Source Verification. In M. K. Blees, K. G. Hartin, D. S. Ireland, & D. E. Hannay (Eds.), *Marine mammal monitoring and mitigation during open water seismic exploration by Statoil USA E&P Inc. in the Chukchi Sea, August-October 2010: 90-day report* (pp. 1-34): LGL Report P1119. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. for Statoil USA E&P Inc., National Marine Fisheries Service (U.S.), and U.S. Fish and Wildlife Service.

O'Brien, J. M., Beck, S., Berrow, S. D., André, M., van der Schaar, M., O'Connor, I., & McKeown, E. P. (2016). *The Use of Deep Water Berths and the Effect of Noise on Bottlenose Dolphins in the Shannon Estuary cSAC*, New York, NY.

Osmek, S., Calambokidis, J., Laake, J., Gearin, P., DeLong, R., Scordino, J., . . . Brown, R. (1996). *Assessment of the Status of Harbor Porpoise (Phocoena phocoena) in Oregon and Washington Waters*. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-76. https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-76.pdf.

Otani, S., Naito, Y., Kato, A., & Kawamura, A. (2000). Diving behavior and swimming speed of a free-ranging harbor porpoise, *Phocoena phocoena*. *Marine Mammal Science, 16*(4), 811-814. doi:10.1111/j.1748-7692.2000.tb00973.x

Otani, S., Naito, Y., Kawamura, A., Kawasaki, M., Nishiwaki, S., & Kato, A. (1998). Diving behavior and performance of harbor porpoises, *Phocoena phocoena*, in Funka Bay, Hokkaido, Japan. *Marine Mammal Science, 14*(2), 209-220. doi:10.1111/j.1748-7692.1998.tb00711.x

Pace, R. M., Corkeron, P. J., & Kraus, S. D. (2017). State-space mark-recapture estimates reveal a recent decline in abundance of North Atlantic right whales. *Ecology and evolution, 7*(21), 8730-8741. doi:doi:10.1002/ece3.3406

Page, H., M. , Dugan, J., E. , Culver, C. S., & Hoesterey, J. C. (2006). Exotic invertebrate species on offshore oil platforms. *Marine Ecology Progress Series, 325*, 101-107.

Palka, D. L., Chavez-Rosales, S., Josephson, E., Cholewiak, D., Haas, H. L., Garrison, L., . . . Orphanides, C. (2017). *Atlantic Marine Assessment Program for Protected Species: 2010-2014*. U.S. Department of the Interior, Bureau of Ocean Energy Management, Atlantic OCS Region. OCS Study BOEM 2017-071. https://www.boem.gov/espis/5/5638.pdf.

Palsbøll, P. J., Allen, J., Berube, M., Clapham, P. J., Feddersen, T. P., Hammond, P. S., . . . Larsen, A. H. (1997). Genetic tagging of humpback whales. *Nature, 388*(6644), 767-769.

Papale, E., Gamba, M., Perez-Gil, M., Martin, V. M., & Giacoma, C. (2015). Dolphins adjust species-specific frequency parameters to compensate for increasing background noise. *PLoS ONE, 10*(4), e0121711. doi:10.1371/journal.pone.0121711

Parks, S. E., Clark, C. W., & Tyack, P. L. (2007). Short-and long-term changes in right whale calling behavior: The potential effects of noise on acoustic communication. *Journal of the Acoustical Society of America, 122*(6), 3725-3731.

Parks, S. E., Cusano, D. A., Bocconcelli, A., Friedlaender, A. S., & Wiley, D. N. (2016). Noise impacts on social sound production by foraging humpback whales. *Proceedings of Meetings on Acoustics, 27*(1), 010009. doi:10.1121/2.0000247

Parks, S. E., Groch, K., Flores, P., Sousa-Lima, R., & Urazghildiiev, I. R. (2016). *Humans, Fish, and Whales: How Right Whales Modify Calling Behavior in Response to Shifting Background Noise Conditions*, New York, NY.

Parks, S. E., Johnson, M., Nowacek, D., & Tyack, P. L. (2010). Individual right whales call louder in increased environmental noise. *Biology Letters, 7*, 33-35.

Parks, S. E., Johnson, M. P., Nowacek, D. P., & Tyack, P. L. (2012). *Changes in Vocal Behavior of North Atlantic Right Whales in Increased Noise*, New York, NY.

Parks, S. E., Urazghildiiev, I., & Clark, C. W. (2009). Variability in ambient noise levels and call parameters of North Atlantic right whales in three habitat areas. *Journal of the Acoustical Society of America, 125*(2), 1230-1239.

Payne, M., & Heinemann, D. W. (1990). *A distributional assessment of cetaceans in the shelf and shelf edge waters of the northeastern United States based on aerial and shipboard surveys, 1978-1988*. Report to National Marine Fisheries Science Center. Woods Hole, MA.

Payne, P. M., & Heinemann, D. W. (1993). The distribution of pilot whales (*Globicephala* spp.) in shelf/shelf edge and slope waters of the north-eastern United States, 1978-1988. *Report of the International Whaling Commission, Special Issue 14*, 51-68.

Payne, P. M., & Selzer, L. A. (1989). The distribution, abundance, and selected prey of the harbor seal, *Phoca vitulina concolor*, in southern New England. *Marine Mammal Science, 5*(2), 173-192. doi:doi:10.1111/j.1748-7692.1989.tb00331.x

Payne, P. M., Selzer, L. A., & Knowlton, A. R. (1984). *Distribution and density of cetaceans, marine turtles, and seabirds in the shelf waters of the northeastern United States, June 1980-December 1983, based on shipboard observations*. Report to National Marine Fisheries Service. Woods Hole, MA.

Petersen, J. K., & Malm, T. (2006). Offshore Windmill Farms: Threats to or Possibilities for the Marine Environment. *Ambio Special Report, 35*(2), 75-80. doi:10.1579/0044-7447(2006)35[75:OWFTTO]2.0.CO;2

Pettis, H., Pace, R. M., Schick, R. S., & Hamilton, P. (2017). *North Atlantic right whale consortium 2017 annual report card*. https://www.narwc.org/uploads/1/1/6/6/116623219/2017_report_cardfinal.pdf.

Pile Dynamics, Inc. (2010). GRLWEAP.

Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., . . . Tavolga, W. N. (2014). *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*: ASA Press and Springer.

Potter, J. R., Thillet, M., Douglas, C., Chitre, M. A., Doborzynski, Z., & Seekings, P. J. (2007). Visual and Passive Acoustic Marine Mammal Observations and High-Frequency Seismic Source Characteristics Recorded During a Seismic Survey. *IEEE Journal of Oceanic Engineering, 32*(2), 469-483.

Racca, R. G., Rutenko, A., Bröker, K., & Austin, M. (2012). *A line in the water - design and enactment of a closed loop, model based sound level boundary estimation strategy for mitigation of behavioural impacts from a seismic survey*. Paper presented at the 11th European Conference on Underwater Acoustics 2012, Edinburgh, United Kingdom.

Racca, R. G., Rutenko, A., Bröker, K., & Gailey, G. (2012). *Model based sound level estimation and in-field adjustment for real-time mitigation of behavioural impacts from a seismic survey and post-event evaluation of sound exposure for individual whales.* Paper presented at the Acoustics 2012 Fremantle: Acoustics, Development and the Environment, Fremantle, Australia.

Rako Gospić, N., & Picciulin, M. (2016). Changes in whistle structure of resident bottlenose dolphins in relation to underwater noise and boat traffic. *Marine Pollution Bulletin, 105*(1), 193-198.

Reeves, R. R. (1992). *The Sierra Club handbook of seals and sirenians*. San Francisco, CA: Sierra Club Books.

Reeves, R. R., & Read, A. J. (2003). Bottlenose dolphin, harbor porpoise, sperm whale and other toothed cetaceans. In G. A. Feldhamer, B. C. Thomspon, & J. A. Chapman (Eds.), *Wild Mammals of North America: Biology, Management and Conservation* (2nd ed., pp. 397-424). Baltimore, MD: John Hopkins University Press.

Reeves, R. R., & Whitehead, H. (1997). Status of the sperm whale, *Physeter macrocephalus*, in Canada. *Canadian Field-Naturalist, 111*(2), 293-307.

Reichmuth, C., Mulsow, J., Finneran, J. J., Houser, D. S., & Supin, A. Y. (2007). Measurement and Response Characteristics of Auditory Brainstem Responses in Pinnipeds. *Aquatic Mammals, 33*(1), 132-150.

Reiser, C. M., Funk, D. W., Rodrigues, R., & Hannay, D. E. (2011). *Marine mammal monitoring and mitigation during marine geophysical surveys by Shell Offshore, Inc. in the Alaskan Chukchi and Beaufort seas, July–October 2010: 90-day report* (P1171E–1)(Report by LGL Alaska Research Associates Inc. and JASCO applied Sciences for Shell Offshore Inc, National Marine Fishery Services, and U.S. Fish and Wildlife Services.

Rice, A. N., Tielens, J. T., Estabrook, B. J., Muirhead, C. A., Rahaman, A., Guerra, M., & Clark, C. W. (2014). Variation of ocean acoustic environments along the western North Atlantic coast: A case study in context of the right whale migration route. *Ecological Informatics, 21*, 89-99.

Richardson, D. T. (1976). *Assessment of harbor and gray seal populations in Maine 1974-1975*. Final report for Marine Mammal Commission. Washington, DC.

Richardson, D. T., & Rough, V. (1993). *A field guide to whales, porpoises, and seals from Cape Cod to Newfoundland*. Washington, DC: Smithsonian Institution Press.

Richardson, W. J., Greene, C. R., Jr., Malme, C. I., & Thomson, D. H. (1995). *Marine Mammals and Noise*. San Diego, CA: Academic Press.

Richardson, W. J., & Malme, C. I. (1993). Man-made noise and behavioral responses In J. J. Burnes, J. J. Montague, & C. J. Cowles (Eds.), *The bowhead whale* (pp. 631-700). Spec. Publi. 2 Soc. Mar. Mammal., Lawrence, KS.

Richardson, W. J., Miller, G. W., & Greene, C. R., Jr. (1999). Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. *Journal of the Acoustical Society of America, 106*(4), 2281-2281.

Richardson, W. J., Würsig, B., & Greene, C. R., Jr. (1986). Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. *Journal of the Acoustical Society of America, 79*(4), 1117-1128.

Risch, D., Clark, C. W., Dugan, P. J., Popescu, M., Siebert, U., & Van Parijs, S. M. (2013). Minke whale acoustic behavior and multi-year seasonal and diel vocalization patterns in Massachusetts Bay, USA. *Marine Ecology Progress Series, 489*, 279-295. doi:10.3354/meps10426

Risch, D., Corkeron, P. J., Ellison, W. T., & Van Parijs, S. M. (2012). Changes in humpback whale song occurrence in response to an acoustic source 200 km away. *PLoS ONE, 7*(1), e29741.

Roberts, J. J., Best, B. D., Mannocci, L., Fujioka, E., Halpin, P. N., Palka, D. L., . . . Lockhart, G. G. (2016). Habitat-based cetacean density models for the U.S. Atlantic and Gulf of Mexico. *Scientific Reports, 6*. doi:10.1038/srep22615

Roberts, J. J., Best, B. D., Mannocci, L., Halpin, P. N., Palka, D. L., Garrison, L. P., . . . McLellan, W. M. (2015). *Density Model for Seals (Phocidae) Along the U.S. East Coast, Preliminary Results*. Version 3.2. Marine Geospatial Ecology Lab, Duke University. Durham, NC.

Roberts, J. J., Mannocci, L., & Halpin, P. N. (2017). *Final project report: Marine species density data gap assessments and update for the AFTT study area, 2016-2017 (Opt. Year 1)*. Document version 1.4. Report prepared for Naval Facilities Engineering Command, Atlantic by the Duke University Marine Geospatial Ecology Lab. Durham, NC.

Roberts, J. J., Mannocci, L., Schick, R. S., & Halpin, P. N. (2018). *Final Project Report: Marine Species Density Data Gap Assessments and Update for the AFTT Study Area, 2017-2018 (Opt. Year 2)*. Document version 1.2. Report by the Duke University Marine Geospatial Ecology Lab for Naval Facilities Engineering Command, Atlantic Durham, NC, USA.

Robinson, S. P., Theobald, P. D., Hayman, G., Wang, L. S., Lepper, P. A., Humphrey, V., & Mumford, S. (2011). *Measurement of Noise Arising from Marine Aggregate Dredging Operations*. MALSF (MEPF Ref no. 09/P108).

Rone, B. K., & Pace, I., Richard M. (2012). A simple photograph-based approach for discriminating between free-ranging long-finned (*Globicephala melas*) and short-finned (*G. macrorhynchus*) pilot whales off the east coast of the United States. *Marine Mammal Science, 28*(2), 254-275. doi:doi:10.1111/j.1748-7692.2011.00488.x

Rosel, P. E., Hansen, L., & Hohn, A. A. (2009). Restricted dispersal in a continuously distributed marine species: Common bottlenose dolphins *Tursiops truncatus* in coastal waters of the western North Atlantic. *Molecular Ecology, 18*(24), 5030-5045.

Rosenfeld, M., George, M., & Terhune, J. M. (1988). Evidence of autumnal harbour seal, *Phoca vitulina*, movement from Canada to the United States. *Canadian Field-Naturalist, 102*(3), 527-529.

Russell, D. J. F., Brasseur, S. M. J. M., Thompson, D., Hastie, G. D., Janik, V. M., Aarts, G., . . . McConnell, B. (2014). Marine mammals trace anthropogenic structures at sea. *Current Biology, 24*(14), R638-R639.

Sairanen, E. E. (2014). *Baltic Sea underwater soundscape: Weather and ship induced sounds and the effect of shipping on harbor porpoise (Phocoena phocoena) activity.* (M.Sc.), University of Helsinki, Helsinki, Finland. Retrieved from https://helda.helsinki.fi/bitstream/handle/10138/153043/Gradu_SairanenEeva(1).pdf?sequence=1

Sammarco, P. W., Porter, S. A., & Cairns, S. D. (2010). A new coral species introduced into the Atlantic Ocean – *Tubastraea micranthus* (Ehrenberg 1834)(Cnidaria, Anthozoa, Scleractinia): An invasive threat? *Aquatic Invasions, 5*(2), 131-140.

Scheidat, M., Tougaard, J., Brasseur, S., Carstensen, J., van Polanen Petel, T., Teilmann, J., & Reijnders, P. (2011). Harbour porpoises (*Phocoena phocoena*) and wind farms: A case study in the Dutch North Sea. *Environmental Research Letters, 6*(2), 025102.

Scheifele, P. M., Andrew, S., Cooper, A. G., Darre, M., Musiek, F. E., & Max, L. (2005). Indication of a Lombard vocal response in the St. Lawrence River beluga. *Journal of the Acoustical Society of America, 117*(3), 1486-1492. doi:10.1121/1.1835508

Schneider, D. C., & Payne, P. M. (1983). Factors affecting haul-out of harbor seals at a site in southeastern Massachusetts. *Journal of Mammalogy, 64*(3), 518-520.

Schreer, J. F., & Kovacs, K. M. (1997). Allometry of diving capacity in air-breathing vertebrates. *Canadian Journal of Zoology, 75*(3), 339-358. doi:10.1139/z97-044

Schroeder, C. L. (2000). *Population status and distribution of the harbor seal in Rhode Island waters.* (M.S.), University of Rhode Island, Narragansett, RI.

Sciacca, V., Viola, S., Pulvirenti, S., Riccobene, G., Caruso, F., De Domenico, E., & Pavan, G. (2016). Shipping noise and seismic airgun surveys in the Ionian Sea: Potential impact on Mediterranean fin whale. *Proceedings of Meetings on Acoustics, 27*(1), 040010. doi:10.1121/2.0000311

Scott, M. D., & Chivers, S. J. (2009). Movements and diving behavior of pelagic spotted dolphins. *Marine Mammal Science, 25*(1), 137-160.

Scott, T. M., & Sadove, S. S. (1997). Sperm whale, *Physeter macrocephalus*, sightings in the shallow shelf waters off Long Island, New York. *Marine Mammal Science, 13*(2), 317-321. doi:doi:10.1111/j.1748-7692.1997.tb00636.x

Selzer, L. A., & Payne, P. M. (1988). The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. *Marine Mammal Science, 4*(2), 141-153.

Sergeant, D. E. (1965). Migrations of harp seals *Pagophilus groenlandicus* (Erxleben) in the Northwest Atlantic. *Journal of the Fisheries Board of Canada, 22*(2), 433-464.

Sergeant, D. E. (1977). Stocks of fin whales (*Balaenoptera physalus L.*) in the North Atlantic Ocean. *Reports of the International Whaling Commission, 27*, 460-473.

Sergeant, D. E., Mansfield, A. W., & Beck, B. (1970). Inshore Records of Cetacea for Eastern Canada, 1949–68. *Journal of the Fisheries Research Board of Canada, 27*(11), 1903-1915. doi:10.1139/f70-216

Sieswerda, P. L., Spagnoli, C. A., & Rosenthal, D. S. (2015). *Notes on a new feeding ground for humpback whales in the Western New York Bight*. Paper presented at the Southeast and Mid-Atlantic Marine Mammal Symposium, Virginia Beach, VI.

Sills, J. M., Southall, B. L., & Reichmuth, C. (2014). Amphibious hearing in spotted seals (*Phoca largha*): Underwater audiograms, aerial audiograms and critical ratio measurements. *Journal of Experimental Biology, 217*(5), 726-734.

Sills, J. M., Southall, B. L., & Reichmuth, C. (2017). The influence of temporally varying noise from seismic air guns on the detection of underwater sounds by seals. *Journal of the Acoustical Society of America, 141*(2), 996-1008.

Smith, J. N., Grantham, H. S., Gales, N., Double, M. C., Noad, M. J., & Paton, D. (2012). Identification of humpback whale breeding and calving habitat in the Great Barrier Reef. *Marine Ecology Progress Series, 447*, 259-272.

Smultea, M. A., Holst, M., Koski, W. R., & Stoltz, S. (2004). *Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the southeast Caribbean Sea and adjacent Atlantic Ocean, April–June 2004* TA2822-26).

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., Jr., . . . Tyack, P. L. (2007). Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals, 33*(4), 411-521.

Southall, B. L., Ellison, W. T., Clark, C., Mann, D. A., & Tollit, D. (2014). *Analytical Framework For Assessing Potential Effects Of Seismic Airgun Surveys On Marine Mammals In The Gulf Of Mexico (Gomex)* Southall Environmental Associates, Inc.

Southall, B. L., Nowaceck, D. P., Miller, P. J. O., & Tyack, P. L. (2016). Experimental field studies to measure behavioral responses of cetaceans to sonar. *Endangered Species Research, 31*, 293-315.

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., . . . Robertson, J. (2007). Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. *BioScience, 57*(7), 573-583. doi:10.1641/B570707

Stockin, K. A., Fairbairns, R. S., Parsons, E. C. M., & Sims, D. W. (2001). Effects of diel and seasonal cycles on the dive duration of the minke whale (*Balaenoptera acutorostrata*). *Journal of the Marine Biological Association of the United Kingdom, 81*(1), 189-190.

Stone, C. J. (2015). *Marine mammal observations during seismic surveys from 1994-2010* 463a). Report for Joint Nature Conservation Committee. Peterborough, UK. http://jncc.defra.gov.uk/pdf/JNCC%20Report%20463a_Final.pdf.

Stone, C. J., & Tasker, M. L. (2006). The effects of seismic airguns on cetaceans in UK waters. *Journal of Cetacean Research and Management, 8*(3), 255.

Sutcliffe, M. H., & Brodie, P. F. (1977). *Whale distributions in Nova Scotia waters*. Fisheries and Marine Service Technical Report No. 722. http://www.dfo-mpo.gc.ca/Library/18300.pdf.

Swingle, W. M., Barco, S. G., Pitchford, T. D., Mclellan, W. A., & Pabst, D. A. (1993). Appearance of juvenile humpback whales feeding in nearshore waters of Virginia. *Marine Mammal Science, 9*(3), 309-315. doi:doi:10.1111/j.1748-7692.1993.tb00458.x

Teilmann, J., Miller, M., Kirkrterp, R. A., Kastelein, R. A., Madsen, B. K., Nielsen, B. K., & Au, W. W. L. (2002). Characteristics of echolocation signals used by a harbour porpoise (*Phocoena phocoena*) in a target detection experiment. *Aquatic Mammals, 28*, 275-284.

Temte, J. L., & Wiig, Ø. (1991). Clines revisited: The timing of pupping in the harbour seal (*Phoca vitulina*). *Journal of Zoology, 224*(4), 617-632.

Tennessen, J. B., & Parks, S. E. (2016). Acoustic propagation modeling indicates vocal compensation in noise improves communication range for North Atlantic right whales. *Endangered Species Research, 30*, 225-237.

Terhune, J. M. (1999). Pitch separation as a possible jamming-avoidance mechanism in underwater calls of bearded seals (*Erignathus barbatus*). *Canadian Journal of Zoology, 77*(7), 1025-1034.

TetraTech. (2014). *Hydroacoustic Survey Report of Geotechnical Activities Virginia Offshore Wind Technology Advancement Project (VOWTAP).*

Thode, A. M., Kim, K. H., Blackwell, S. B., Greene, C. R., Nations, C. S., McDonald, T. L., & Macrander, A. M. (2012). Automated detection and localization of bowhead whale sounds in the presence of seismic airgun surveys. *Journal of the Acoustical Society of America, 131*(5), 3726-3747.

Todd, V. L. G., Lepper, P. A., & Todd, I. B. (2007). *Do porpoises target offshore installations as feeding stations?* Paper presented at the Improving Environmental Performance: A Challenge for the Oil Industry, Amsterdam, the Netherlands.

Tollit, D. J., Thompson, P. M., & Greenstreet, S. P. R. (1997). Prey selection by harbour seals, *Phoca vitulina*, in relation to variations in prey abundance. *Canadian Journal of Zoology, 75*(9), 1508-1518. doi:10.1139/z97-774

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H., & Rasmussen, P. (2009). Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena* (L.)). *Journal of the Acoustical Society of America, 126*(1), 11-14.

Tougaard, J., & Henrikson, O. D. (2009). Underwater noise from three types of offshore wind turbines: Estimation of impact zones for harbor porpoises and harbor seals. *Journal of the Acoustical Society of America, 125*(6), 3766-3773. doi:10.1121/1.3117444

Tougaard, J., Madsen, P. T., & Wahlberg, M. (2008). Underwater noise from construction and operation of offshore wind farms. *Bioacoustics, 17*(1-3), 143-146. doi:10.1080/09524622.2008.9753795

Tougaard, J., Wright, A. J., & Madsen, P. T. (2015). Cetacean noise criteria revisited in the light of proposed exposure limits for harbour porpoises. *Marine Pollution Bulletin, 90*(1), 196-208.

Tougaard, J., Wright, A. J., & Madsen, P. T. (2016). Noise Exposure Criteria for Harbor Porpoises. In A. N. Popper & A. D. Hawkins (Eds.), *The Effects of Noise on Aquatic Life II* (pp. 1167-1173). New York: Springer.

Tubelli, A., Zosuls, A., Ketten, D., & Mountain, D. C. (2012). *Prediction of a mysticete audiogram via finite element analysis of the middle ear.* Paper presented at the The effects of noise on aquatic life.

Tyack, P., Johnson, M., & Miller, P. (2003). Tracking Responses of Sperm Whales to Experimental Exposures of Airguns. In A. E. Jochens & D. C. Biggs (Eds.), *Sperm Whale Seismic Study in the Gulf of Mexico; Annual Report: Year 1*. New Orleans: Report prepared by Texas A&M University for U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. OCS Study MMS 2003-069.

Tyack, P. L., & Janik, V. M. (2013). Effects of Noise on Acoustic Signal Production in Marine Mammals. In H. Brumm (Ed.), *Animal Communication and Noise* (pp. 251-271). Berlin, Heidelberg: Springer.

Vineyard Wind. (2016). *Vineyard Wind protected species observer report 2016 geophysical and geotechnical survey*

Vineyard Wind. (2017). *Vineyard Wind protected species observer report 2017 geophysical and geotechnical survey*

Vineyard Wind. (2018). *Draft construction and operations plan volume I, June 8, 2018*.

Ward, B. G. (1999). *Movement patterns and feeding ecology of the Pacific coast bottlenose dolphin (Tursiops truncatus).* (Master), San Diego State University,

Waring, G. T., Josephson, E., Maze-Foley, K., & Rosel, P. E. (Eds.). (2015). *US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2014* (Vol. 231): NOAA Tech Memo NMFS NE.

Warner, G., Erbe, C., & Hannay, D. E. (2010). Underwater Sound Measurements. In C. M. Reiser, D. W. Funk, R. Rodrigues, & D. Hannay (Eds.), *Marine Mammal Monitoring and Mitigation during Open Water Shallow Hazards and Site Clearance Surveys by Shell Offshore Inc. in the Alaskan Chukchi Sea, July-October 2009: 90-Day Report* (pp. 1-54): LGL Report P1112-1. Report by LGL Alaska Research Associates Inc. and JASCO Applied Sciences for Shell Offshore Inc., National Marine Fisheries Service (U.S.), and U.S. Fish and Wildlife Service.

Wartzok, D., & Ketten, D. E. (1999). Marine Mammal Sensory Systems. In J. Reynolds & S. Rommel (Eds.), *Biology of Marine Mammals* (pp. 117-175). Washington, DC: Smithsonian Institution Press.

Wartzok, D., Popper, A. N., Gordon, J., & Merrill, J. (2003). Factors affecting the responses of marine mammals to acoustic disturbance. *Marine Technology Society Journal, 37*(4), 6-15. doi:10.4031/002533203787537041

Watwood, S. L., & Buonantony, D. M. (2012). *Dive distribution and group size parameters for marine species occuring in Navy training and testing areas in the North Atlantic and North Pacifiic Oceans*. Naval Undersea Warfare Center Division, Newport, Rhode Island.

Watwood, S. L., Miller, P. J. O., Johnson, M. P., Madsen, P. T., & Tyack, P. L. (2006). Deep-diving foraging behaviour of sperm whales (*Physeter macrocephalus*). *Journal of Animal Ecology, 75*(3), 814-825.

Weilgart, L. S. (2014). *Are We Mitigating Underwater-Noise Producing Activities Adequately?: A Comparision of Level A and Level B Cetacean Takes*. International Whaling Commission Working Paper, SC/65b.

Weir, C. R. (2008). Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. *Aquatic Mammals, 34*(1), 71-83.

Wells, R. S., Manire, C. A., Byrd, L., Smith, D., Gannon, J. G., Fauquier, D., & Mullin, K. D. (2009). Movements and dive patterns of a rehabilitated Risso's dolphin, *Grampus griseus*, in the Gulf of Mexico and Atlantic Ocean. *Marine Mammal Science, 25*(2), 420-429.

Wensveen, P. J., von Benda-Beckmann, A. M., Ainslie, M. A., Lam, F.-P. A., Kvadsheim, P. H., Tyack, P. L., & Miller, P. J. O. (2015). How effectively do horizontal and vertical response strategies of long-finned pilot whales reduce sound exposure from naval sonar? *Marine Environmental Research, 106*, 68-81.

Westgate, A. J., Head, A. J., Berggren, P., Koopman, H. N., & Gaskin, D. E. (1995). Diving behaviour of harbour porpoises, *Phocoena phocoena*. *Canadian Journal of Fisheries and Aquatic Sciences, 52*(5), 1064-1073. doi:10.1139/f95-104

Whitehead, H. (2002). Estimates of the current population size and historical trajectory for sperm whales. *Marine Ecology Progress Series, 242*, 295-304.

Whitehead, H. (2003). *Sperm whales: Social evolution in the ocean*: The University of Chicago Press.

Whitehead, H. (2009). Sperm Whale: *Physeter macrocephalus*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 1091-1097). London: Academic Press.

Whitman, A. A., & Payne, P. M. (1990). Age of harbour seals, *Phoca vitulina concolor*, wintering in southern New England. *Canadian Field-Naturalist, 104*(4), 579-582.

Whitt, A. D., Dudzinski, K., & Laliberté, J. R. (2013). North Atlantic right whale distribution and seasonal occurrence in nearshore waters off New Jersey, USA, and implications for management. *Endangered Species Research, 20*(1), 59-69.

Wilhelmsson, D., Malm, T., & Öhman, M. C. (2006). The influence of offshore windpower on demersal fish. *ICES Journal of Marine Science, 63*(5), 775-784. doi:10.1016/j.icesjms.2006.02.001

Wilson, S. C. (1978). *Social Organization and Behavior of Harbor Seals, Phoca Vitulina Concolor', in Maine*. Final Report to U.S. Marine Mammal Commission in Fulfillment of Contract MM6AC013.

Wind Europe. (2017). *The European offshore wind industry—Key trends and statistics 2016*. Brussels, Belgium. https://windeurope.org/about-wind/statistics/offshore/european-offshore-wind-industry-key-trends-and-statistics-2016/.

Wood, J., Southall, B. L., & Tollit, D. J. (2012). *PG&E offshore 3-D Seismic Survey Project Environmental Impact Report–Marine Mammal Technical Draft Report*. SMRU Ltd. https://www.coastal.ca.gov/energy/seismic/mm-technical-report-EIR.pdf.

Würsig, B., & Würsig, M. (1979). Behavior and ecology of the bottlenose dolphin, *Tursiops truncatus* in the South Atlantic. *Fishery Bulletin, 77*(2), 399-412.

Zhang, Z. Y., & Tindle, C. T. (1995). Improved equivalent fluid approximations for a low shear speed ocean bottom. *Journal of the Acoustical Society of America, 98*(6), 3391-3396.

Appendix A. Underwater Acoustic Modeling of Construction Noise

REDACTED

Appendix B. Animal Movement and Exposure Modeling

B.1. Introduction

To assess the risk of impacts from exposure, an estimate of received sound levels for the animals in the area during operation of the Project is required. Sound sources move as do animals. The sound fields may be complex, and the sound received by an animal is a function of where the animal is at any given time. To a reasonable approximation, the location of the sound source(s) is known, and acoustic modeling can be used to predict the 3-D sound field. The location and movement of animals within the sound field, however, is unknown. Realistic animal movement within the sound field can be simulated. Repeated random sampling (Monte Carlo method simulating many animals within the operations area) is used to estimate the sound exposure history of the population of simulated animals during the operation.

Monte Carlo methods provide a heuristic approach for determining the probability distribution function (PDF) of complex situations, such as animals moving in a sound field. The probability of an event's occurrence is determined by the frequency with which it occurs in the simulation. The greater the number of random samples, in this case the more simulated animals (animats), the better the approximation of the PDF. Animats are randomly placed, or seeded, within the simulation boundary at a specified density (animats/km^2). Higher densities provide a finer PDF estimate resolution but require more computational resources. To ensure good representation of the PDF, the animat density is set as high as practical allowing for computation time. The animat density is much higher than the real-world density to ensure good representation of the PDF. The resulting PDF is scaled using the real-world density.

Several models for marine mammal movement have been developed (Ellison, Clark, & Bishop, 1987; Frankel, Ellison, & Buchanan, 2002; Houser, 2006). These models use an underlying Markov chain to transition from one state to another based on probabilities determined from measured swimming behavior. The parameters may represent simple states, such as the speed or heading of the animal, or complex states, such as likelihood of participating in foraging, play, rest, or travel. Attractions and aversions to variables like anthropogenic sounds and different depth ranges can be included in the models.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was based on the open-source marine mammal movement and behavior model (3MB; Houser, 2006) and used to predict the exposure of animats (virtual marine mammals and sea turtles) to sound arising from sound sources in simulated representative surveys. Inside JASMINE, the sound source location mimics the movement of the source vessel through the proposed survey pattern. Animats are programmed to behave like the marine animals likely to be present in the survey area. The parameters used for forecasting realistic behaviors (e.g., diving, foraging, aversion, surface times, etc.) are determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species (see Appendix A). An individual animat's modeled sound exposure levels are summed over the total simulation duration, such as 24 hours or the entire simulation, to determine its total received energy, and then compared to the assumed threshold criteria.

JASMINE uses the same animal movement algorithms as the 3MB model (Houser, 2006) but has been extended to be directly compatible with MONM and FWRAM acoustic field predictions, for inclusion of source tracks, and importantly for animats to change behavioral states based on time and space dependent modeled variables such as received levels for aversion behavior.

B.2. Animal movement parameters

JASMINE uses previously measured behavior to forecast behavior in new situations and locations. The parameters used for forecasting realistic behavior are determined (and interpreted) from marine species studies (e.g., tagging studies). Each parameter in the model is described as a probability distribution. When limited or no information is available for a species parameter, a Gaussian or uniform distribution may be chosen for that parameter. For the Gaussian distribution, the user determines the mean and standard deviation of the distribution from which parameter values are drawn. For the uniform distribution, the user determines the maximum and minimum distribution from which parameter values are drawn. When detailed information about the movement and behavior of a species are available, a user-created distribution vector, including cumulative transition probabilities, may be used (referred to here as a vector model; Houser, 2006). Different sets of parameters can be defined for different behavior states. The probability of an animat starting out in or transitioning into a given behavior state can in turn be defined in terms of the animat's current behavioral state, depth, and the time of day. In addition, each travel parameter and behavioral state has a termination function that governs how long the parameter value or overall behavioral state persists in simulation.

The parameters used in JASMINE describe animal movement in both the vertical and horizontal planes. The parameters relating to travel in these two planes are briefly described below.

Travel sub-models

- **Direction**– determines an animat's choice of direction in the horizontal plane. Sub-models are available for determining the heading of animats, allowing for movement to range from strongly biased to undirected. A random walk model can be used for behaviors with no directional preference, such as feeding and playing. In a random walk, all bearings are equally likely at each parameter transition time step. A correlated random walk can be used to smooth the changes in bearing by using the current heading as the mean of the distribution from which to draw the next heading. An additional variant of the correlated random walk is available that includes a directional bias for use in situations where animals have a preferred absolute direction, such as migration. A user-defined vector of directional probabilities can also be input to control animat heading. For more detailed discussion of these parameters, see Houser (2006) and Houser and Cross (1999).
- **Travel rate**–defines an animat's rate of travel in the horizontal plane. When combined with vertical speed and dive depth, the dive profile of the animat is produced.

Dive sub-models

- **Ascent rate**–defines an animat's rate of travel in the vertical plane during the ascent portion of a dive.
- **Descent rate**–defines an animat's rate of travel in the vertical plane during the descent portion of a dive.
- **Depth**–defines an animat's maximum dive depth.
- **Bottom following**–determines whether an animat returns to the surface once reaching the ocean floor, or whether it follows the contours of the bathymetry.
- **Reversals**–determines whether multiple vertical excursions occur once an animat reaches the maximum dive depth. This behavior is used to emulate the foraging behavior of some marine mammal species at depth. Reversal-specific ascent and descent rates may be specified.
- **Surface interval**–determines the duration an animat spends at, or near, the surface before diving again.

B.2.1. Exposure integration time

The interval over which acoustic exposure (L_E) should be integrated and maximal exposure (L_p) determined is not well defined. Both Southall et al. (2007) and the NMFS (2018a) recommend a 24 h baseline accumulation period, but state that there may be situations where this is not appropriate (e.g., a high-level source and confined population). Resetting the integration after 24 h can lead to overestimating the number of individual animals exposed because individuals can be counted multiple times during an operation. The type of animal movement engine used in this study simulates realistic movement using swimming behavior collected over relatively short periods (hours to days) and does not include large-scale movement such as migratory circulation patterns. Therefore the simulation time should be limited to a few weeks, the approximate scale of the collected data (Houser, 2006). For this study, one-week simulations (i.e., 7 days) were modeled for each scenario.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that could approach the survey area during an operation is included. However, there are limits to the simulation area, and computational overhead increases with area. For practical reasons, the simulation area is limited in this analysis to a maximum distance of 200 km (124.2 miles) from the Offshore Project Area. In the simulation, every animat that reaches a border is replaced by another animat entering at the opposing border—e.g., an animat crossing the northern border of the simulation is replaced by one entering the southern border at the same longitude. When this action places the animat in an inappropriate water depth, the animat is randomly placed on the map at a depth suited to its species definition (Appendix B). The exposures of all animats (including those leaving the simulation and those entering) are kept for analysis. This approach maintains a consistent animat density and allows for longer integration periods with finite simulation areas.

B.2.2. Aversion

Animals may avoid loud sounds by moving away from the source, and the risk assessment framework (Southall, Ellison, Clark, Mann, & Tollit, 2014) suggests implementing aversion in the animal movement model and making a comparison between the exposure estimates with and without aversion. Aversion is implemented in JASMINE by defining a new behavioral state that an animat may transition in to when a received level is exceeded.

There are very few data on which aversive behavior can be based. Because of the dearth of information and to be consistent within this report, aversion probability is based on the Wood et al. (2012) step function that was used to estimate potential behavioral disruption. Animats will be assumed to avert by changing their headings by a fixed amount away from the source, with higher received levels associated with a greater deflection (Tables B-1 and B-2). Aversion thresholds for marine mammals are based on the Wood et al. (2012) step function. Animats remain in the aversive state for a specified amount of time, depending on the level of exposure that triggered aversion (Tables B-1 and B-2). During this time, travel parameters are recalculated periodically as with normal behaviors. At the end of the aversion interval, the animat once again applies the parameters in Tables B-1 and B-2and, depending on the current level of exposure, either begins another aversion interval or transitions to a non-aversive behavior; while aversion begins immediately, transition to a regular behavior occurs at the end of the next surface interval, consistent with regular behavior transitions.

Table B-1. Aversion parameters for the animal movement simulation of North Atlantic right whales based on Wood et al. (2012) behavioral response criteria.

Probability of aversion	Received sound level (SPL, dB re 1 µPa)	Change in course (°)	Duration of aversion(s)
10%	140	10	300
50%	160	20	60
90%	180	30	30

Table B-2. Aversion parameters for the animal movement simulation of Harbor porpoise based on Wood et al. (2012) behavioral response criteria.

Probability of aversion	Received sound level (SPL, dB re 1 µPa)	Change in course (°)	Duration of aversion(s)
50%	120	20	60
90%	140	30	30

B.2.3. Seeding density and scaling

The exposure criteria for impulsive sounds were used to determine the number of animats exceeding exposure thresholds. To generate statistically reliable probability density functions, all simulations were seeded with an animat density of 0.5 animats/km^2 over the entire simulation area. Some species have depth preference restrictions, e.g., Sperm whales prefer water >1000m, and the simulation location contained a relatively high portion of shallow water areas. The local modeling density, that is the density of animats near the construction area, was determined by dividing the simulation seeding density by the proportion of seedable area for each species. To evaluate potential Level B or Level A harassment, threshold exceedance was determined in 24 hr time windows for each species. From the numbers of animats exceeding threshold, the numbers of individual animals for each species predicted to exceed threshold were determined by scaling the animat results by the ratio of local real-world density to local modeling density. As described in Section 6.5.1, the local real-world density estimates were obtained from the habitat-based models of Roberts et al. (2015; 2017).

B.2.4. Simulation Exposure Results

The following tables show the number of animats exceeding Level A and Level B sound exposure thresholds for the installation of one monopile foundation in a day, two monopile foundations in a day, and one jacket foundation in a day.

Table B-3. The average number of animats exposed to sound levels above threshold exposure criteria for installation of one jacket foundation for a 24 h period (NMFS 2018a) and 0, 6, and 12 dB attenuation.

Species	No attenuation			6 dB			12 dB		
	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level Behavior max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)
Fin Whale*	108.86	89.21	248.71	24.50	26.50	201.57	1.14	1.64	138.64
Humpback Whale	460.14	395.00	766.36	149.07	147.64	609.57	9.21	14.57	404.50
Minke Whale	125.57	135.00	805.21	11.50	10.93	620.43	1.93	1.21	377.50
North Atlantic Right Whale*	121.14	101.00	294.43	25.57	25.50	236.43	1.86	1.79	159.07
Sei Whale*	106.57	90.29	243.93	24.86	27.57	199.57	1.21	1.57	138.50
Atlantic White-Sided Dolphin	0.00	0.00	335.21	0.00	0.00	258.14	0.00	0.00	156.86
Common Bottlenose Dolphin	0.00	0.00	23.21	0.00	0.00	16.21	0.00	0.00	9.64
Pilot Whales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Risso's Dolphin	0.07	0.07	210.71	0.00	0.07	166.57	0.00	0.00	116.00
Short-Beaked Common Dolphin	0.07	0.07	212.86	0.07	0.00	167.14	0.07	0.00	116.71
Sperm Whale*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor Porpoise	3.29	4.29	164.00	1.86	1.79	129.71	0.50	0.86	87.07
Gray Seal	0.64	1.00	63.79	0.29	0.50	50.07	0.07	0.14	33.43
Harbor Seal	0.36	1.00	81.21	0.21	0.29	62.50	0.00	0.14	42.00
Harp Seal	1.00	2.00	78.14	0.36	0.07	60.57	0.07	0.00	41.50

* Endangered species

Table B-4. The average number of animats exposed to sound levels above threshold exposure criteria for installation of one monopile foundation for a 24 h period (NMFS 2018a) and 0, 6, and 12 dB attenuation.

Species	No attenuation			6 dB			12 dB		
	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)
Fin Whale*	19.86	13.50	140.36	5.21	2.86	88.71	0.43	0.29	57.57
Humpback Whale	103.29	78.50	385.21	33.71	24.57	242.79	5.29	2.43	157.71
Minke Whale	20.07	17.14	333.64	1.71	1.86	221.43	0.79	0.57	146.29
North Atlantic Right Whale*	19.50	17.43	168.36	4.64	2.64	104.86	0.21	0.21	68.71
Sei Whale*	23.36	15.21	144.21	5.36	3.36	92.07	0.71	0.29	62.57
Atlantic White-Sided Dolphin	0.00	0.00	156.57	0.00	0.00	93.64	0.00	0.00	58.29
Common Bottlenose Dolphin	0.07	0.00	31.07	0.00	0.00	18.50	0.00	0.00	12.07
Pilot Whales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Risso's Dolphin	0.29	0.14	134.57	0.00	0.00	83.14	0.00	0.00	52.43
Short-Beaked Common Dolphin	0.00	0.14	135.57	0.00	0.00	85.71	0.00	0.00	56.07
Sperm Whale*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor Porpoise	2.21	2.07	115.50	0.79	1.29	69.86	0.21	0.50	41.79
Gray Seal	0.07	0.00	57.14	0.00	0.00	34.57	0.00	0.00	20.43
Harbor Seal	0.14	0.07	65.93	0.07	0.00	40.29	0.07	0.00	25.43
Harp Seal	0.29	0.14	63.86	0.14	0.14	38.50	0.00	0.00	23.07

* Endangered species

Table B-5. The average number of animats exposed to sound levels above threshold exposure criteria for installation of two monopile foundations for a 24 h period (NMFS 2018a) and 0, 6, and 12 dB attenuation.

Species	No attenuation			6 dB			12 dB		
	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)	Level A (L_{pk})	Level A (L_E)	Level B max. SPL ($L_{p,24hr}$)
Fin Whale*	43.64	32.43	223.86	11.07	7.57	153.79	1.36	0.79	106.71
Humpback Whale	210.00	162.86	633.36	72.71	56.14	424.29	10.14	7.07	290.21
Minke Whale	41.29	39.00	584.86	3.29	4.00	409.29	0.57	1.21	285.57
North Atlantic Right Whale*	40.36	34.79	260.21	7.86	7.14	178.50	0.64	0.64	121.21
Sei Whale*	44.07	33.71	222.64	8.79	8.29	151.36	0.86	0.64	105.43
Atlantic White-Sided Dolphin	0.07	0.07	271.07	0.00	0.07	175.36	0.00	0.00	113.64
Common Bottlenose Dolphin	0.07	0.00	38.21	0.00	0.00	24.79	0.00	0.00	16.29
Pilot Whales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Risso's Dolphin	0.07	0.14	199.14	0.00	0.00	135.43	0.00	0.00	93.36
Short-Beaked Common Dolphin	0.00	0.14	199.71	0.00	0.07	137.71	0.00	0.00	95.29
Sperm Whale*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor Porpoise	4.00	3.93	168.86	1.57	2.57	110.86	0.50	1.36	72.36
Gray Seal	0.57	0.07	71.57	0.14	0.00	48.36	0.07	0.00	32.07
Harbor Seal	0.50	1.00	85.93	0.07	0.64	58.86	0.07	0.14	39.43
Harp Seal	0.79	0.21	81.86	0.29	0.00	54.14	0.07	0.00	35.93

* Endangered species

B.3. Marine Mammal Species-Specific Details

Most marine mammals likely to be near the Offshore Project Area are mid-frequency cetaceans. Fin, Humpback, Minke, North Atlantic Right, and Sei Whales are the low-frequency cetaceans in the Project Area and the Harbor Porpoise is the only high-frequency cetacean species. The Fin Whale, North Atlantic Right Whale, Sei Whale, and Sperm Whale are endangered species, although all marine mammals are protected under the MMPA. Details for each of the marine mammal species are listed below.

B.3.1. Fin Whales (*Balaenoptera physalus*)

Table B-6. *Fin Whales*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Non-foraging shallow	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.7 (0.5)	Lafortuna, Jahoda, Azzellino, Saibene, and Colombini (2003)
	Ascent rate (m/s)	Gaussian 1.7 (0.4)	Croll, Acevedo-Gutiérrez, Tershy, and Urbán-Ramírez (2001)
	Descent rate (m/s)	Gaussian 2.0 (0.2)	Croll et al. (2001)
	Average depth (m)	Gaussian 28.2 (1.8)	Croll et al. (2001)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 90 (30)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	1	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	Gaussian 0.7 (0.2)	Approximated (Croll et al., 2001)
	Reversal descent dive rate (m/s)	Gaussian 0.7 (0.2)	Approximated (Croll et al., 2001)
	Time in reversal (s)	Gaussian 1 (0.2)	Approximated (Croll et al., 2001)
	Surface interval (s)	Gaussian 123.8 (42.3)	Acevedo-Gutierrez et al. (2002)
	Bout duration (s)	Sigmoidal T_{50} = 10, k = 10	Approximated (Watwood & Buonantony, 2012)
Non-foraging Deep	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.7 (0.5)	Lafortuna et al. (2003)
	Ascent rate (m/s)	Gaussian 1.7 (0.4)	Croll et al. (2001)
	Descent rate (m/s)	Gaussian 2.0 (0.2)	Croll et al. (2001)
	Average depth (m)	Gaussian 120 (33.5)	Croll et al. (2001)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 80 (19.2)	Acevedo-Gutiérrez, Croll, and Tershy (2002)

Behavior	Variable	Value	Reference
	Bout duration (s)	Sigmoidal T_{50} = 15, k = 15	Approximated (Watwood & Buonantony, 2012)
Foraging Shallow	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.6 (0.6)	Goldbogen et al. (2006)
	Ascent rate (m/s)	Gaussian 2.1 (0.3)	Goldbogen et al. (2006)
	Descent rate (m/s)	Gaussian 3.0 (0.2)	Goldbogen et al. (2006)
	Average depth (m)	Gaussian 46 (4.8)	Croll et al. (2001)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 3.1 (1.1)	Croll et al. (2001), Goldbogen et al. (2006)
	Probability of reversal	0.95	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	Gaussian 1.7 (0.4)	Croll et al. (2001)
	Reversal descent dive rate (m/s)	Gaussian 1.4 (0.5)	Croll et al. (2001)
	Time in reversal (s)	Gaussian 13.7 (2.8)	Croll et al. (2001)
	Surface interval (s)	Gaussian 123.8 (42.3)	Acevedo-Gutiérrez et al. (2002)
	Bout duration (s)	Sigmoidal T_{50} = 30, k = 15	Approximated (Watwood & Buonantony, 2012)
Foraging Deep	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.6 (0.6)	Jeremy A. Goldbogen et al. (2006)
	Ascent rate (m/s)	Gaussian 2.1 (0.3)	Jeremy A. Goldbogen et al. (2006)
	Descent rate (m/s)	Gaussian 3.0 (0.2)	Jeremy A. Goldbogen et al. (2006)
	Average depth (m)	Gaussian 248.0 (18.0)	Jeremy A. Goldbogen et al. (2006)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 3.1 (1.1)	Croll et al. (2001) Goldbogen et al. (2006)
	Probability of reversal	0.95	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	Gaussian 1.7 (0.4)	Croll et al. (2001)
	Reversal descent dive rate (m/s)	Gaussian 1.4 (0.5)	Croll et al. (2001)
	Time in reversal (s)	Gaussian 13.7 (2.8)	Croll et al. (2001)
	Surface interval (s)	Gaussian 123.8 (42.3)	Acevedo-Gutiérrez et al. (2002)
	Bout duration (s)	Sigmoidal T_{50} = 50, k = 15	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
General	Shore following (m)	30	Approximated (Watwood & Buonantony, 2012)
	Depth limit on seeding (m)	30 (minimum), 2000 (maximum)	Approximated (Watwood & Buonantony, 2012)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.2. Humpback Whales (*Megaptera novaeangliae*)

Table B-7. *Humpback Whales*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Migrating	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.8–0.25	Meynecke, Vindenes, and Teixeira (2013) Murase, Tamura, Otani, and Nishiwaki (2015)
	Ascent rate (m/s)	Gaussian 1.9 (0.25)	Dolphin (1987)
	Descent rate (m/s)	Gaussian 1.7 (0.7)	Dolphin (1987)
	Average depth (m)	Gaussian 45 (10)	Smith et al. (2012)
	Bottom following	No	Approximated (based on figure in R. A. Dunlop et al., 2013)
	Reversals	Gaussian 7 (3)	Alves, Dinis, Cascão, and Freitas (2010)
	Probability of reversal	1	Approximated (based on figure in R. A. Dunlop et al., 2013)
	Reversal ascent dive rate (m/s)	Gaussian 0.1 (0.1)	Approximated (based on figure in R. A. Dunlop et al., 2013)
	Reversal descent dive rate (m/s)	Gaussian 0.1 (0.1)	Approximated (based on figure in R. A. Dunlop et al., 2013)
	Time in reversal (s)	Gaussian 60 (15)	Approximated (based on figure in R. A. Dunlop et al., 2013)
	Surface interval (s)	Gaussian, 60 (27)	Dolphin (1987)
General	Shore following (m)	10	Approximated (based on Smith et al., 2012)
	Depth limit on seeding (m)	20 (minimum), 70 (maximum)	Approximated (based on Smith et al., 2012)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.3. Minke Whales (*Balaenoptera acutorostrata*)

Table B-8. *Minke Whales:* Data values and references input in JASMINE to create diving behavior.

Behavior	Variable	Value	Reference
Feeding dive	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 3.25 (0.3)	Approximated (Blix & Folkow, 1995)
	Ascent rate (m/s)	Gaussian 2.1 (0.3)	Approximated (fin whale - J. A. Goldbogen et al., 2011)
	Descent rate (m/s)	Gaussian 3 (0.2)	Approximated (fin whale - J. A. Goldbogen et al., 2011)
	Average depth (m)	Gaussian 35 (20)	Approximated (based on figure in Blix & Folkow, 1995)
	Bottom following	No	Approximated (Blix & Folkow, 1995)
	Reversals	Gaussian 3.1 (1.1)	Approximated (fin whale - Croll et al., 2001; Jeremy A. Goldbogen et al., 2006)
	Probability of reversal	0.95	Approximated (Blix & Folkow, 1995)
	Reversal ascent dive rate (m/s)	Gaussian 1.7 (0.4)	Fin whale–Croll et al. (2001)
	Reversal descent dive rate (m/s)	Gaussian 1.4 (0.5)	Fin whale–Croll et al. (2001)
	Time in reversal (s)	Gaussian 13.7 (2.8)	Fin whale–Croll et al. (2001)
	Surface interval (s)	Gaussian 66.1 (96.7)	Stockin, Fairbairns, Parsons, and Sims (2001)
	Bout duration (s)	Gaussian 1500 (500)	Approximated (based on figure in Blix & Folkow, 1995)
Cruising dive	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 3.25 (0.3)	Approximated (Blix & Folkow, 1995)
	Ascent rate (m/s)	Gaussian 1.7 (0.4)	Approximated (fin whale - J. A. Goldbogen et al., 2011)

Behavior	Variable	Value	Reference
	Descent rate (m/s)	Gaussian 2.0 (0.2)	Approximated (fin whale - J. A. Goldbogen et al., 2011)
	Average depth (m)	Gaussian 15 (10)	Approximated (based on figure in Blix & Folkow, 1995)
	Bottom following	No	Approximated (based on figure in Blix & Folkow, 1995)
	Reversals	No	Approximated (based on figure in Blix & Folkow, 1995)
	Surface interval (s)	Gaussian 66.1 (96.7)	Stockin et al. (2001)
	Bout duration (s)	Gaussian 1000 (600)	Approximated (based on figure in Blix & Folkow, 1995)
Sleeping	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 3.25 (0.3)	Approximated (Blix & Folkow, 1995)
	Ascent rate (m/s)	Gaussian 1.7 (0.4)	Approximated (fin whale - J. A. Goldbogen et al., 2011)
	Descent rate (m/s)	Gaussian 2.0 (0.2)	Approximated (fin whale - J. A. Goldbogen et al., 2011)
	Average depth (m)	Gaussian 10 (5)	Approximated (based on figure in Blix & Folkow, 1995)
	Bottom following	No	Approximated (based on figure in Blix & Folkow, 1995)
	Reversals	No	Approximated (based on figure in Blix & Folkow, 1995)
	Surface interval (s)	Gaussian 66.1 (96.7)	Stockin et al. (2001)
	Bout duration (s)	Gaussian 2000 (400)	Approximated (based on figure in Blix & Folkow, 1995)
Unknown	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 3.25 (0.3)	Approximated (Blix & Folkow, 1995)
	Ascent rate (m/s)	Gaussian 1.7 (0.4)	Approximated (fin whale - J. A. Goldbogen et al., 2011)

Behavior	Variable	Value	Reference
	Descent rate (m/s)	Gaussian 2.0 (0.2)	Approximated (fin whale - J. A. Goldbogen et al., 2011)
	Average depth (m)	Gaussian 20 (10)	Approximated (based on figure in Blix & Folkow, 1995)
	Bottom following	No	Approximated (based on figure in Blix & Folkow, 1995)
	Reversals	No	Approximated (based on figure in Blix & Folkow, 1995)
	Surface interval (s)	Gaussian 66.1 (96.7)	Stockin et al. (2001)
	Bout duration (s)	Gaussian 1500 (500)	Approximated (based on figure in Blix & Folkow, 1995)
General	Shore following (m)	80	Approximated (Hooker, Whitehead, & Gowans, 1999)
	Depth limit on seeding (m)	80 (minimum), 200 (maximum)	Hooker et al. (1999)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.4. North Atlantic Right Whales (*Eubalaena glacialis*)

Table B-9. *North Atlantic Right Whales*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Foraging dive	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.47 (0.26)	Baugmartner and Mate (2003)
	Ascent rate (m/s)	Gaussian 1.47 (0.26)	Baugmartner and Mate (2003)
	Descent rate (m/s)	Gaussian 1.4 (0.3)	Baugmartner and Mate (2003)
	Average depth (m)	Gaussian 121.2 (24.2)	Baugmartner and Mate (2003)
	Bottom following	No	Approximated (based on figure in Baugmartner & Mate, 2003)
	Reversals	Gaussian 1.0 (0)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Probability of reversal	1.0	Approximated (based on figure in Baugmartner & Mate, 2003)
	Reversal ascent dive rate (m/s)	Gaussian 0.01 (0.01)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Reversal descent dive rate (m/s)	Gaussian 0.01 (0.01)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Time in reversal (s)	Gaussian 420.0 (60)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Surface interval (s)	Gaussian 187.8 (59.4)	Baugmartner and Mate (2003)
	Bout duration (s)	Gaussian 3600 (600)	Approximated (based on figure in Baugmartner & Mate, 2003)
V-shape	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.47 (0.26)	Baugmartner and Mate (2003)
	Ascent rate (m/s)	Gaussian 1.47 (0.26)	Baugmartner and Mate (2003)
	Descent rate (m/s)	Gaussian 1.4 (0.3)	Baugmartner and Mate (2003)
	Average depth (m)	Gaussian 121.2 (24.2)	Baugmartner and Mate (2003)
	Bottom following	No	Approximated (based on figure in Baugmartner & Mate, 2003)

Behavior	Variable	Value	Reference
	Reversals	No	Approximated (based on figure in Baugmartner & Mate, 2003)
	Surface interval (s)	Gaussian 440 (120)	Baugmartner and Mate (2003)
	Bout duration (s)	Gaussian 1800 (600)	Approximated (based on figure in Baugmartner & Mate, 2003)
Other	Travel direction	Correlated random walk	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (based on fin whale - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 1.47 (0.26)	Baugmartner and Mate (2003)
	Ascent rate (m/s)	Gaussian 1.47 (0.26)	Baugmartner and Mate (2003)
	Descent rate (m/s)	Gaussian 1.4 (0.3)	Baugmartner and Mate (2003)
	Average depth (m)	Gaussian 121.2 (24.2)	Baugmartner and Mate (2003)
	Bottom following	No	Approximated (based on figure in Baugmartner & Mate, 2003)
	Reversals	Random 1.0–10	Approximated (based on figure in Baugmartner & Mate, 2003)
	Probability of reversal	0.3	Approximated (based on figure in Baugmartner & Mate, 2003)
	Reversal ascent dive rate (m/s)	Gaussian 0.08 (0.05)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Reversal descent dive rate (m/s)	Gaussian 0.01 (0.01)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Time in reversal (s)	Gaussian 200 (60)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Surface interval (s)	Gaussian 440 (120)	Approximated (based on figure in Baugmartner & Mate, 2003)
	Bout duration (s)	Gaussian 1200 (600)	Approximated (based on figure in Baugmartner & Mate, 2003)
General	Shore following (m)	30	Approximated (based on Baugmartner & Mate, 2003)
	Depth limit on seeding (m)	30 (minimum), 200 (maximum)	Baumgartner and Mate (2005)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.5. Sei Whales (*Balaenoptera borealis*)

We used Fin Whale behavior definition as a surrogate for Sei Whales.

B.3.6. Atlantic White-sided Dolphins (*Lagenorhynchus acutus*)

Table B-10. *Atlantic White-sided Dolphins*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Day	Travel direction	Correlated random walk	Approximated (odontocete - sperm whale Watwood and Buonantony (2012))
	Perturbation value	10.0	Approximated (odontocete - sperm whale Watwood and Buonantony (2012))
	Termination coefficient	0.2	Approximated (odontocete - sperm whale Watwood and Buonantony (2012))
	Travel rate (m/s)	Gaussian 1.58 (1.02)	Bruce R. Mate, Stafford, Nawojchik, and Dunn (1994)
	Ascent rate (m/s)	Gaussian 0.42 (0.24)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Descent rate (m/s)	Gaussian 0.58 (0.34)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Average depth (m)	Gaussian 22.1 (15.71)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Bottom following	Yes	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Reversals	No	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Surface interval (s)	Gaussian 68.4 (304.8)	Spotted dolphin value – Scott and Chives (2009)
	Bout duration (s)	Sigmoidal T_{50} = 3600, k = 7	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
Night	Travel direction	Correlated random walk	Approximated (odontocete - sperm whale Watwood and Buonantony (2012))
	Perturbation value	10.0	Approximated (odontocete - sperm whale Watwood and Buonantony (2012))
	Termination coefficient	0.2	Approximated (odontocete - sperm whale Watwood and Buonantony (2012))
	Travel rate (m/s)	Gaussian 1.58 (1.02)	Bruce R. Mate et al. (1994)
	Ascent rate (m/s)	Gaussian 0.74 (0.41)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Descent rate (m/s)	Gaussian 0.93 (0.54)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Average depth (m)	Gaussian 24.0 (27.1)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Bottom following	No	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)

Behavior	Variable	Value	Reference
	Reversals	Gaussian 3.0 (1.0)	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Probability of reversal	0.5	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Reversal ascent dive rate (m/s)	Gaussian 0.74 (0.41)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Reversal descent dive rate (m/s)	Gaussian 0.93 (0.54)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Time in reversal (s)	Gaussian 39.0 (55.2)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Surface interval (s)	Gaussian 49.8 (108.6)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Bout duration (s)	Sigmoidal T_{50} = 3600, k = 7	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
General	Shore following (m)	2	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Depth limit on seeding (m)	2 (minimum), 300 (maximum)	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.7. Bottlenose Dolphins (*Tursiops truncatus*)

Table B-11. *Bottlenose Dolphins*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Foraging	Travel direction	Vector model	Ward (1999)
	Travel rate (m/s)	Vector model	Ward (1999)
	Ascent rate (m/s)	Gaussian 2.1 (0.3)	Houser, Dankiewicz -Talmadge, Stockard, and Ponganis (2010)
	Descent rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average depth (m)	Gaussian 25 (5)	Hastie, Wilson, and Thompson (2006)
	Bottom following	Yes	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 18 (1.1)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	0.09	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	1.0 (0.2)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	1.0 (0.2)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 1 (0.1)	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 46.4 (2.5)	Lopez (2009)
	Bout duration (s)	Gaussian 252 (210)	Ward (1999)
Playing	Travel direction	Vector model	Ward (1999)
	Travel rate (m/s)	Vector model	Ward (1999)
	Ascent rate (m/s)	Gaussian 2.1 (0.3)	Houser et al. (2010)
	Descent rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average depth (m)	Gaussian 7 (3)	Hastie et al. (2006); Würsig and Würsig (1979)
	Bottom following	Yes	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 3 (2)	Approximated (Watwood & Buonantony, 2012)
	Bout duration (s)	Gaussian 138 (54)	Ward (1999)
Resting	Travel direction	Vector model	Ward (1999)
	Travel rate (m/s)	Vector model	Ward (1999)
	Ascent rate (m/s)	Gaussian 0.5 (0.1)	Approximated (Watwood & Buonantony, 2012)
	Descent rate (m/s)	Gaussian 0.5 (0.1)	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
	Average depth (m)	Random, max = 2	Approximated (Watwood & Buonantony, 2012)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 3 (2)	Approximated (Watwood & Buonantony, 2012)
	Bout duration (s)	Gaussian 174 (96)	Ward (1999)
Socializing	Travel direction	Vector model	Ward (1999)
	Travel rate (m/s)	Vector model	Ward (1999)
	Ascent rate (m/s)	Gaussian 2.1 (0.3)	Houser et al. (2010)
	Descent rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average depth (m)	Random, max = 10	Hastie et al. (2006) Würsig and Würsig (1979)
	Bottom following	Yes	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 3 (2)	Approximated (Watwood & Buonantony, 2012)
	Bout duration (s)	Gaussian 204 (174)	Ward (1999)
Travel	Travel direction	Vector model	Ward (1999)
	Travel rate (m/s)	Vector model	Ward (1999)
	Ascent rate (m/s)	Gaussian 2.1 (0.3)	Houser et al. (2010)
	Descent rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average depth (m)	Gaussian 7 (3)	Hastie et al. (2006) Würsig and Würsig (1979)
	Bottom following	Yes	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 3 (2)	Approximated (Watwood & Buonantony, 2012)
	Bout duration	Gaussian 306 (276)	Ward (1999)
General	Shore following (m)	2	Würsig and Würsig (1979)
	Depth limit on seeding (m)	2 (minimum), 40 (maximum)	Würsig and Würsig (1979)

Approximated: value based on the best fit for diving profile. Those values were not available from literature but were estimated producing a diving profile similar to D-tag results for example.

B.3.8. Pilot Whales (*Globicephala sp.*)

Table B-12. *Long-finned Pilot Whales*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Deep – Night	Travel direction	Correlated random walk	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Perturbation value	10	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Termination coefficient	0.2	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Travel rate (m/s)	Gaussian 1.3 (0.8)	Bloch et al. (2003)
	Ascent rate (m/s)	Gaussian 2.02 (0.68)	R.W. Baird, Borsani, Hanson, and Tyack (2002)
	Descent rate (m/s)	Gaussian 1.75 (0.34)	R.W. Baird et al. (2002)
	Average depth (m)	Random 50–828	Heide-Jorgensen et al. (2002)
	Bottom following	No	Approximated (figure in R.W. Baird et al., 2002)
	Reversals	Gaussian 3.0 (1.0)	Approximated (figure in R.W. Baird et al., 2002)
	Probability of reversal	0.8	Approximated (figure in R.W. Baird et al., 2002)
	Reversal ascent dive rate (m/s)	Gaussian 0.02 (0.02)	Approximated (figure in R.W. Baird et al., 2002)
	Reversal descent dive rate (m/s)	Gaussian 0.02 (0.02)	Approximated (figure in R.W. Baird et al., 2002)
	Time in reversal (s)	Gaussian 50.0 (30.0)	Approximated (figure in R.W. Baird et al., 2002)
	Surface interval (s)	Gaussian 480 (30)	Approximated (Baird et al. 2002)
	Bout duration (s)	Gaussian 600 (300)	Approximated (figure in R.W. Baird et al., 2002)
Shallow - Day	Travel direction	Correlated random walk	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Perturbation value	10	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Termination coefficient	0.2	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Travel rate (m/s)	Gaussian 1.3 (0.8)	Bloch et al. (2003)
	Ascent rate (m/s)	Gaussian 2.02 (0.68)	R.W. Baird et al. (2002)
	Descent rate (m/s)	Gaussian 1.75 (0.34)	R.W. Baird et al. (2002)

Behavior	Variable	Value	Reference
	Average depth (m)	Gaussian 15 (3.0)	Heide-Jorgensen et al. (2002)
	Bottom following	No	Approximated (figure in R.W. Baird et al., 2002)
	Reversals	No	Approximated (figure in R.W. Baird et al., 2002)
	Surface interval (s)	Gaussian 30 (30)	Approximated (figure in R.W. Baird et al., 2002)
	Bout duration (s)	Gaussian 3000 (600)	Approximated (figure in R.W. Baird et al., 2002)
General	Shore following (m)	100	Approximated (B.R. Mate, Lagerquist, Winsor, Geraci, & Prescott, 2005)
	Depth limit on seeding (m)	100 (minimum), 3000 (maximum)	Approximated (B.R. Mate et al., 2005)

Approximated: value based on the best fit for diving profile. Those values were not available from literature but were estimated producing a diving profile similar to D-tag results for example.

B.3.9. Risso's Dolphins (*Grampus griseus*)

Table B-13. *Risso's Dolphins:* Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Shallow dive	Travel direction	Correlated random walk	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Perturbation value	10	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Termination coefficient	0.2	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Travel rate (m/s)	Gaussian 1.997 (1.058)	Wells et al. (2009)
	Ascent rate (m/s)	Gaussian 0.42 (0.24)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Descent rate (m/s)	Gaussian 0.58 (0.34)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Average depth (m)	Gaussian 8.0 (20.0)	Wells et al. (2009)
	Bottom following	No	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Surface interval (s)	Gaussian 11.0 (4.0)	Bearzi, Reeves, Remonato, Pierantonio, and Airoldi (2011)
	Bout duration (s)	T_{50} = 3600 (s), k = 7	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
Deep dive	Travel direction	Correlated random walk	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Perturbation value	10	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Termination coefficient	0.2	Approximated (odontocete - sperm whale (Watwood & Buonantony, 2012))
	Travel rate (m/s)	Gaussian 1.997 (1.058)	Wells et al. (2009)
	Ascent rate (m/s)	Gaussian 0.74 (0.41)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Descent rate (m/s)	Gaussian 0.93 (0.54)	Spotted dolphin value (M. D. Scott & Chivers, 2009)
	Average depth (m)	Random 20–500	Wells et al. (2009)
	Bottom following	No	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Reversals	No	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
	Surface interval (s)	Gaussian 11.0 (4.0)	Bearzi et al. (2011)

Behavior	Variable	Value	Reference
	Bout duration (s)	T_{50} = 3600 (s), k = 7	Approximated spotted dolphin value (M. D. Scott & Chivers, 2009)
General	Shore following (m)	2	Approximated (Wells et al., 2009)
	Depth limit on seeding (m)	2 (minimum), 500 (maximum)	Approximated (Wells et al., 2009)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.10. Short-beaked Common Dolphins (*Delphinus delphis*)

We used Risso's Dolphin behaviors as a surrogate for Short-beaked Common Dolphins.

B.3.11. Sperm Whales (*Physeter macrocephalus*)

Table B-14. *Sperm Whales*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Deep foraging dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.88 (0.27)	P. J. O. Miller, Johnson, Tyack, and Terray (2004)
	Ascent rate (m/s)	Gaussian 1.3 (0.2)	Watwood, Miller, Johnson, Madsen, and Tyack (2006)
	Descent rate (m/s)	Gaussian 1.1 (0.2)	Watwood et al. (2006)
	Average depth (m)	Gaussian 546.9 (130)	Watwood et al. (2006)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 8.2 (4.2)	Aoki et al. (2007)
	Probability of reversal	1	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	1.8 (0.5)	Aoki et al. (2007)
	Reversal descent dive rate (m/s)	1.8 (0.5)	Aoki et al. (2007)
	Time in reversal (s)	Gaussian 141 (82.7)	Aoki et al. (2007) Amano and Yoshioka (2003)
	Surface interval (s)	Gaussian 486 (156)	Watwood et al. (2006)
	Bout duration (s)	Gaussian 42012 (20820)	Approximated (Watwood & Buonantony, 2012)
V Dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.88 (0.27)	P. J. O. Miller et al. (2004)
	Ascent rate (m/s)	Gaussian 0.67 (0.43)	Amano and Yoshioka (2003)
	Descent rate (m/s)	Gaussian 0.85 (0.05)	Amano and Yoshioka (2003)
	Average depth (m)	Gaussian 282.7 (69.9)	Amano and Yoshioka (2003)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 408 (114)	Approximated (Watwood & Buonantony, 2012)
	Bout duration (s)	Gaussian 2286 (384)	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
Inactive bottom time	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.88 (0.27)	P. J. O. Miller et al. (2004)
	Ascent rate (m/s)	Gaussian 1.13 (0.07)	Amano and Yoshioka (2003)
	Descent rate (m/s)	Gaussian 1.4 (0.13)	Amano and Yoshioka (2003)
	Average depth (m)	Gaussian 490 (74.6)	Amano and Yoshioka (2003)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 1 (0)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	1	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	0.1 (0.1)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	0.1 (0.1)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 1188 (174.6)	Amano and Yoshioka (2003)
	Surface interval (s)	Gaussian 486 (156)	Watwood et al. (2006)
	Bout duration (s)	Gaussian 6192 (4518)	Approximated (Watwood & Buonantony, 2012)
Surface active	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.88 (0.27)	P. J. O. Miller et al. (2004)
	Ascent rate (m/s)	Gaussian 0.67 (0.43)	Amano and Yoshioka (2003)
	Descent rate (m/s)	Gaussian 0.85 (0.05)	Amano and Yoshioka (2003)
	Average depth (m)	Gaussian 25 (25)	Amano and Yoshioka (2003)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 408 (114)	Amano and Yoshioka (2003)
	Bout duration (s)	Gaussian 3744 (2370)	Approximated (Watwood & Buonantony, 2012)
Surface inactive–head up	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0 (0)	Approximated (Watwood & Buonantony, 2012)
	Ascent rate (m/s)	Gaussian 0.1 (0.1)	P. J. O. Miller, Aoki, Rendell, and Amano (2008)
	Descent rate (m/s)	Gaussian 0.1 (0.1)	P. J. O. Miller et al. (2008)
	Average depth (m)	Gaussian 8.6 (4.8)	P. J. O. Miller et al. (2008)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 1 (0)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	1	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	0 (0)	P. J. O. Miller et al. (2008)
	Reversal descent dive rate (m/s)	0 (0)	P. J. O. Miller et al. (2008)
	Time in reversal (s)	Gaussian 708 (522)	P. J. O. Miller et al. (2008)
	Surface interval (s)	Gaussian 462 (360)	P. J. O. Miller et al. (2008)
	Bout duration	T50 = 486 (s), k = 0.9	Approximated (Watwood & Buonantony, 2012)
Surface inactive–head down	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0 (0)	Approximated (Watwood & Buonantony, 2012)
	Ascent rate (m/s)	Gaussian 0.1 (0.1)	P. J. O. Miller et al. (2008)
	Descent rate (m/s)	Gaussian 0.1 (0.1)	P. J. O. Miller et al. (2008)
	Average depth (m)	Gaussian 16.5 (4.9)	P. J. O. Miller et al. (2008)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 1 (0)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	1	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	0 (0)	P. J. O. Miller et al. (2008)
	Reversal descent dive rate (m/s)	0 (0)	P. J. O. Miller et al. (2008)
	Time in reversal (s)	Gaussian 804 (522)	P. J. O. Miller et al. (2008)
	Surface interval (s)	Gaussian 462 (360)	P. J. O. Miller et al. (2008)
	Bout duration	T50 = 486 (s), k = 0.9	Approximated (Watwood & Buonantony, 2012)
General	Depth limit on seeding (m)	500	Herzing and Elliser (2016)

Approximated: value based on the best fit for diving profile. Those values were not available from literature but were estimated producing a diving profile similar to D-tag results for example.

B.3.12. Harbor Porpoises (*Phocoena phocoena*)

Table B-15. *Harbor Porpoises*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Daytime	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.9 (0.3)	Otani, Naito, Kato, and Kawamura (2000)
	Ascent rate (m/s)	Gaussian 0.87 (0.38)	Westgate, Head, Berggren, Koopman, and Gaskin (1995)
	Descent rate (m/s)	Gaussian 0.99 (0.34)	Westgate et al. (1995)
	Average depth (m)	Gaussian 22.5 (11.6)	Westgate et al. (1995)
	Bottom following	Yes	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 1 (0)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	0.84	Westgate et al. (1995)
	Reversal ascent dive rate (m/s)	Gaussian 0.0 (0.0)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	Gaussian 0.0 (0.0)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 20.5 (27.8)	Westgate et al. (1995)
	Surface interval (s)	Gaussian 31.6 (73.8)	Otani et al. (1998) Otani et al. (2000)
	Bout duration (s)	T_{50} = 600 (s), k = 1	Approximated (Watwood & Buonantony, 2012)
Nighttime	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.9 (0.3)	Westgate et al. (1995)
	Ascent rate (m/s)	Gaussian 1.34 (0.53)	Westgate et al. (1995)
	Descent rate (m/s)	Gaussian 1.44 (0.51)	Westgate et al. (1995)
	Average depth (m)	Gaussian 37.5 (12.5)	Westgate et al. (1995)
	Bottom following	Yes	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 1 (0)	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
	Probability of reversal	0.84	Approximated (Watwood & Buonantony, 2012)
	Reversal ascent dive rate (m/s)	Gaussian 0.0 (0.0)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	Gaussian 0.0 (0.0)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 10.3 (13.9)	Westgate et al. (1995)
	Surface interval (s)	Gaussian 31.6 (73.8)	Otani et al. (1998) Otani et al. (2000)
	Bout duration (s)	T_{50} = 600 (s), k = 1	Approximated (Watwood & Buonantony, 2012)
General	Shore following (m)	10	Approximated (Watwood & Buonantony, 2012)
	Depth limit on seeding (m)	10 (minimum), 200 (maximum)	Osmek et al. (1996)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.13. Gray Seals (*Halichoerus grypus*)

Table B-16. *Gray Seals:* Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Square	Travel direction	Correlated random walk	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.111 (0.861)	Breed, Jonsen, Myers, Bowen, and Leonard (2009)
	Ascent rate (m/s)	Gaussian 0.9 (0.04)	Beck, Bowen, McMillan, and Iverson (2003)
	Descent rate (m/s)	Gaussian 1.0 (0.03)	Beck et al. (2003)
	Average depth (m)	Gaussian 62 (3.5)	Beck et al. (2003)
	Bottom following	Yes	Approximated (Beck et al., 2003)
	Reversals	No	Approximated (Beck et al., 2003)
	Surface interval (s)	Gaussian 132 (7.2)	Approximated (Beck et al., 2003)
	Bout duration (s)	Gaussian 2700 (1800)	Approximated (Beck et al., 2003)
Right skewed square	Travel direction	Correlated random walk	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.111 (0.861)	Breed et al. (2009)
	Ascent rate (m/s)	Gaussian 0.6 (0.02)	Beck et al. (2003)
	Descent rate (m/s)	Gaussian 1.5 (0.05)	Beck et al. (2003)
	Average depth (m)	Gaussian 53.0 (3.9)	Beck et al. (2003)
	Bottom following	No	Approximated (Beck et al., 2003)
	Reversals	No	Approximated (Beck et al., 2003)
	Surface interval (s)	Gaussian 132 (7.2)	Approximated (Beck et al., 2003)
	Bout duration (s)	Gaussian 1200 (300)	Approximated (Beck et al., 2003)

Behavior	Variable	Value	Reference
Left skewed square	Travel direction	Correlated random walk	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.111 (0.861)	Breed et al. (2009)
	Ascent rate (m/s)	Gaussian 1.2 (0.12)	Beck et al. (2003)
	Descent rate (m/s)	Gaussian 0.4 (0.05)	Beck et al. (2003)
	Average depth (m)	Gaussian 32.0 (1.7)	Beck et al. (2003)
	Bottom following	No	Approximated (Beck et al., 2003)
	Reversals	No	Approximated (Beck et al., 2003)
	Surface interval (s)	Gaussian 132 (7.2)	Approximated (Beck et al., 2003)
	Bout duration (s)	Gaussian 1200 (300)	Approximated (Beck et al., 2003)
V-shaped	Travel direction	Correlated random walk	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.111 (0.861)	Breed et al. (2009)
	Ascent rate (m/s)	Gaussian 0.7 (0.11)	Beck et al. (2003)
	Descent rate (m/s)	Gaussian 0.5 (0.05)	Beck et al. (2003)
	Average depth (m)	Gaussian 26.0 (1.1)	Beck et al. (2003)
	Bottom following	No	Approximated (Beck et al., 2003)
	Reversals	No	Approximated (Beck et al., 2003)
	Surface interval (s)	Gaussian 132 (7.2)	Approximated (Beck et al., 2003)
	Bout duration (s)	Gaussian 600 (300)	Approximated (Beck et al., 2003)
Wiggle	Travel direction	Correlated random walk	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
	Perturbation value	10	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.111 (0.861)	Breed et al. (2009)
	Ascent rate (m/s)	Gaussian 0.9 (0.08)	Beck et al. (2003)
	Descent rate (m/s)	Gaussian 1.0 (0.04)	Beck et al. (2003)
	Average depth (m)	Gaussian 26.0 (1.1)	Beck et al. (2003)
	Bottom following	No	Approximated (Beck et al., 2003)
	Reversals	Random 2–4	Approximated (Beck et al., 2003)
	Probability of reversal	1.0	Approximated (Beck et al., 2003)
	Time in reversal (s)	Random 30–90	Approximated (Beck et al., 2003)
	Surface interval (s)	Gaussian 132 (7.2)	Approximated (Beck et al., 2003)
	Bout duration	Gaussian 1800 (900)	Approximated (Beck et al., 2003)
General	Shore following (m)	2.1	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Depth limit on seeding (m)	<500 m	Approximated (Jessopp, Cronin, & Hart, 2013)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.14. Harbor Seals (*Phoca vitulina*)

Table B-17. *Harbor Seals*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Type 0 dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.37 (0.39)	Véronique Lesage, Hammill, and Kovacs (1999)
	Ascent rate (m/s)	Gaussian 0.71 (0.46)	Véronique Lesage, Hammill, et al. (1999)
	Descent rate (m/s)	Gaussian 0.76 (0.47)	Véronique Lesage, Hammill, et al. (1999)
	Average depth (m)	Gaussian 2 (1)	Véronique Lesage, Hammill, et al. (1999)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 10 (2)	Véronique Lesage, Hammill, et al. (1999)
	Bout duration (s)	Gaussian 198 (1674)	Approximated (Watwood & Buonantony, 2012)
Type 1 dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.48 (0.32)	Véronique Lesage, Hammill, et al. (1999)
	Ascent rate (m/s)	Gaussian 1.13 (0.16)	Véronique Lesage, Hammill, et al. (1999)
	Descent rate (m/s)	Gaussian 1.12 (0.19)	Véronique Lesage, Hammill, et al. (1999)
	Average depth (m)	Gaussian 282.7 (69.9)	Véronique Lesage, Hammill, et al. (1999)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 5 (2)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	0.08	Véronique Lesage, Hammill, et al. (1999)
	Reversal ascent dive rate (m/s)	Gaussian 1.13 (0.16)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	Gaussian 1.12 (0.19)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 5 (2)	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 42.6 (23.5)	Véronique Lesage, Hammill, et al. (1999)
	Bout duration (s)	Gaussian 654 (1314)	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
Type 2 dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.37 (0.39)	Véronique Lesage, Hammill, et al. (1999)
	Ascent rate (m/s)	Gaussian 0.61 (0.25)	Véronique Lesage, Hammill, et al. (1999)
	Descent rate (m/s)	Gaussian 0.66 (0.27)	Véronique Lesage, Hammill, et al. (1999)
	Average depth (m)	Gaussian 12.2 (9.07)	Véronique Lesage, Hammill, et al. (1999)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	No	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 43.8 (60.7)	Véronique Lesage, Hammill, et al. (1999)
	Bout duration (s)	Gaussian 138 (180)	Approximated (Watwood & Buonantony, 2012)
Type 3 dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.89 (0.42)	Véronique Lesage, Hammill, et al. (1999)
	Ascent rate (m/s)	Gaussian 0.85 (0.23)	Véronique Lesage, Hammill, et al. (1999)
	Descent rate (m/s)	Gaussian 0.64 (0.25)	Véronique Lesage, Hammill, et al. (1999)
	Average depth (m)	Gaussian 51.85 (21.56)	Véronique Lesage, Hammill, et al. (1999)
	Bottom following	No	Approximated (Watwood & Buonantony, 2012)
	Reversals	Gaussian 5 (2)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	0.08	Véronique Lesage, Hammill, et al. (1999)
	Reversal ascent dive rate (m/s)	Gaussian 0.85 (0.23)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	Gaussian 0.64 (0.25)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 5 (1)	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 408 (114)	Véronique Lesage, Hammill, et al. (1999)
	Bout duration (s)	Gaussian 252 (306)	Approximated (Watwood & Buonantony, 2012)
Type 4 dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.5 (0.32)	Véronique Lesage, Hammill, et al. (1999)
	Ascent rate (m/s)	Gaussian 0.38 (0.18)	Véronique Lesage, Hammill, et al. (1999)
	Descent rate (m/s)	Gaussian 0.76 (0.19)	Véronique Lesage, Hammill, et al. (1999)
	Average depth (m)	Gaussian 27.27 (10.14)	Véronique Lesage, Hammill, et al. (1999)
	Bottom following	Yes	Véronique Lesage, Hammill, et al. (1999)
	Reversals	Gaussian 5 (2)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	0.08	Véronique Lesage, Hammill, et al. (1999)
	Reversal ascent dive rate (m/s)	Gaussian 0.38 (0.18)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	Gaussian 0.76 (0.19)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 5 (1)	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 38.6 (34.8)	Véronique Lesage, Hammill, et al. (1999)
	Bout duration	Gaussian 306 (498)	Approximated (Watwood & Buonantony, 2012)
Type 5 dive	Travel direction	Correlated random walk	Approximated (Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.21 (0.31)	Véronique Lesage, Hammill, et al. (1999)
	Ascent rate (m/s)	Gaussian 0.78 (0.74)	Véronique Lesage, Hammill, et al. (1999)
	Descent rate (m/s)	Gaussian 0.70 (0.17)	Véronique Lesage, Hammill, et al. (1999)
	Average depth (m)	Gaussian 65.14 (31.07)	Véronique Lesage, Hammill, et al. (1999)
	Bottom following	Yes	Véronique Lesage, Hammill, et al. (1999)
	Reversals	Gaussian 5 (2)	Approximated (Watwood & Buonantony, 2012)
	Probability of reversal	0.08	Véronique Lesage, Hammill, et al. (1999)
	Reversal ascent dive rate (m/s)	Gaussian 0.38 (0.18)	Approximated (Watwood & Buonantony, 2012)
	Reversal descent dive rate (m/s)	Gaussian 0.76 (0.19)	Approximated (Watwood & Buonantony, 2012)
	Time in reversal (s)	Gaussian 5 (1)	Approximated (Watwood & Buonantony, 2012)
	Surface interval (s)	Gaussian 44.8 (31.9)	Véronique Lesage, Hammill, et al. (1999)
	Bout duration	Gaussian 414 (1122)	Approximated (Watwood & Buonantony, 2012)
General	Shore following (m)	2.1	Approximated (Watwood & Buonantony, 2012)

Behavior	Variable	Value	Reference
	Depth limit on seeding (m)	<250 m	Lowry, Frost, Hoep, and Delong (2001) Gjertz, Lydersen, and Wiig (2001) Lander, Harvey, Hanni, and Morgan (2002)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.3.15. Harp Seals (*Pagophilus groenlandicus*)

Table B-18. *Harp Seals*: Data values and references input in JASMINE to create diving behavior (number values represent means [standard deviations] unless otherwise indicated).

Behavior	Variable	Value	Reference
Dive	Travel direction	Correlated random walk	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Perturbation value	10	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Termination coefficient	0.2	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Travel rate (m/s)	Gaussian 0.48 (0.32)	Harbor seal surrogate - Dive type 1 (Véronique Lesage, Hammill, et al., 1999)
	Ascent rate (m/s)	Gaussian 0.85 (0.1)	Folkow, Nordøy, and Blix (2004)
	Descent rate (m/s)	Gaussian 0.85 (0.1)	Folkow et al. (2004)
	Average depth (m)	Gaussian 76.51 (21.14)	Approximated (Folkow et al., 2004; Nordøy, Folkow, Potelov, Prischemikhin, & Blix, 2008)
	Bottom following	No	Approximated (Folkow et al., 2004; Nordøy et al., 2008)
	Reversals	Gaussian 5 (2)	Harbor seal surrogate - Dive type 1 (Véronique Lesage, Hammill, et al., 1999)
	Probability of reversal	0.88	Harbor seal surrogate - Dive type 1 (Véronique Lesage, Hammill, et al., 1999)
	Reversal ascent dive rate (m/s)	Gaussian 0.85 (0.1)	Folkow et al. (2004)
	Reversal descent dive rate (m/s)	Gaussian 0.85 (0.1)	Folkow et al. (2004)
	Time in reversal (s)	Gaussian 5 (1)	Harbor seal surrogate - Dive type 1 (Véronique Lesage, Hammill, et al., 1999)
	Surface interval (s)	Gaussian 42.6 (23.5)	Harbor seal surrogate - Dive type 1 (Véronique Lesage, Hammill, et al., 1999)
General	Shore following (m)	2.1	Approximated (harbor seal surrogate - Watwood & Buonantony, 2012)
	Depth limit on seeding (m)	<250 m	Harbor seal surrogate - Lowry et al. (2001) Gjertz et al. (2001) Lander et al. (2002)

Approximated: Value based on the best fit for diving profile. Those values were unavailable from literature, but they were estimated to produce a diving profile similar to D-tag results, for example.

B.4. Animat Seeding Area

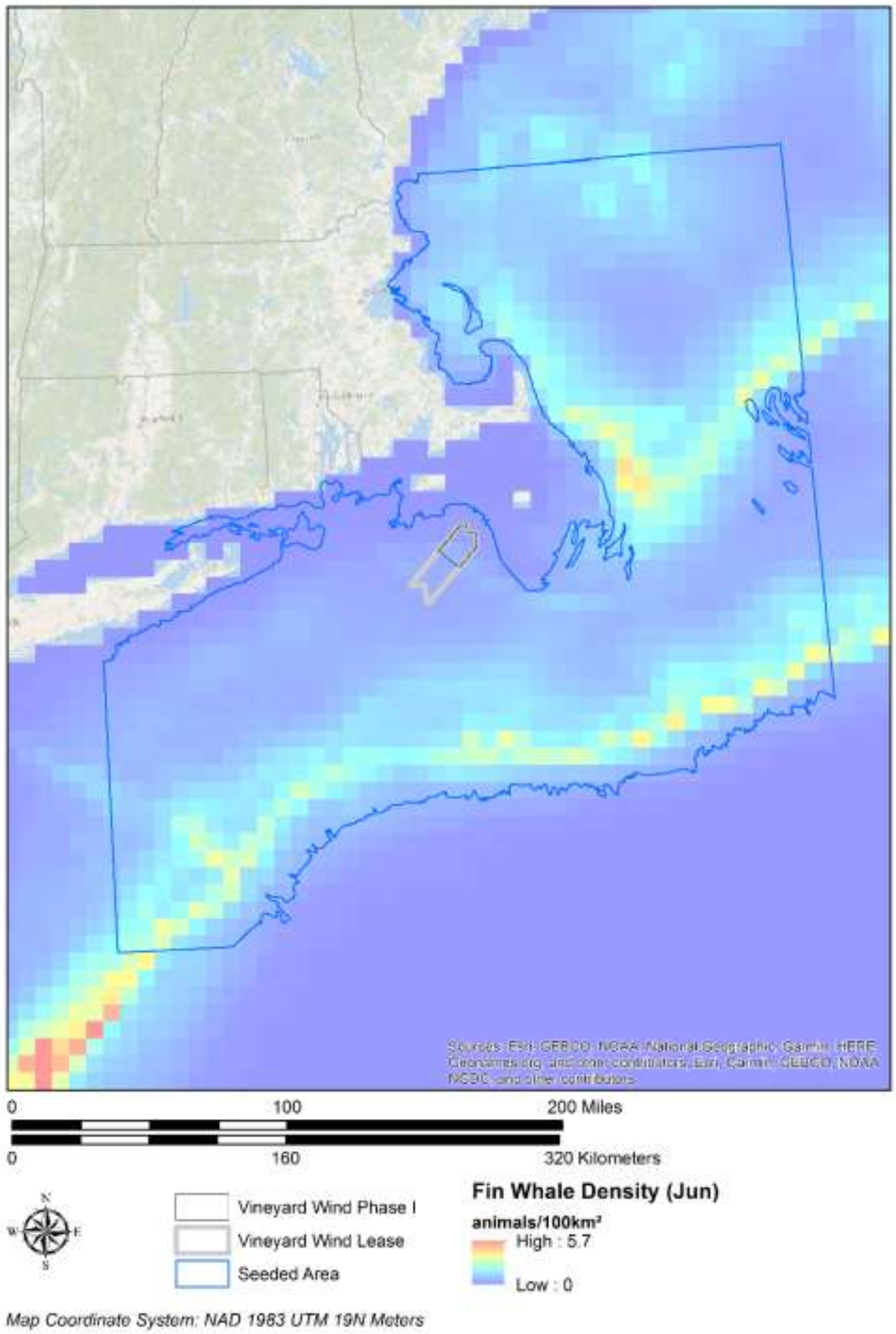

Figure B-1. Map of Fin Whale animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for June, the month with the highest density in the simulation.

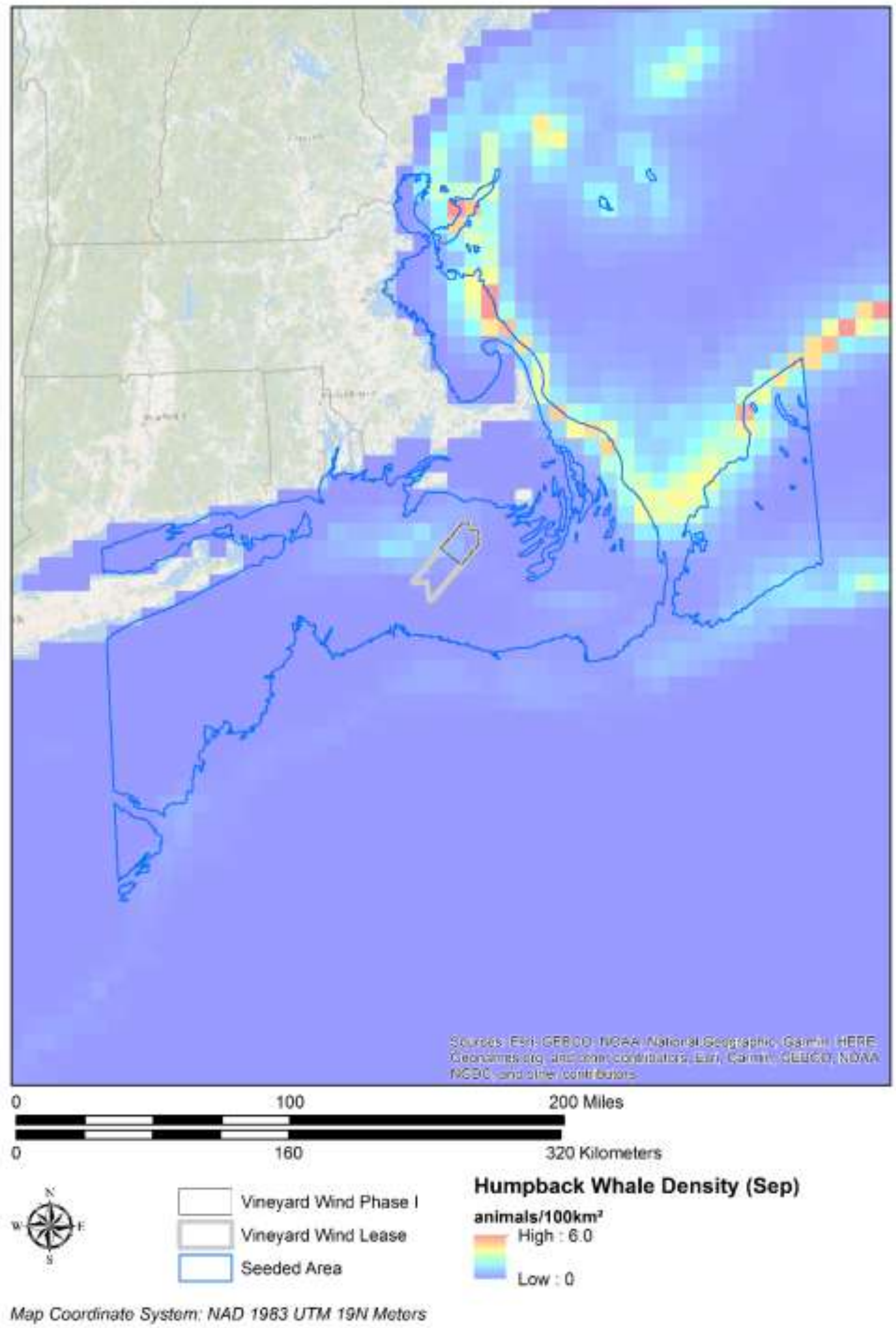

Figure B-2. Map of Humpback Whale animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for September, the month with the highest density in the simulation.

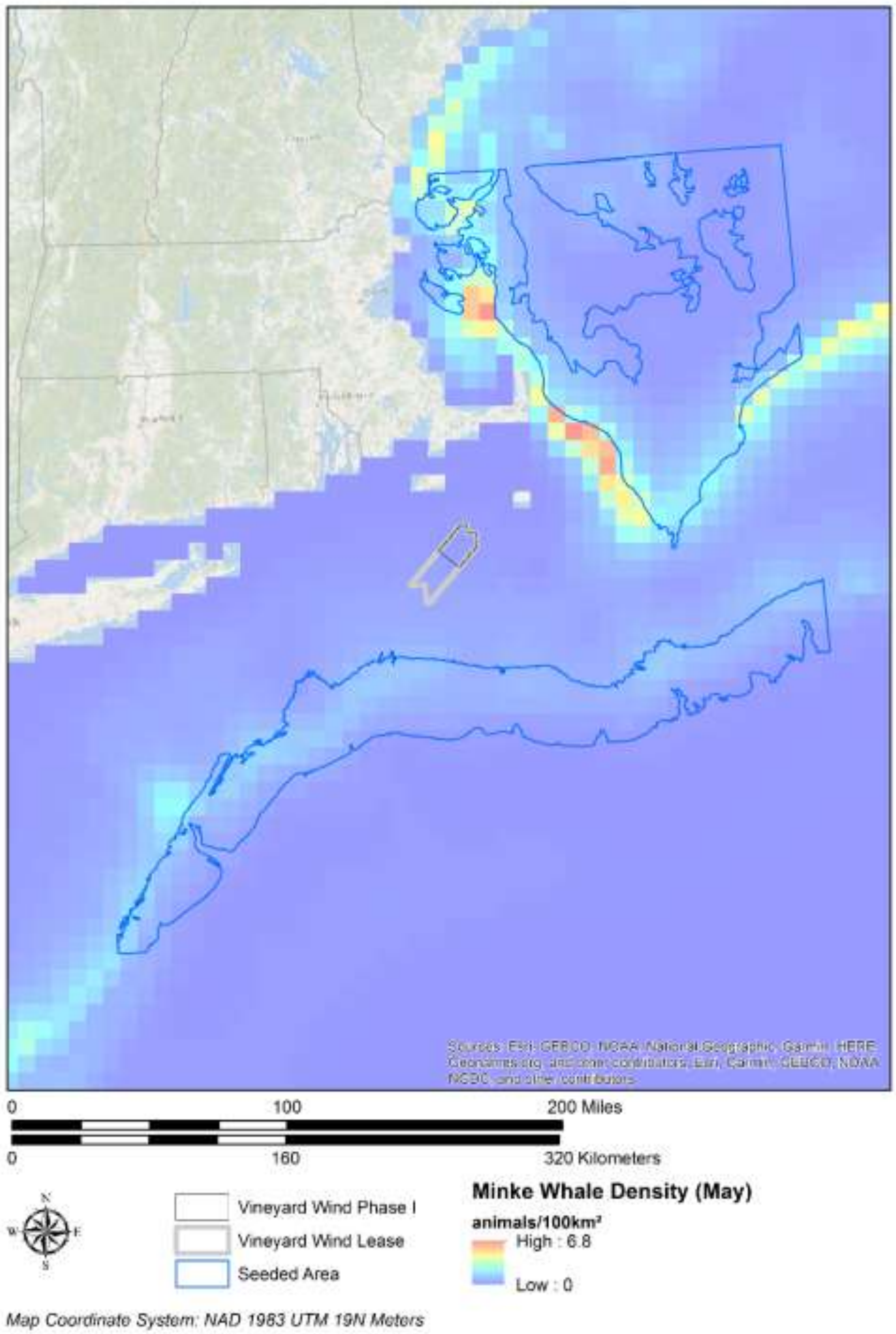

Figure B-3. Map of Minke Whale animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for May, the month with the highest density in the simulation.

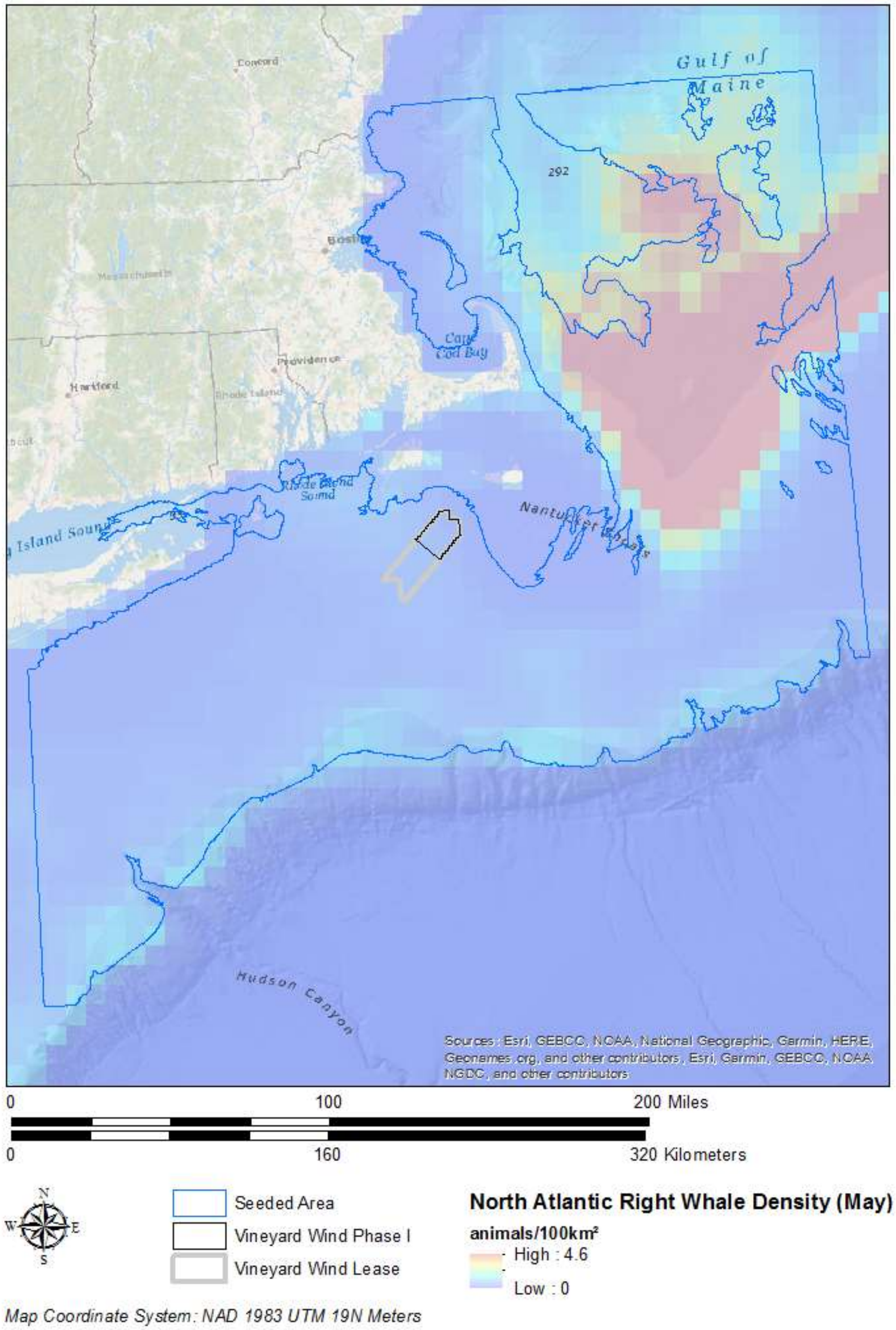

Figure B-4. Map of NARW animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for May, the month with the highest density in the simulation.

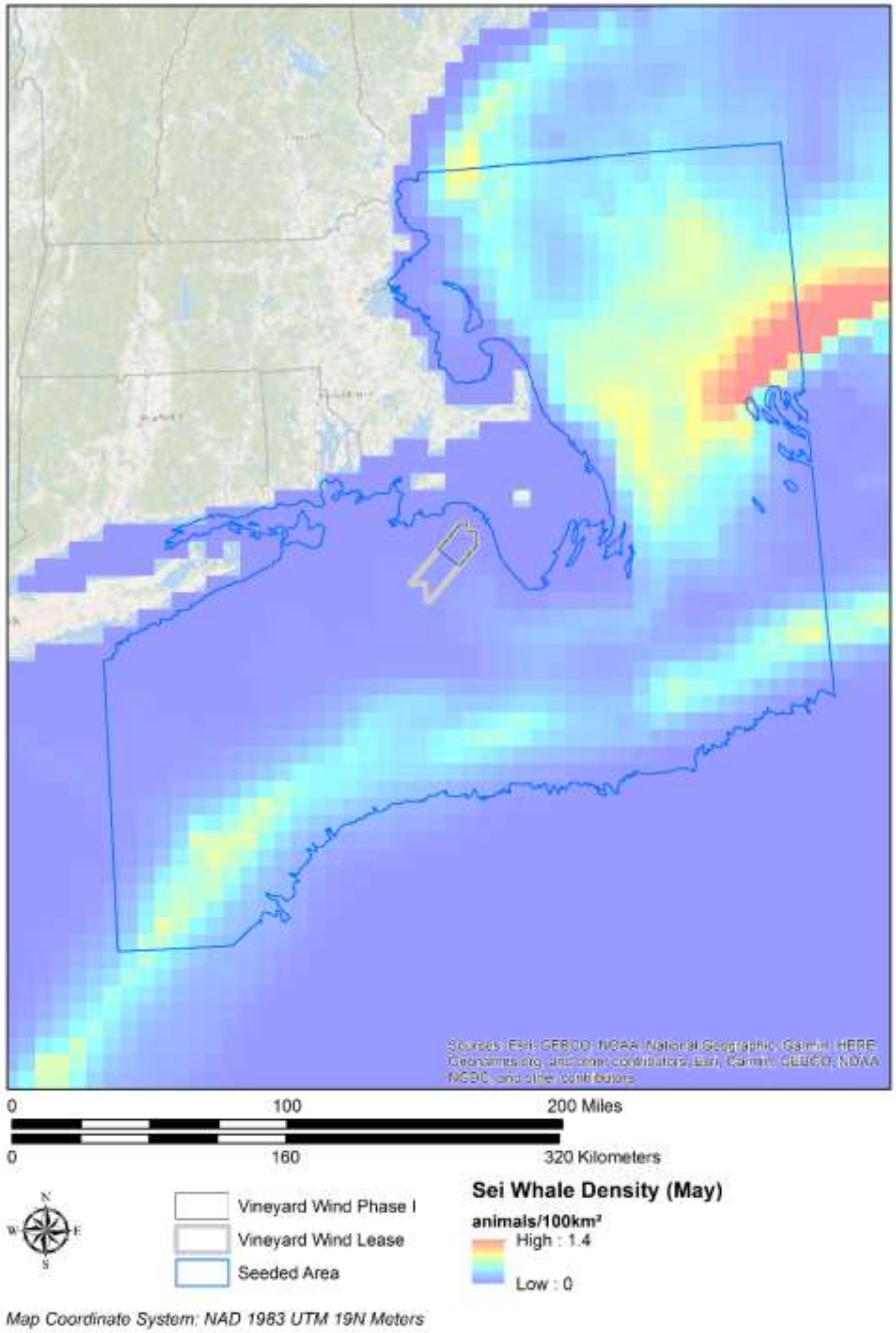

Figure B-5. Map of Sei Whale animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for May, the month with the highest density in the simulation.

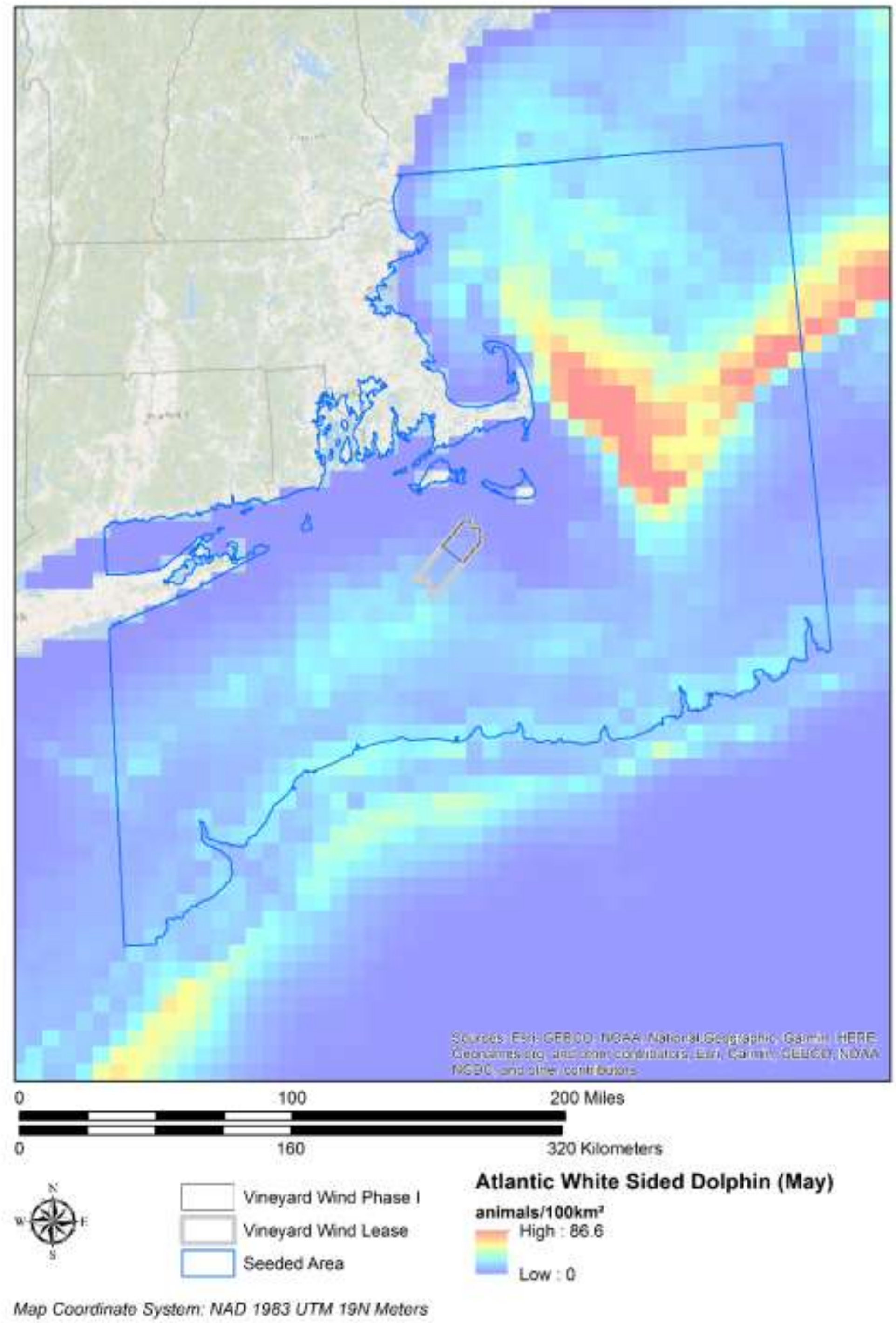

Figure B-6. Map of Atlantic White-sided Dolphin animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018)_ENREF_312 for May, the month with the highest density in the simulation.

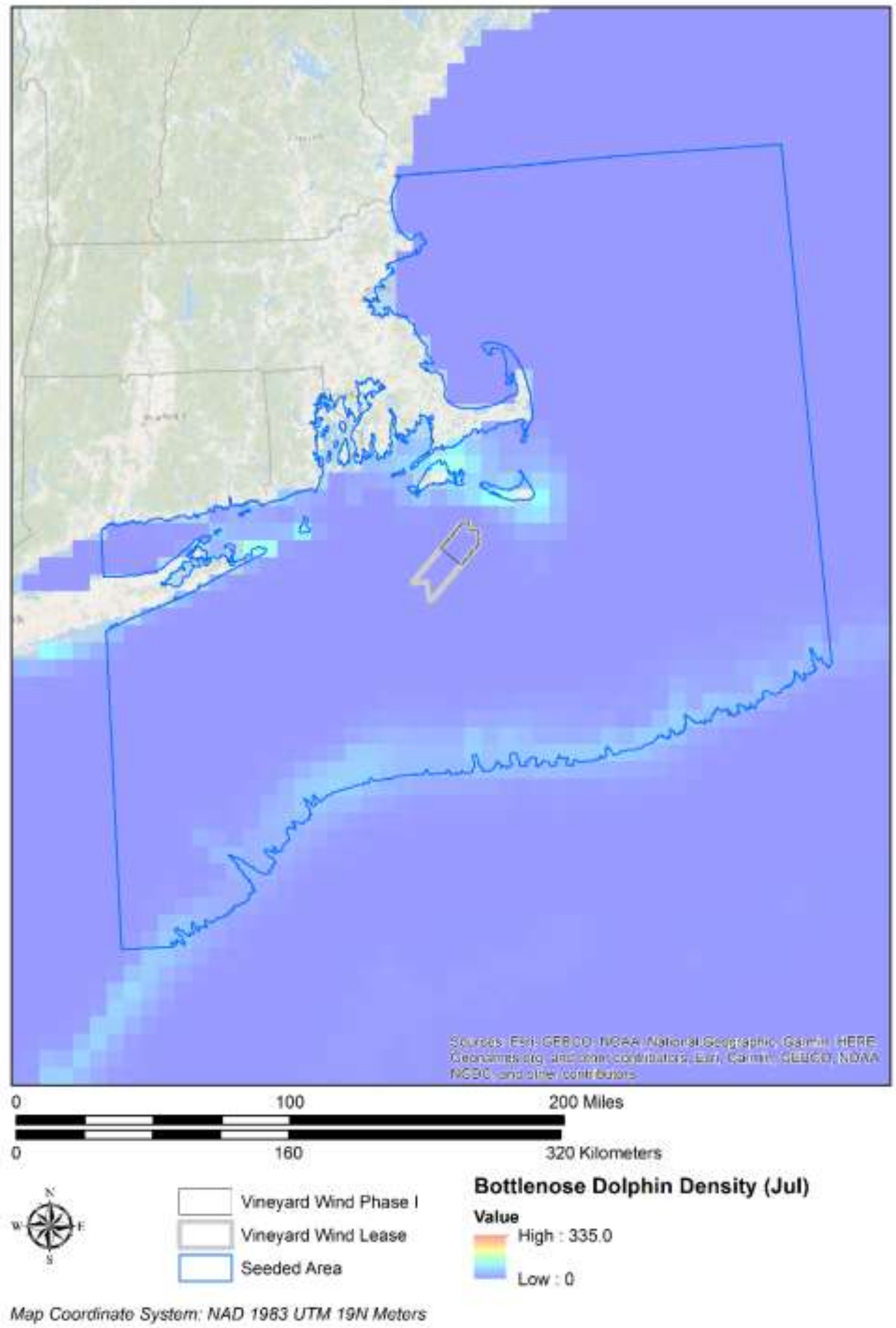

Figure B-7. Map of Bottlenose Dolphin animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018)_ENREF_312 for July, the month with the highest density in the simulation.

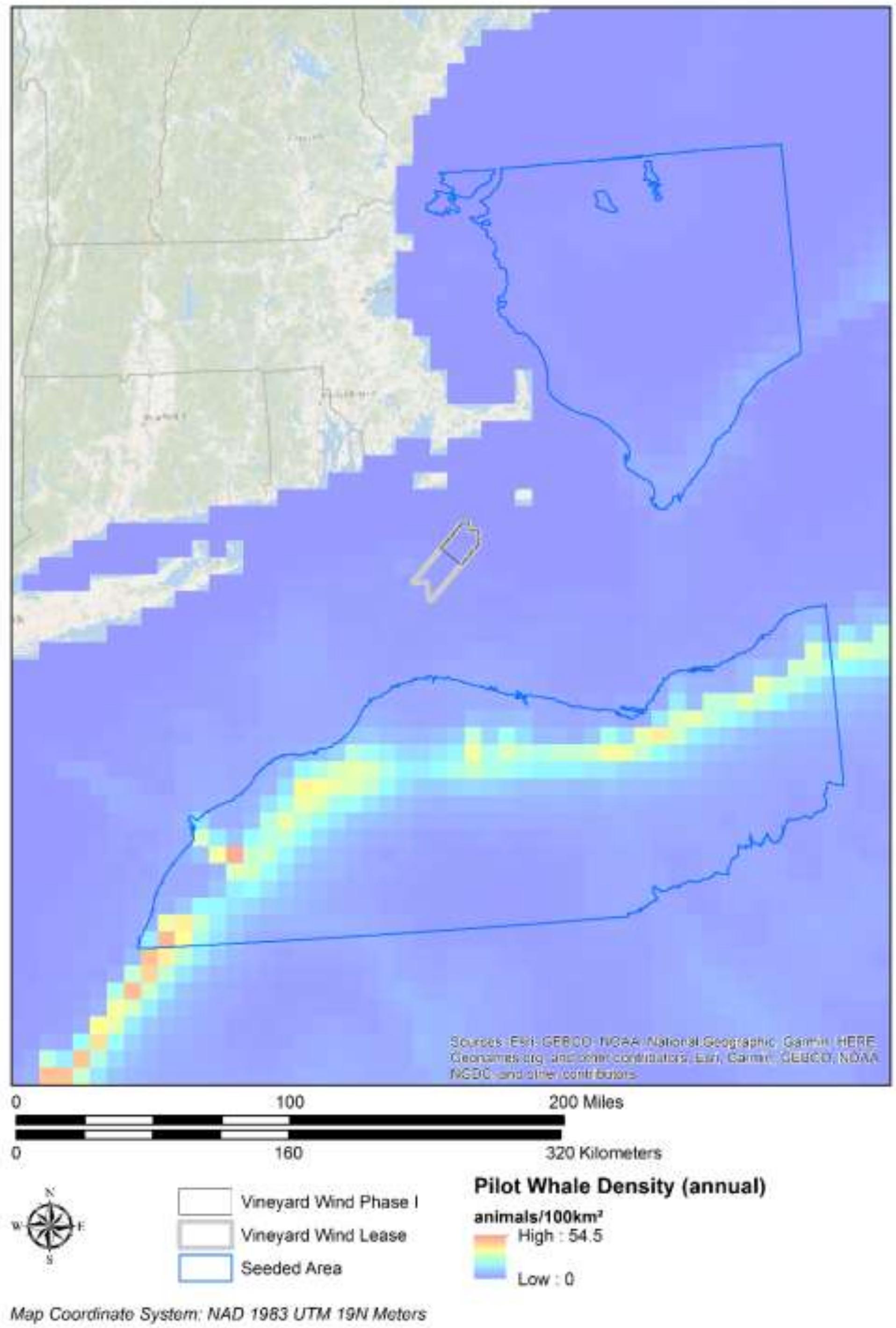

Figure B-8. Map of Pilot Whale animat seeding range with annual density from Roberts et al. (2016) and Roberts et al. (2018)_ENREF_312.

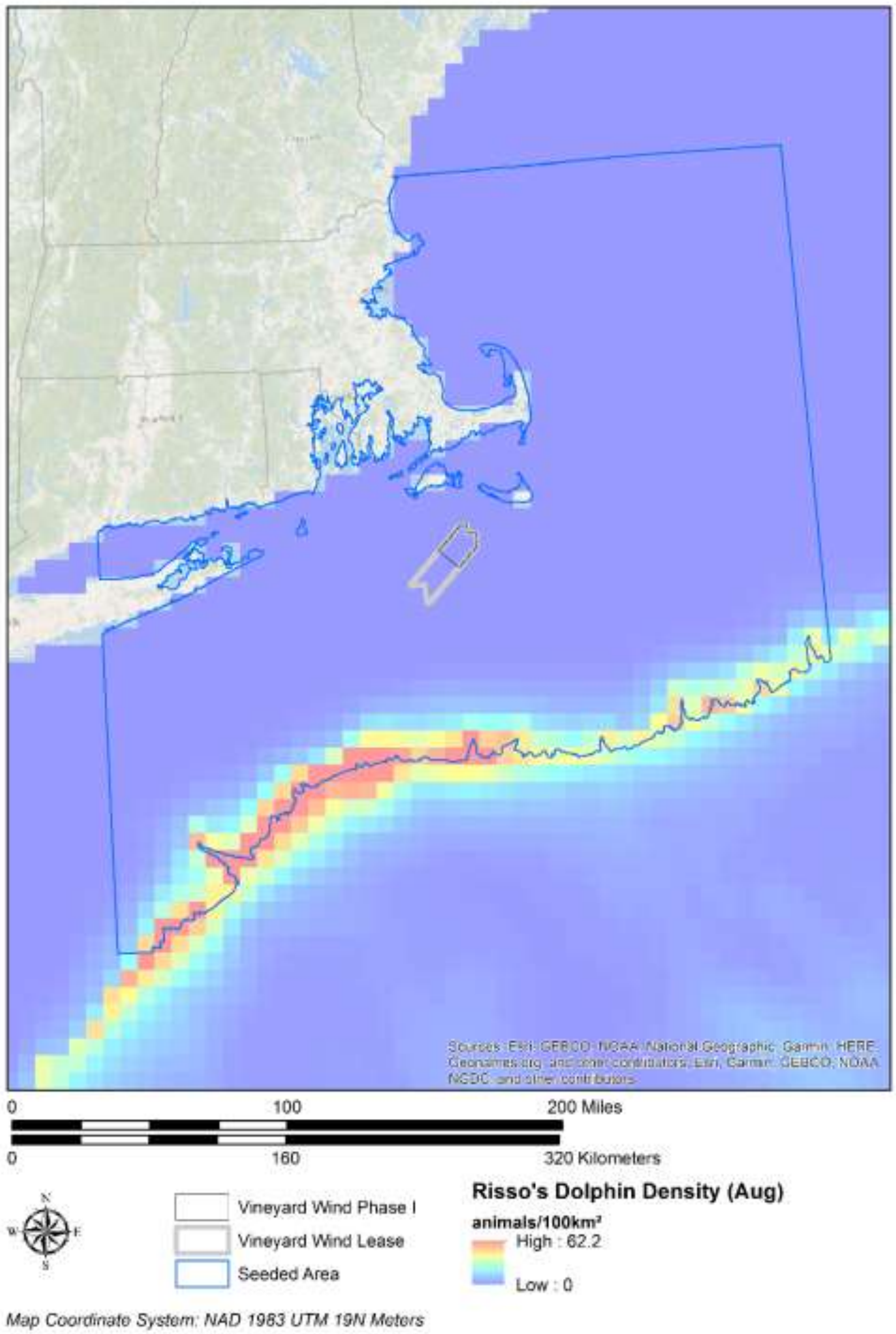

Figure B-9. Map of Risso's Dolphin animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for August, the month with the highest density in the simulation.

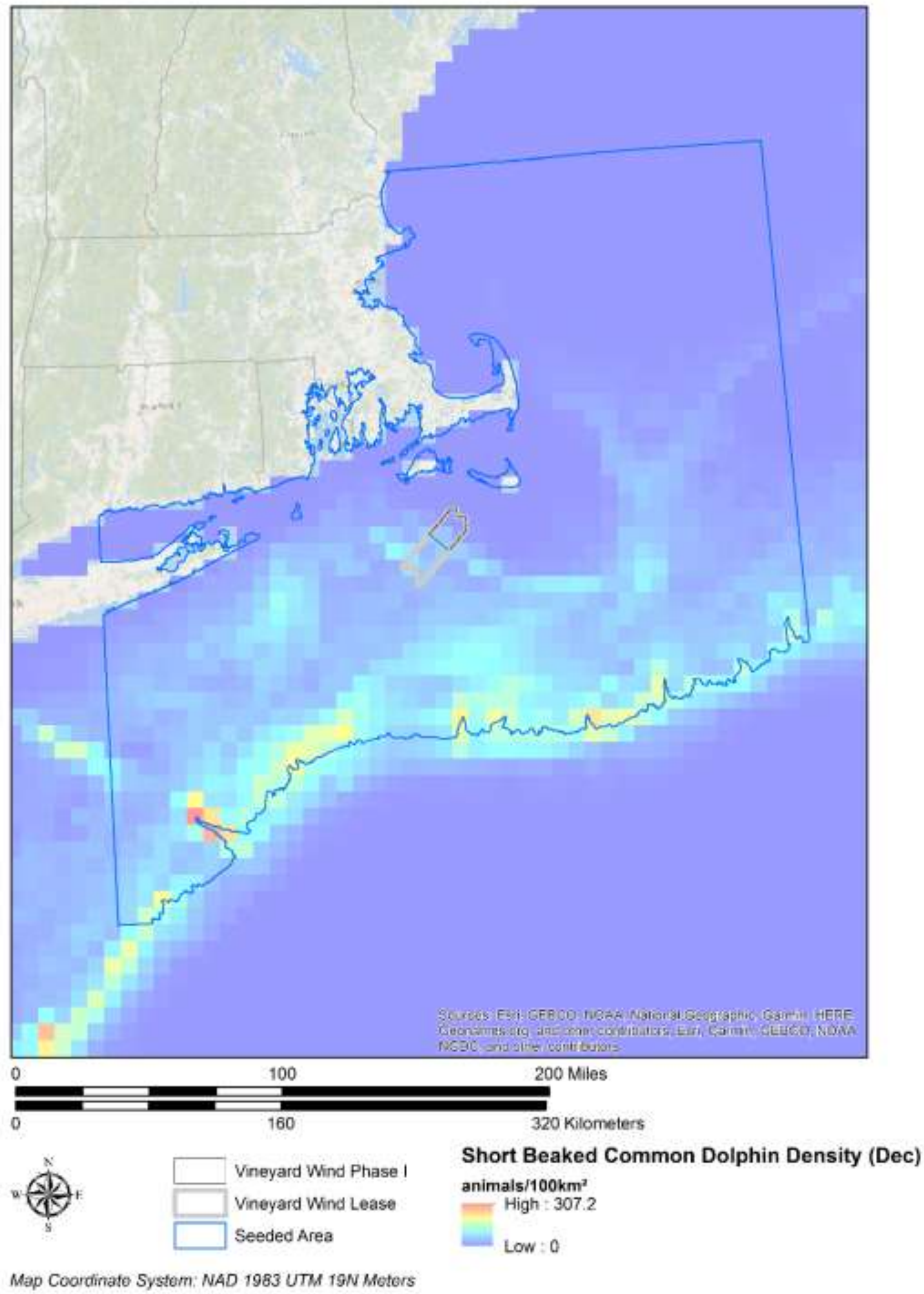

Figure B-10. Map of Short-beaked Common Dolphin animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for December, the month with the highest density in the simulation.

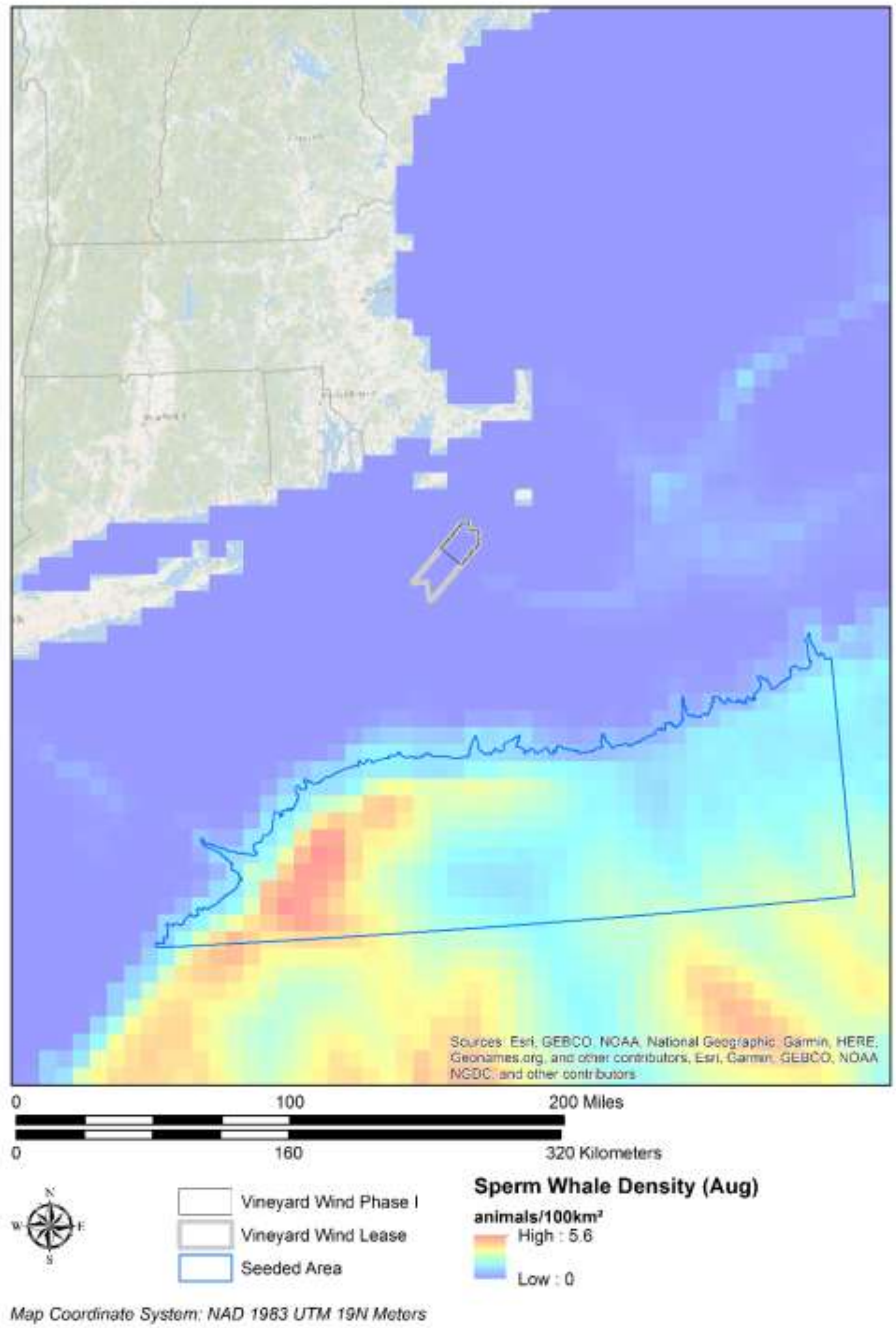

Figure B-11. Map of Sperm Whale animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for August, the month with the highest density in the simulation.

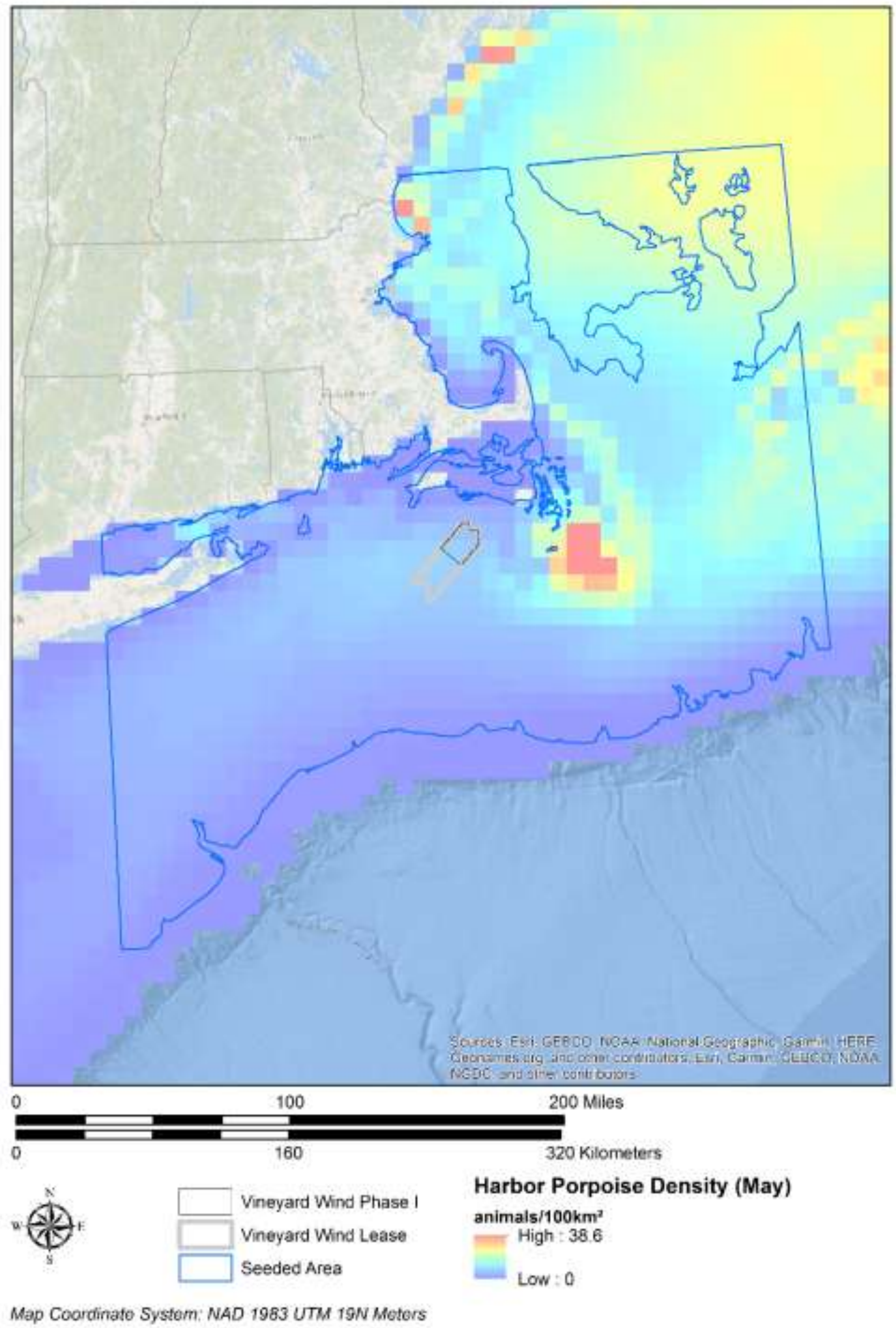

Figure B-12. Map of Harbor Porpoise animat seeding range with density from Roberts et al. (2016) and Roberts et al. (2018) for May, the month with the highest density in the simulation.

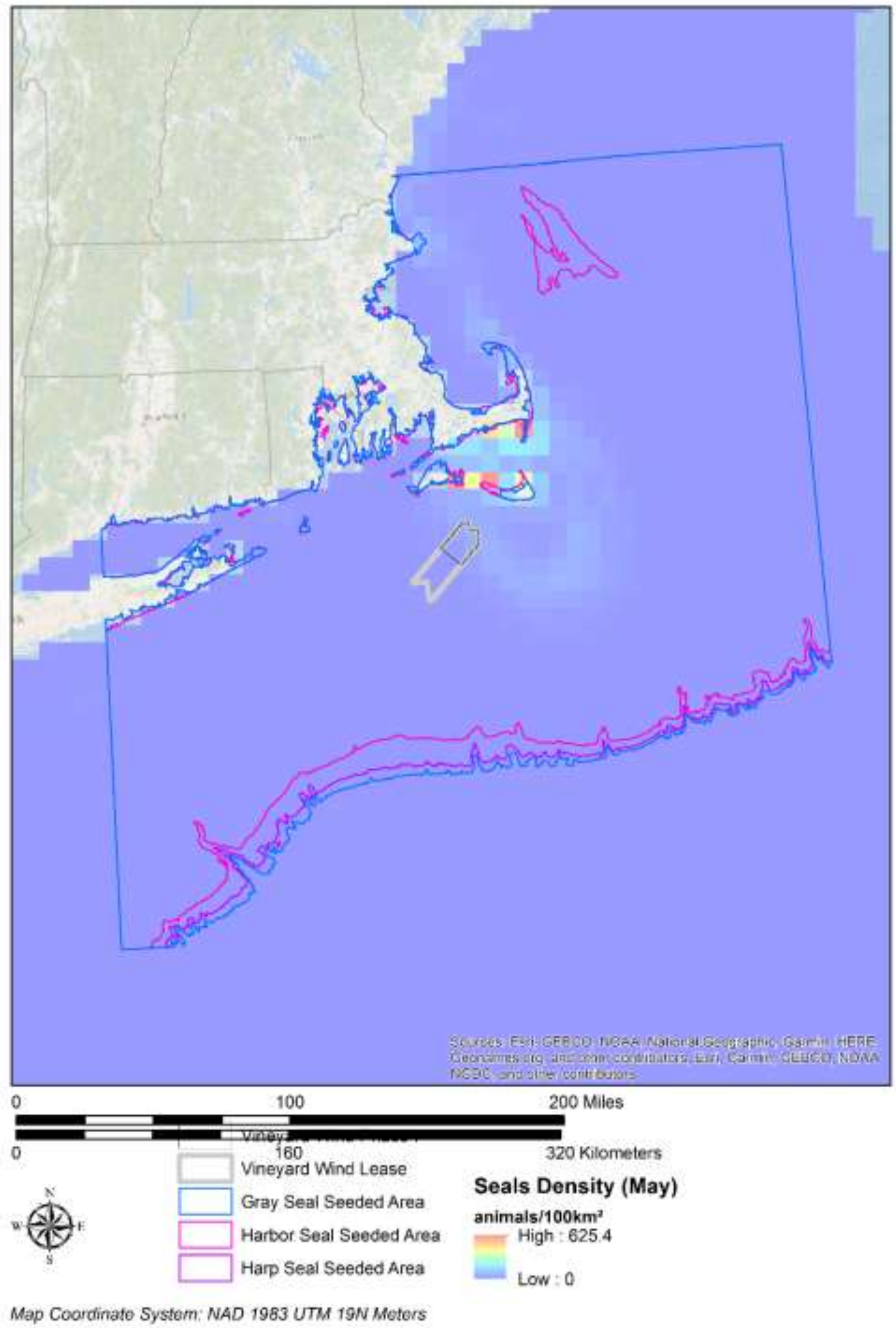

Figure B-13. Map of Gray, Harbor, and Harp Seal animat seeding range with density from Roberts et al. (2015) and Roberts et al. (2018) for May, the month with the highest density in the simulation.

Appendix C. Vineyard Wind Draft Monitoring Framework: Sound Field Verification and Visual and Acoustic Monitoring

C.1. Introduction

Vineyard Wind, LLC (Vineyard Wind) proposes to conduct visual and passive acoustic monitoring (PAM) and underwater sound field verification (SFV) for the proposed wind energy project in Federal waters offshore Massachusetts, Bureau of Ocean Energy Management (BOEM) Renewable Energy Lease Number OCS-A 0501 (the Project). Vineyard Wind submitted a Construction and Operations Plan (COP) to BOEM (dated December 19, 2017) and an Incidental Harassment Authorization (IHA) application to National Marine Fisheries Service (NMFS) (dated September 2018). In accordance with these filings, Vineyard Wind will implement monitoring and mitigation measures that include both visual and acoustic components. A monitoring and mitigation summary table is included in Vineyard Wind's COP (Appendix III-M) and the IHA application (Section 11). The objective for this monitoring framework is to describe the proposed methods for:

- visual monitoring for marine mammals and sea turtles during pile driving and vessel transit,
- measurement of *in situ* underwater sound levels (i.e., SFV) during pile driving activities to confirm that measured sound levels are at, or below modeled predictions used to estimate Level A and Level B exposures,
- passive acoustic monitoring (PAM) for marine mammal impact mitigation during pile driving, and
- long-range (~10 km) PAM for North Atlantic Right Whale (NARW) (*Eubalaena glacialis*) during pile driving construction from May 1-14 and November 1-December 31.

C.2. Monitoring Framework Scope

C.2.1. Visual Monitoring

C.2.1.1. Visual monitoring of clearance and monitoring zones

A minimum of two PSOs will maintain watch during daylight hours when pile driving is underway. PSOs will be deployed on the installation vessel, and will check the NMFS Sighting Advisory System for NARW activity. PSOs will monitor with reticle binoculars, both clearance and monitoring zones to the extent practicable, and will request a temporary cessation of pile driving if a marine mammal or sea turtle is observed within, or approaching the established, species-specific clearance zones. When a marine mammal or sea turtle sighting is made, the PSO will record:

- species, group size, age/size/sex categories (if determinable);
- observed behavior;
- heading (if consistent), bearing, and distance from the observer; and
- time, location, speed, and activity of the vessel, sea state, and visibility.

The vessel's position and speed, water depth, sea state, and visibility will also be recorded at the start and end of each observation period, and whenever there is a change in any of those variables that materially affects sighting conditions.

C.2.1.2. Additional visual mitigation monitoring for NARW (May 1-14)

Vineyard Wind will implement additional visual mitigation monitoring measures for NARW over an extended ~10 km radial distance from each pile driving location from May 1 to May 14. Prior to piling, an aerial- or vessel-based line transect survey will be conducted in this area with transect spacing of approximately 4 km. Surveys will employ two PSOs positioned on either side of the aircraft or vessel who will have direct communication to the lead PSO on duty. Surveys will commence only after PSOs determine that visibility is adequate for monitoring. On days with sun glare, aerial surveys will begin at least one hour after sunrise. If a NARW is sighted during these visual surveys, piling operations will not be conducted that day unless an additional survey is conducted to confirm the ~10 km zone is clear of NARW.

C.2.1.3. Visual monitoring during vessel transit

A dedicated observer who has undergone environmental and protected species observation training will be stationed on vessels traveling over 10 knots while transiting to and from the Wind Development Area (WDA) during speed restriction time periods. Observers will ensure maintenance of setback distances between animals and vessels (see IHA Mitigation Table for setback distances).

C.2.2. Acoustic Monitoring

C.2.2.1. Sound field verification (SFV)

The SFV involves the measurement of pile-driving underwater sound levels at various distances from the piles. Measured sound levels will be compared with acoustic model predictions used to estimate Level A and Level B sound exposure numbers included in permit applications to regulatory agencies.

During the SFV, Vineyard Wind plans to deploy two autonomous acoustic recorders (Figure C-1). Each acoustic recorder will consist of a vertical line array with two hydrophones deployed at depths spanning the water column (one near seabed and one in the water column). The proposed deployment locations are:

1. ~750 m, and
2. ~1500 m from the pile.

These distances from the sound source allow for interactions of sound with the physical environment (e.g., geoacoustics, water properties), providing a more accurate assessment of propagation than closer measurements.

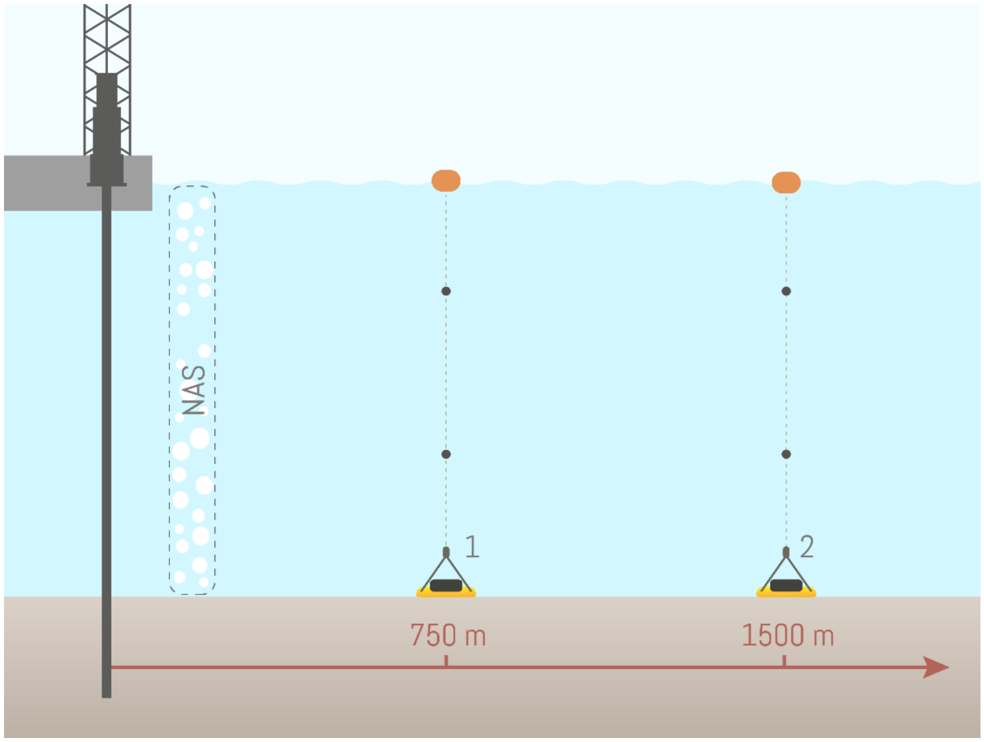

Figure C-1. Example illustration of a recorder array deployment for SFV.

SFV for the two pile types proposed in the COP Maximum Envelope, monopiles and jacket piles, will be conducted. Monopile and jacket foundations use different pile diameters, providing an opportunity to assess the influence of both geoacoustic properties and pile size.

Equipment specifications

Autonomous monitoring equipment will adequately sample levels and frequency content of sounds produced during pile driving. Mooring systems will be designed to minimize noise, and recorder and hydrophone sensitivity chosen to measure the sound level ranges from ambient to peak pressure during pile driving. Recording will be set to a minimum sampling rate of 64 kilosamples per second (ksps), an analysis band of ~10 Hz – 32 kHz.

Data analysis

Data will be stored on each acoustic recorder and downloaded once the recording is complete and the recorder retrieved. A concise report will be generated to summarize the results of the SFV and will be delivered to Vineyard Wind within 72 hours of retrieving the recorders. A full report will be generated once all pile monitoring is complete. The full analysis will use acoustic software to detect each pile impulse and calculate the following:

- Maximum peak pressure level (PK) (dB re 1 μPa)
- The maximum sound pressure levels (SPL) (90% energy, 100 ms integration time, dB re 1 μPa)
- The maximum single strike broadband sound exposure level (SEL, dB re 1 $\mu Pa^2 \cdot s$)
- The maximum decidecade-band single-strike SEL
- The pile driving broadband sound exposure level (SEL_{24hr}, dB re 1 $\mu Pa^2 \cdot s$)

Results will be presented in both tabulated and graphical form, with sound level verses range plots and associated empirical equations. The report will include tables of the maximum distances to the relevant acoustic threshold levels, based on the 90th percentile empirical function fits.

C.2.2.2. Acoustic monitoring of clearance zones

PAM will be utilized during pile driving to detect vocalizations of marine mammals inside clearance zones. Trained PAM operators will deploy acoustic equipment from a location in the vicinity of the installation to reduce acoustic interference. Additional details on acoustic monitoring of clearance zones are included in the IHA Monitoring and Mitigation table. Recording will be set to a minimum sampling rate of 128 kilosamples per second (ksps), an analysis band of ~10 Hz – 64 kHz.

C.2.2.3. Long-range mitigation monitoring for NARW (May 1-14 and November 1-December 31)

For the long-range mitigation monitoring of NARW, acoustic systems will be deployed to monitor for NARW vocalizations in an extended PAM zone of approximately 10 km around each pile during two time periods: May 1-14 and November 1-December 31. The selected monitoring approach shall demonstrate that the equipment type and configuration can effectively monitor the extended zone and communicate detections in near real-time so that Vineyard Wind is notified of any NARW vocalization detections as quickly as possible after detection to implement mitigation as needed. The system may be a static buoy, hydrophone array from a manned vessel, or an autonomous system.

Equipment specifications

NARW vocalization energy is typically below 500 Hz but may range up to 4 kHz. Therefore, the minimum specifications for acoustic sampling focused on the detection of NARW is 1 ksps, for an analysis band of ~10 Hz – 500 Hz. Recording systems will be designed to minimize self-noise.

Data analysis

On-site data processing and analysis will facilitate the near real-time detection of NARW and notification to Vineyard Wind and other stakeholders, as appropriate. In addition, data collected on the acoustic recorders will be stored internally for post-processing and analysis.