New England Wind Offshore Wind Farm

Application for Marine Mammal Protection Act (MMPA) Rulemaking and Letter of Authorization

Prepared by:

JASCO Applied Sciences (USA) Inc.

July 2022

Submitted to:

Permits and Conservation Division,
Office of Protected Resources, NOAA Fisheries

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:

Park City Wind LLC

Prepared by:
JASCO Applied Sciences (USA) Inc.
8701 Georgia Avenue, Suite 410
Silver Spring, MD 20910 USA
Tel: +1-301-565-3500
www.jasco.com

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Executive Summary

New England Wind is the proposal to develop offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0534 along with associated offshore and onshore cabling, onshore substations, and onshore operations and maintenance (O&M) facilities. Park City Wind LLC, a wholly owned subsidiary of Avangrid Renewables, LLC, is the Proponent for this Letter of Authorization (LOA) and will be responsible for the construction, operation, and decommissioning of New England Wind. This LOA application is being submitted to request the non-lethal take of marine mammals incidental to proposed construction of New England Wind.

New England Wind will be developed in two Phases with a maximum of 130 wind turbine generator (WTG) and electrical service platform (ESP) positions. Two positions may potentially have co-located ESPs (i.e., two foundations installed at one grid position[1]), resulting in 132 foundations. Four or five offshore export cables will transmit electricity generated by the WTGs to onshore transmission systems in the Town of Barnstable, Massachusetts. Figure 1 provides an overview of New England Wind.

New England Wind's offshore renewable wind energy facilities are located immediately southwest of Vineyard Wind 1, which is located in Lease Area OCS-A 0501. New England Wind will occupy all of Lease Area OCS-A 0534 and potentially a portion of Lease Area OCS-A 0501 in the event that Vineyard Wind 1 does not develop "spare" or extra positions included in Lease Area OCS-A 0501 and Vineyard Wind 1 assigns those positions to Lease Area OCS-A 0534. For the purposes of the LOA, the Southern Wind Development Area (SWDA) is defined as all of Lease Area OCS-A 0534 and the southwest portion of Lease Area OCS-A 0501, as shown in Figure 1.

The SWDA may be approximately 411–453 square kilometers (km^2) (101,590–111,939 acres) in size depending upon the final footprint of Vineyard Wind 1. At this time, the Proponent does not intend to develop the two positions in the separate aliquots located along the northeastern boundary of Lease Area OCS-A 0501 as part of New England Wind (see Figure 1). The SWDA (excluding the two separate aliquots that are closer to shore) is just over 32 kilometers (km) (20 miles [mi]) from the southwest corner of Martha's Vineyard and approximately 38 km (24 mi) from Nantucket. The WTGs and ESPs in the SWDA will be oriented in an east-west, north-south grid pattern with 1 nautical mile (NM) (1.85 km) spacing between positions.

Each Phase of New England Wind will be developed and permitted using a Project Design Envelope (the "Envelope"). This allows the Proponent to properly define and bracket the characteristics of each Phase for the purposes of environmental review while maintaining a reasonable degree of flexibility with respect to the selection of key components, such as the WTGs, foundations, offshore cables, and ESPs. To assess potential impacts and benefits to various resources, a "maximum design scenario," or the design scenario with the maximum impacts anticipated for that resource, is established considering the Envelope parameters for each Phase that have the potential to cause the greatest effect. For some resources, this approach overestimates potential environmental impacts as the maximum design scenario is not the scenario that the Proponent is likely to employ.

[1] If co-located ESPs are used, each ESP's monopile foundation would be located within 76 m (250 ft) of one of the potential ESP grid locations (i.e., the monopiles would be separated by up to 152 m [500 ft]).

Phase 1 of New England Wind

Phase 1, also known as Park City Wind, will be developed immediately southwest of the Vineyard Wind 1 project. The Phase 1 Envelope allows for 41 to 62 WTGs and one or two ESP(s). Depending upon the capacity of the WTGs, Phase 1 will occupy 150–231 km^2 (37,066–57,081 acres) of the SWDA. The Phase 1 Envelope includes two WTG foundation types: monopiles and piled jackets. Strings of WTGs will connect with the ESP(s) via a submarine inter-array cable transmission system. The ESP(s) will include step-up transformers that increase the voltage of power generated by the WTGs prior to transmission and other electrical equipment. The ESP(s) will also be supported by a monopile or jacket foundation. Two high-voltage alternating current (HVAC) offshore export cables up to 101 km (54 NM) in length (per cable) installed within the SWDA and an Offshore Export Cable Corridor (OECC) will transmit electricity from the ESP(s) to a landfall site at the Craigville Public Beach or Covell’s Beach in the Town of Barnstable. Underground onshore export cables, located principally in roadway layouts, will connect the landfall site to a new Phase 1 onshore substation in Barnstable. Grid interconnection cables will then connect the Phase 1 onshore substation to the ISO New England (ISO-NE) electric grid at Eversource’s existing 345 kilovolt substation in West Barnstable.

Phase 2 of New England Wind

Phase 2, also known as Commonwealth Wind, will be immediately southwest of Phase 1 and will occupy the remainder of the SWDA. Phase 2 may include one or more projects, depending on market conditions. The footprint and total number of WTG and ESP positions in Phase 2 depends upon the final footprint of Phase 1; Phase 2 is expected to contain 64 to 88 WTG/ESP positions (up to three positions will be occupied by ESPs) within an area ranging from 222–303 km^2 (54,857–74,873 acres). The Phase 2 Envelope includes three general WTG foundation types: monopiles, jackets (with piles or suction buckets), or bottom-frame foundations (with piles or suction buckets). Inter-array cables will transmit electricity from the WTGs to the ESP(s). The ESP(s) will also be supported by a monopile or jacket foundation (with piles or suction buckets).

Two or three HVAC offshore export cables, each with a maximum length of 116–124 km (63–67 NM) per cable, will transmit power from the ESP(s) to shore. The Proponent intends to install all Phase 2 offshore export cables within the same OECC as the Phase 1 cables from the northwestern corner of the SWDA to within approximately 2–3 km (1–2 mi) of shore, at which point the OECC for Phase 2 will diverge to reach the Dowses Beach Landfall Site and/or Wianno Avenue Landfall Site in Barnstable. However, the Proponent has also identified two variations of the Phase 2 OECC in the event that technical, logistical, grid interconnection, or other unforeseen issues arise during the engineering and permitting processes that preclude one or more Phase 2 offshore export cables from being installed within all or a portion of the OECC. These variations of the Phase 2 OECC—the Western Muskeget Variant and the South Coast Variant—are shown on Figure 2.

Underground onshore export cables, located primarily within existing roadway layouts, will connect the landfall site(s) to one or two new onshore substations in the Town of Barnstable. Grid interconnection cables will then connect the onshore substation site(s) to the West Barnstable Substation. If the Phase 2 OECC South Coast Variant is employed and electricity generated by Phase 2 is delivered to a second grid interconnection point, Phase 2 could include one onshore transmission system in Barnstable and/or an onshore transmission system(s) in proximity to the second grid interconnection point.

For both Phases, to support construction and operation activities, the Proponent will use a combination of North Atlantic ports in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and/or Canada. During appropriate time periods, New England Wind-related vessels traveling to/from Salem Harbor will transit at 18.4 km per hour (10 knots) or less within NOAA-designated North Atlantic right whale critical habitat and outside critical habitat.

Pile installation, limited geophysical survey work, and the potential for disposal of unexploded ordnance (UXO) associated with the proposed offshore wind energy construction activities have the potential to affect marine mammals and could result in harassment under the Marine Mammal Protection Act (MMPA) of 1972, as amended. Pursuant to MMPA Section 101(a)(5)(A), Park City Wind LLC submits this LOA application to the National Marine Fisheries Service (NMFS) for the authorization of incidental, but not intentional, take of individuals of 39 marine mammal species during the specified activities for the Proposed Action for a period of up to 5 years beginning in 2025. The yearly numbers of requested takes relative to the species' populations fall with the MMPA small numbers determination. The impact analysis suggests negligible impact of the proposed activities. Additionally, ceremonial or subsistence use considerations are not applicable.

To assess potential impacts to marine mammals from sound exposure associated with anthropogenic activities described in this LOA, JASCO Applied Sciences (USA) Inc. (JASCO) performed acoustic modeling of impact pile driving and density-based exposure estimation for HRG surveys and for drilling and vibratory setting used during pile installation on behalf of the Proponent. As the final construction schedule is unknown at this early stage in the construction planning process, a conservative approach was taken in the assessment. To provide the Proponent flexibility, the modeling assumed two different possible schedules with 133 foundations[2].

The modeling is a three-step process that first characterizes the sounds produced by the various sources, then determines how the sounds propagate within the surrounding water column in the lease area using local bathymetry and sound velocity profiles, and then estimates species-specific exposure probabilities by combining the computed sound fields with simulated animal movement. The result is a probabilistic estimate of the number of individual animals predicted to experience sound levels exceeding pre-established United States (US) regulatory threshold criteria for marine mammal Level A and Level B harassment. Predicted exposures and the methods used to convert these to Level A and Level B requested takes are described in detail in Section 6. For rare species, with densities too low to provide meaningful model results, the take request is based on the species' average group size. The take request for modeled species is shown below in Table ES-1 and Table ES-2, and for rare species in Table ES-3 and Table ES-4. Year assignments of takes reflect the currently projected construction start year of 2025 and are subject to change because exact project start dates and construction schedules are not currently available. The animal movement modeling examined two potential construction schedules. It is anticipated that under construction schedule A, all takes would occur during 2025–2026 and under construction schedule B, all takes would occur during 2025–2027.

Both Level A and Level B takes are requested in this LOA for impact pile driving, with the exceptions of the Atlantic spotted dolphin (for which the modeling predicts no Level A exposures), most rare species, and the North Atlantic right whale (NARW), for which specific mitigations will be implemented during piling to ensure that no Level A take occurs. Level A harassment associated with pile driving activities will be minimized for all species and avoided for NARW by implementing the mitigation measures described in Section 9.1. Level B takes are being requested for exposure to vibratory pile setting and drilling sounds. Only Level B takes are associated with geophysical surveys. Level A takes are also being requested for

[2] A total of 132 foundations are presently proposed, which includes 130 WTG/ESP grid positions with two positions potentially having co-located ESPs (i.e., two foundations installed at one grid position). An earlier plan for New England Wind included one additional foundation for a potential reactive compensation station (RCS), bringing the total to 133 foundations. Therefore, hydroacoustic modeling presented in this application includes 133 foundations (completed prior to the elimination of the potential RCS), resulting in a conservative estimate of animal exposures for a project with 132 foundations.

potential UXO detonation. The conservative assumptions (see Section 6) used to estimate exposures and calculate takes likely overestimate the real potential take numbers.

Regulations governing the issuance of incidental take under certain circumstances are codified at 50 Code of Federal Regulations part 216, subpart I (Sections 216.101–216.108). Section 216.104 sets forth 14 specific items that must be addressed in requests for take pursuant to Section 101 (a)(5)(A) of the MMPA. These 14 items are addressed in Sections 1 through 14 of this LOA application.

Table ES-1. Requested Level A and Level B takes[a] by year for all activities for the effective period of the LOA (5-year total).

	Species	Population size	2025[b]			2026			2027			2028			2029		
			Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %
LF	Fin whale[c]	6,802	11	826	12.31	24	875	13.22	9	350	5.28	0	3	0.04	0	3	0.04
LF	Minke whale	21,968	5	303	1.40	13	323	1.53	6	133	0.63	0	2	0.01	0	2	0.01
LF	Humpback whale	1,396	7	375	27.36	14	398	29.51	6	160	11.89	0	3	0.21	0	3	0.21
LF	North Atlantic right whale[c]	368	0	88	23.91	0	91	24.73	0	46	12.50	0	7	1.90	0	7	1.90
LF	Sei whale[c]	6,292	1	30	0.49	2	30	0.51	1	15	0.25	0	2	0.03	0	2	0.03
MF	Atlantic white-sided dolphin	93,233	2	10,492	11.26	2	11,170	11.98	1	4,773	5.12	0	57	0.06	0	57	0.06
MF	Atlantic spotted dolphin	39,921	0	343	0.86	1	361	0.91	0	178	0.45	0	30	0.08	0	30	0.08
MF	Short-beaked common dolphin	172,974	6	33,730	19.50	4	35,879	20.74	1	15,030	8.69	0	400	0.23	0	400	0.23
MF	Bottlenose dolphin, offshore	62,851	1	14,788	23.53	2	16,267	25.89	1	6,510	10.36	0	256	0.41	0	256	0.41
MF	Risso’s dolphin	35,215	1	336	0.96	1	345	0.98	1	144	0.41	0	7	0.02	0	7	0.02
MF	Long-finned pilot whale	39,215	1	1,310	3.34	2	1,395	3.56	1	588	1.50	0	17	0.04	0	17	0.04
MF	Short-finned pilot whale	28,924	1	960	3.32	2	1,029	3.56	0	432	1.49	0	9	0.03	0	9	0.03
MF	Sperm whale[c]	4,349	1	59	1.38	1	67	1.56	1	28	0.67	0	2	0.05	0	2	0.05
HF	Harbor porpoise	95,543	44	3,197	3.39	262	3,727	4.18	45	1,496	1.61	0	113	0.12	0	113	0.12
PPW	Gray seal	27,300	1	2,513	9.21	10	2,232	8.21	1	1,230	4.51	0	262	0.96	0	262	0.96
PPW	Harbor seal	61,336	1	5,648	9.21	23	5,012	8.21	2	2,771	4.52	0	588	0.96	0	588	0.96
PPW	Harp seal	7,600,000	1	2,516	0.03	10	2,235	0.03	1	1,235	0.02	0	262	0.00	0	262	0.00

[a] Take is the yearly request for all sound-producing activities calculated as described in Sections 6.1–6.7. For days when pile installation includes both vibratory setting and drilling, only the vibratory setting Level B takes are included (because more takes are predicted for this activity) and not the drilling Level B takes to avoid double counting.

[b] For the purpose of this LOA request, Year 1 is assumed to be 2025. These dates reflect the currently projected construction start year and are subject to change because exact project start dates and construction schedules are not currently available.

[c] Listed as Endangered under the ESA.

Table ES-2. Summary of requested Level A and Level B takes[a] for all activities for the effective period of the LOA (5-year total).

Species		Population size	5 Year Total		
			Level A	Level B	Max Percent
LF	Fin whale[b]	6,802	40	1,948	29.23
	Minke whale	21,968	22	740	3.47
	Humpback whale	1,396	23	878	64.54
	North Atlantic right whale[b]	368	0	228	61.96
	Sei whale[b]	6,292	3	76	1.26
MF	Atlantic white-sided dolphin	93,233	3	25,510	27.36
	Atlantic spotted dolphin	39,921	1	898	2.25
	Short-beaked common dolphin	172,974	8	78,887	45.61
	Bottlenose dolphin, offshore	62,851	2	36,505	58.08
	Risso's dolphin	35,215	1	782	2.22
	Long-finned pilot whale	39,215	2	3,114	7.95
	Short-finned pilot whale	28,924	2	2,283	7.90
	Sperm whale[b]	4,349	1	149	3.45
HF	Harbor porpoise	95,543	340	8,244	8.98
PPW	Gray seal	27,300	11	6,390	23.45
	Harbor seal	61,336	25	14,382	23.49
	Harp seal	7,600,000	11	6,405	0.08

[a] Take is the total request for all sound-producing activities calculated as described in Sections 6.1–6.7. For days when pile installation includes both vibratory setting and drilling, only the vibratory setting Level B takes are included (because more takes are predicted for this activity) and not the drilling Level B takes to avoid double counting.

[b] Listed as Endangered under the ESA.

Table ES-3. Yearly number of Level A and Level B takes[a] requested for rare species for all activities for the effective period of the LOA (5-year total).

	Species	Stock SIZE	2025[b]			2026			2027			2028			2029		
			Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %
LF	Blue whale[c]	402	1	2	0.75	1	2	0.75	1	2	0.75	0	0	0.00	0	0	0.00
MF	Clymene dolphin	4,237	0	167	3.94	0	167	3.94	0	167	3.94	0	0	0.00	0	0	0.00
	False killer whale[d]	1,791	0	10	0.56	0	10	0.56	0	10	0.56	0	5	0.28	0	5	0.28
	Fraser's dolphin	NA	0	192	NA	0	192	NA	0	192	NA	0	0	NA	0	0	NA
	Killer whale[d]	NA	0	4	NA	0	4	NA	0	4	NA	0	2	NA	0	2	NA
	Melon-headed whale	NA	0	109	NA	0	109	NA	0	109	NA	0	0	NA	0	0	NA
	Pantropical spotted dolphin	6,593	0	60	0.91	0	60	0.91	0	60	0.91	0	0	0.00	0	0	0.00
	Pygmy killer whale	NA	0	5	NA	0	5	NA	0	5	NA	0	0	NA	0	0	NA
	Rough-toothed dolphin	136	0	14	10.29	0	14	10.29	0	14	10.29	0	0	0.00	0	0	0.00
	Spinner dolphin	4,102	0	51	1.24	0	51	1.24	0	51	1.24	0	0	0.00	0	0	0.00
	Striped dolphin	67,036	0	64	0.10	0	64	0.10	0	64	0.10	0	0	0.00	0	0	0.00
	White-beaked dolphin[d]	536,016	0	60	0.01	0	60	0.01	0	60	0.01	0	30	0.01	0	30	0.01
	Beluga whale	131,450	0	2	0.00	0	2	0.00	0	2	0.00	0	0	0.00	0	0	0.00
	Cuvier's beaked whale	5,744	0	3	0.05	0	3	0.05	0	3	0.05	0	0	0.00	0	0	0.00
	Blainville's beaked whale	10,107	0	4	0.04	0	4	0.04	0	4	0.04	0	0	0.00	0	0	0.00
	Gervais' beaked whale	10,107	0	4	0.04	0	4	0.04	0	4	0.04	0	0	0.00	0	0	0.00
	Sowerby's beaked whale	10,107	0	4	0.04	0	4	0.04	0	4	0.04	0	0	0.00	0	0	0.00
	True's beaked whale	10,107	0	3	0.03	0	3	0.03	0	3	0.03	0	0	0.00	0	0	0.00
	Northern bottlenose whale	NA	0	4	NA	0	4	NA	0	4	NA	0	0	NA	0	0	NA
HF	Dwarf sperm whale	7,750	2	2	0.05	2	2	0.05	2	2	0.05	0	0	0.00	0	0	0.00
	Pygmy sperm whale	7,750	2	2	0.05	2	2	0.05	2	2	0.05	0	0	0.00	0	0	0.00
PPW	Hooded seal	NA	0	1	NA	0	1	NA	0	1	NA	0	0	NA	0	0	NA

[a] Take is the yearly request for all sound-producing activities calculated as described in Sections 6.1–6.7.
[b] For the purpose of this LOA request, Year 1 is assumed to be 2025. These dates reflect the currently projected construction start year and are subject to change because exact project start dates and construction schedules are not currently available.
[c] Listed as Endangered under the ESA.
[d] Take for these species is based on PSO sighting group sizes; for all other species group size is from OBIS data.

Table ES-4. Summary of total Level A and Level B takes[a] requested for rare species for all activities for the effective period of the LOA (5-year total).

	Species	Stock Size	5-Year total		
			Level A	Level B	Max %
LF	Blue whale[b]	402	2	4	1.49
MF	Clymene dolphin	4,237	0	334	7.88
	False killer whale[c]	1,791	0	25	1.40
	Fraser's dolphin	NA	0	384	NA
	Killer whale[c]	NA	0	10	NA
	Melon-headed whale	NA	0	218	NA
	Pantropical spotted dolphin	6,593	0	120	1.82
	Pygmy killer whale	NA	0	10	NA
	Rough-toothed dolphin	136	0	28	20.59
	Spinner dolphin	4,102	0	102	2.49
	Striped dolphin	67,036	0	128	0.19
	White-beaked dolphin[c]	536,016	0	150	0.03
	Beluga whale	131,450	0	4	0.00
	Cuvier's beaked whale	5,744	0	6	0.10
	Blainville's beaked whale	10,107	0	8	0.08
	Gervais' beaked whale	10,107	0	8	0.08
	Sowerby's beaked whale	10,107	0	8	0.08
	True's beaked whale	10,107	0	6	0.06
	Northern bottlenose whale	NA	0	8	NA
HF	Dwarf sperm whale	7,750	4	4	0.10
	Pygmy sperm whale	7,750	4	4	0.10
PPW	Hooded seal	NA	0	2	NA

[a] Take is the total request for impact pile driving and HRG surveys calculated as described in Section 6.6.2 based on group size.
[b] Listed as Endangered under the ESA.
[c] Take for these species is based on PSO sighting group sizes; for all other species group size is from OBIS data.

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Acronyms and Abbreviations

AMAPPS	Atlantic Marine Assessment Program for Protected Species
BHA	bottom hole assembly
BIA	Biologically Important Area
BOEM	Bureau of Ocean Energy Management
CeTAP	Cetacean and Turtle Assessment Program
COP	Construction and Operations Plan
dB	decibel
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)
HRG	high resolution geophysical
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
$L_{E,24h}$	cumulative sound exposure level over a 24 hour period
LF	low frequency (cetacean hearing group)
L_p	sound pressure level
L_{pk}	peak sound pressure level
m	meter
m/s	meters per second
MA	Massachusetts
MF	mid-frequency (cetacean hearing group)
mi	mile
MMPA	Marine Mammal Protection Act
MONM	Marine Operations Noise Model
MP	Monopile

NARW	North Atlantic right whale
NEAq	New England Aquarium
NEFSC	Northeast Fisheries Science Center
NLPSC	Northeast Large Pelagic Survey Collaborative
NM	nautical mile
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
OECC	Offshore Export Cable Corridor
OSP	Optimum Sustainable Population
PAM	passive acoustic monitoring
PDSM	Pile Driving Source Model
PK	peak sound pressure level
PSO	protected species observer
PTS	permanent threshold shift
PW	phocid in water (hearing group)
RI	Rhode Island
rms	root mean square
SEFSC	Southeast Fisheries Science Center
SEL	sound exposure level
SEL_{cum}	cumulative sound exposure level
SLs	sound levels
SPL	sound pressure level
SPUE	sightings per unit effort
SWDA	Southern Wind Development Area
TP	transition piece
TTS	temporary threshold shift
USC.	United States Code
USFWS	US Fish and Wildlife Service
WDA	Wind Development Area
WEA	Wind Energy Area
WTG	wind turbine generator
μPa	micropascal

1. Description of Specified Activity

This application is being submitted for a Letter of Authorization (LOA) for the unintentional and non-lethal take of marine mammals incidental to proposed construction of New England Wind. New England Wind is the proposal to develop offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0534 along with associated offshore and onshore cabling, onshore substations, and onshore operations and maintenance (O&M) facilities. Park City Wind LLC, a wholly owned subsidiary of Avangrid Renewables, LLC, is the Proponent for this LOA and will be responsible for the construction, operation, and decommissioning of New England Wind. The 14 specific items required for this application, as set out by 50 Code of Federal Regulations (CFR) 216.104 Submission of Requests, are addressed in Chapters 1–14 of this application.

New England Wind will be developed in two Phases with a maximum of 130 wind turbine generator (WTG) and electrical service platform (ESP) positions. Two positions may potentially have co-located ESPs (i.e., two foundations installed at one grid position[3]), resulting in 132 foundations. Four or five offshore export cables will transmit electricity generated by the WTGs to onshore transmission systems in the Town of Barnstable, Massachusetts. Figure 1 provides an overview of New England Wind.

Each Phase of New England Wind will be developed and permitted using a Project Design Envelope (the "Envelope"). This allows the Proponent to properly define and bracket the characteristics of each Phase for the purposes of environmental review while maintaining a reasonable degree of flexibility with respect to the selection of key components, such as the WTGs, foundations, offshore cables, and ESPs. To assess potential impacts and benefits to various resources, a "maximum design scenario," or the design scenario with the maximum impacts anticipated for that resource, is established considering the Envelope parameters for each Phase that have the potential to cause the greatest effect. For some resources, this approach overestimates potential environmental impacts as the maximum design scenario is not the scenario that the Proponent is likely to employ. The Envelope for each Phase is described briefly below. The Construction and Operations Plan (COP) provides a detailed description of New England Wind, including tentative construction schedules in Volume I, Sections 3 and 4 (see www.boem.gov/New-England-Wind).

New England Wind has significant environmental benefits. The electricity generated by the WTGs will significantly reduce emissions. New England Wind is expected to reduce carbon dioxide equivalent (CO_2e) emissions from the ISO-NE electric grid by approximately 3.93 million tons per year (tpy), which is the equivalent of taking 775,000 cars off the road over the lifespan of the project. New England Wind will significantly decrease the region's reliance on fossil fuels and enhance the reliability and diversity of regional energy supply. In addition to these important environmental and energy reliability benefits, New England Wind is expected to result in significant long-term economic benefits and high-quality jobs.

New England Wind's offshore renewable wind energy facilities are located immediately southwest of Vineyard Wind 1, which is located in Lease Area OCS-A 0501. New England Wind will occupy all of Lease Area OCS-A 0534 and potentially a portion of Lease Area OCS-A 0501 in the event that Vineyard Wind 1 does not develop "spare" or extra positions included in Lease Area OCS-A 0501 and Vineyard Wind 1 assigns those positions to Lease Area OCS-A 0534. For the purposes of the LOA, the Southern Wind Development Area (SWDA) is defined as all of Lease Area OCS-A 0534 and the southwest portion of Lease Area OCS-A 0501, as shown in Figure 1. The Offshore Development Area is defined as the area

[3] If co-located ESPs are used, each ESP's monopile foundation would be located within 76 m (250 ft) of one of the potential ESP grid locations (i.e., the monopiles would be separated by up to 152 m [500 ft]).

where New England Wind's offshore facilities are physically located, which includes the SWDA as well as the Offshore Export Cable Corridor (OECC).

The SWDA may be approximately 411–453 square kilometers (km^2) (101,590–111,939 acres) in size depending upon the final footprint of Vineyard Wind 1. At this time, the Proponent does not intend to develop the two positions in the separate aliquots located along the northeastern boundary of Lease Area OCS-A 0501 as part of New England Wind (see Figure 1). The SWDA (excluding the two separate aliquots that are closer to shore) is just over 32 kilometers (km) (20 miles [mi]) from the southwest corner of Martha's Vineyard and approximately 38 km (24 mi) from Nantucket. The WTGs and ESPs in the SWDA will be oriented in an east-west, north-south grid pattern with 1 nautical mile (NM) (1.85 km) spacing between positions.

The SWDA lies within Atlantic Exclusive Economic Zone (EEZ), waters that support several marine mammal species and is therefore subject to review under the MMPA (16 United States Code [USC.] 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 operations described in this application. 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 USC. 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. Because of the planned mitigation measures (see Section 11), no lethal takes are anticipated. NOAA has determined that some types of high-resolution geophysical (HRG) sources that operate at and below 180 kilohertz (kHz) have the potential to cause Level B harassment within a short distance of disturbance from the sound source. Additionally, vibratory hammering could be used in the setting of piles and drilling may be required to remove boulders in the case of pile refusal. Both these activities generate sound that could expose marine mammals to sounds above the Level B threshold. Finally, detonation of unexploded ordnances (UXOs) may be required if they are encountered during construction activities, such as cable laying, and when avoidance, physical removal, or alternative combustive removal is not feasible. Sound from detonation of UXOs have the potential to take marine mammals by both Level A and Level B harassment. Sounds from other construction activities, including Project-related vessel activity, topside installation, scour protection, and cable laying were considered (Appendix A). These activities are not expected to contribute significantly to the acoustic footprint of New England Wind construction activities (see Section 1.1 for a description of these activities) and therefore they are not considered in the analysis. Incidental take that may arise from impact pile driving, HRG surveys, vibratory setting of piles, drilling, and UXO detonation is included in this application.

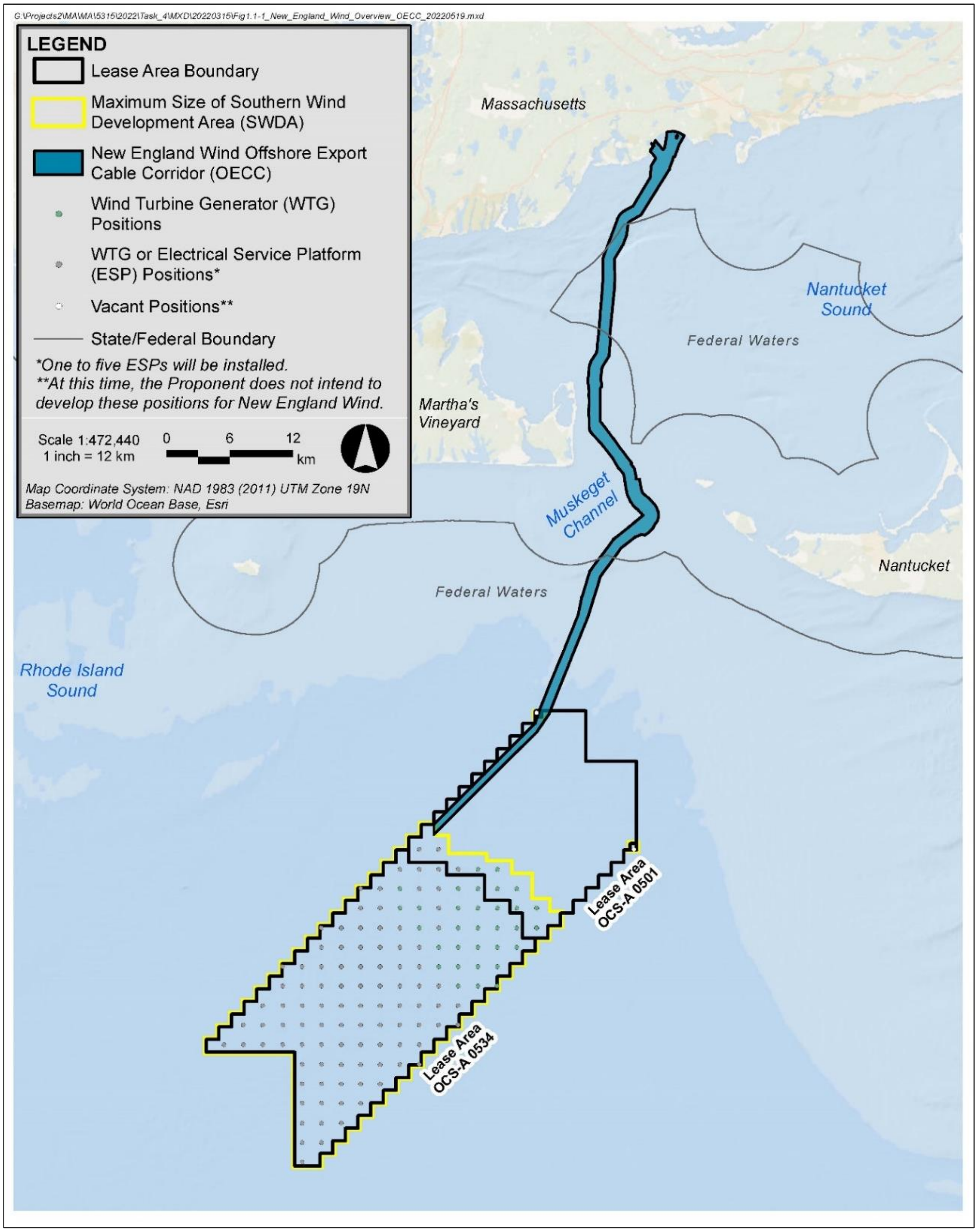

Figure 1. Location of New England Wind SWDA within Lease Area OCS-A 0534 and the SW portion of Lease Area OCS-A 0501.

Phase 1 of New England Wind (Park City Wind)

Phase 1, also known as Park City Wind, will be developed immediately southwest of the Vineyard Wind 1 project. The Phase 1 Envelope allows for 41 to 62 WTGs in a 1 × 1 NM layout and one or two ESP(s). Depending upon the capacity of the WTGs, Phase 1 will occupy 150–231 km^2 (37,066–57,081 acres) of the SWDA. The Phase 1 Envelope includes two WTG foundation types: monopiles and piled jackets. Strings of WTGs will connect with the ESP(s) via a submarine inter-array cable transmission system. The ESP(s) will include step-up transformers that increase the voltage of power generated by the WTGs prior to transmission and other electrical equipment. The ESP(s) will also be supported by a monopile or jacket foundation. If two ESPs supported by monopiles are used, they may be located at two separate positions or co-located at the same grid position. The total number of Phase 1 WTG and ESP foundations ranges from 42 to 64 (see Section 2.2 for details on the number of individual foundation piles).

Two HVAC offshore export cables up to 101 km (54 NM) in length (per cable) installed within the SWDA and an Offshore Export Cable Corridor (OECC) will transmit electricity from the ESP(s) to a landfall site at the Craigville Public Beach or Covell's Beach in the Town of Barnstable. Underground onshore export cables, located principally in existing roadway layouts, will connect the landfall site to a new Phase 1 onshore substation in Barnstable. Grid interconnection cables will then connect the Phase 1 onshore substation to the ISO New England (ISO-NE) electric grid at Eversource's existing 345 kilovolt substation in West Barnstable.

To support Phase 1 construction and operation activities, the Proponent will use a combination of North Atlantic ports in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and/or Canada.

Phase 2 of New England Wind (Commonwealth Wind)

Phase 2, also known as Commonwealth Wind will be immediately southwest of Phase 1 and occupy the remainder of the SWDA. Phase 2 may include one or more projects, depending on market conditions. The footprint and total number of WTG and ESP positions in Phase 2 depends upon the final footprint of Phase 1; Phase 2 is expected to contain 64 to 88 WTG/ESP positions (up to three of those positions will be occupied by ESPs) within an area ranging from 222–303 km^2 (54,857–74,873 acres). The Phase 2 Envelope includes three general WTG foundation types: monopiles, jackets (with piles or suction buckets), or bottom-frame foundations (with piles or suction buckets). The ESP(s) will be supported by a monopile or jacket foundation (with piles or suction buckets). Two of the ESPs, if supported by monopiles, may be co-located at the same grid position. As a result, the maximum number of Phase 2 foundations is 89 (86 WTG positions and three ESPs at two grid positions). See Section 2.2 for details on the number of individual foundation piles.

Inter-array cables will transmit electricity from the WTGs to the ESP(s). Two or three HVAC offshore export cables, each with a maximum length of 116–124 km (63–67 NM) per cable, will transmit power from the ESP(s) to shore. The Proponent intends to install all Phase 2 offshore export cables within the same OECC as the Phase 1 cables from the northwestern corner of the SWDA to within approximately 2-3 km (1–2 mi) of shore, at which point the OECC for each Phase will diverge to reach the Dowses Beach Landfall Site and/or Wianno Avenue Landfall Site in Barnstable. However, the Proponent has also identified two variations of the Phase 2 OECC in the event that technical, logistical, grid interconnection, or other unforeseen issues arise during the engineering and permitting processes that preclude one or more Phase 2 offshore export cables from being installed within all or a portion of the OECC. These variations of the Phase 2 OECC (the Western Muskeget Variant and the South Coast Variant) are shown on Figure 2.

Underground onshore export cables, located primarily within roadway layouts, will connect the landfall site(s) to one or two new onshore substations in the Town of Barnstable. Grid interconnection cables will then connect the onshore substation site(s) to the West Barnstable Substation. If the Phase 2 OECC South Coast Variant is employed and electricity generated by Phase 2 is delivered to a second grid interconnection point, Phase 2 could include one onshore transmission system in Barnstable and/or an onshore transmission system(s) in proximity to the second grid interconnection point.

To support Phase 2 construction and operation activities, the Proponent will use a combination of North Atlantic ports in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and/or Canada.

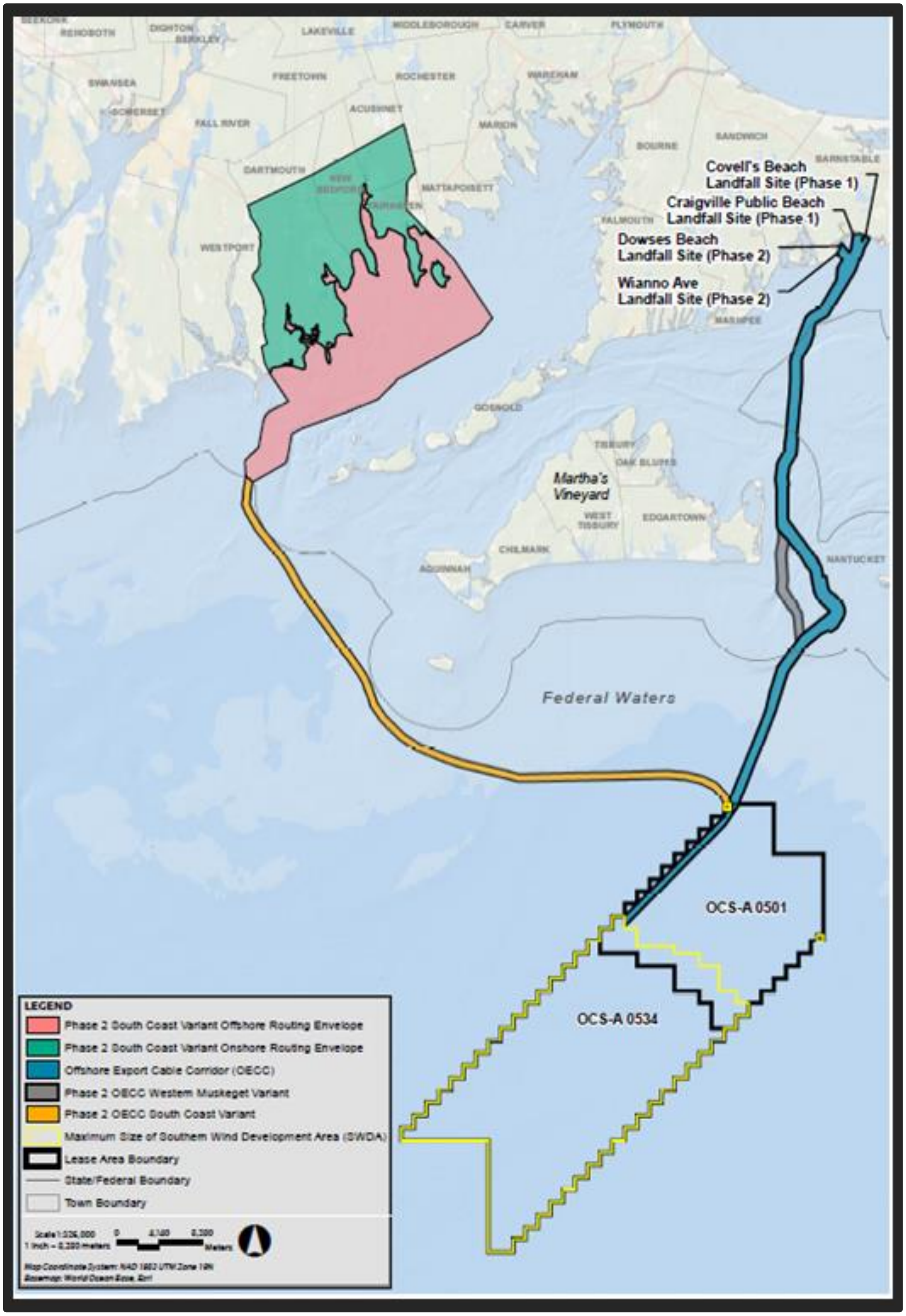

Figure 2. Map showing two potential Phase 2 offshore export cable variants.

1.1. Offshore Project Elements and Construction Activities

The key offshore elements of New England Wind Phases 1 and 2 are described in detail in Sections 3 and 4 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 remaining portions of the offshore export cables are 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. Sections 3.1 and 4.1 of Volume I of the COP provide a tentative schedule and high-level construction plan for Phases 1 and 2, which is summarized below in Section 1.2 of this request.

1.1.1. Cable Laying

Cable burial operations will occur both in the SWDA 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 the landfall sites. For Phases 1 and 2, 66 to 132 kilovolt (kV) inter-array cables will connect “strings” of WTGs to an ESP. To provide additional reliability, the ESPs may be connected with an inter-link cable. The maximum anticipated total length of the Phase 1 inter-array cables is approximately 225 km (121 NM) and the maximum anticipated total length of the inter-link cable is approximately 20 km (11 NM). The maximum anticipated total length of the Phase 2 inter-array cables is approximately 325 km (175 NM) and the maximum anticipated total length of the inter-link cable is approximately ~60 km (~32 NM).

Phase 1 will consist of two offshore export cables with a maximum total length of ~202 km (~109 NM). Phase 2 will consist of two or three offshore export cables with a maximum total length (assuming three cables) of 356 km (~192 NM).

The offshore export cables will likely be transported directly to the Offshore Development Area in a cable laying vessel, on an ocean-going barge, or on a heavy transport vessel (which may also transport the cable laying vessel overseas) and installed by the cable laying vessel upon arrival. Vessel types under consideration for cable installation activities are presented in the COP Volume 1 Table 4.3-1.

For Phases 1 and 2, a pre-lay grapnel run and pre-lay survey are expected to be performed to clear obstructions, such as abandoned fishing gear and other marine debris, and inspect the route prior to cable laying. Large boulders along the route may need to be relocated prior to cable installation. Some dredging of the upper portions of sand waves may also be required prior to cable laying to achieve sufficient burial depth below the stable sea bottom. Following the route clearance activities and any required dredging, offshore export cable laying is expected to be performed primarily via simultaneous lay and bury using jetting techniques (e.g., jet plow or jet trenching) or mechanical plow. However, depending on bottom conditions, water depth, and contractor preferences, other specialty techniques may be used in certain areas to ensure sufficient burial depth. Some dredging may be required prior to cable laying due to the presence of sand waves. No blasting is proposed for cable installation.

Installation of an offshore export cable is anticipated to last approximately 9 months for Phase 1 and approximately 13.5 months for Phase 2; cable installation for each Phase may or may not be continuous and may occur over 1 or 2 years. The estimated installation timeframe for the inter-array cables is over a period of approximately 4–5 months for Phase 1 and 9 months for Phase 2. Installation days are not continuous and do not include equipment preparation or down time that may result from weather, marine mammal observations or maintenance.

To assess the impacts of these activities, a set of computer simulation models was used (see Appendix III-A, COP Volume III for a discussion of sediment dispersion modeling). The model results indicate that most of the suspended sediment mass will settle out quickly and will not be transported for significant distances by the currents. Thus, potential impacts from suspended sediments resulting from cable laying are likely to be short-term and localized with only a minor impact on marine mammal prey and thus are not expected to result in takes of marine mammals.

Potential acoustic impacts from cable installation are expected to derive primarily from the vessel(s) laying the cable. Dredging may be used to remove the upper portions of sand waves within the OECC and will be limited only to the extent required to achieve adequate cable burial depth during cable installation. Dredging could be accomplished by a trailing suction hopper dredge (TSHD) or controlled flow excavation. A TSHD vessel contains one or more drag arms that extend from the vessel, rest on the seafloor, and suction up sediments. Controlled flow excavation uses a pressurized stream of water to push sediments to the side. If needed, dredging will only occur in limited areas with an expected duration of a few days per cable.

During a similar type of underwater construction activity, Robinson et al. (2011) measured sound levels radiated from marine aggregate dredgers, mainly 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 "traveling 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, cone penetrometer tests (CPTs), and drilling small boreholes diminishes below the NMFS Level B harassment thresholds (120 decibels [dB] for continuous sound sources) relatively near to the sound source and is unlikely to cause harassment to marine mammals (NMFS 2009, Reiser et al. 2011, TetraTech 2014). Based on these studies, sounds from cable laying activities are anticipated to be comparable to vessel acoustic impacts expected in the WDA for other general construction and installation vessel activities or non-construction-related vessels that may be present in the area. As noted above, because of the operation of the propulsion system, noise radiated by a self-propelled dredge at <500 Hz is similar to that of a merchant vessel (Robinson et al. 2011) and higher frequency sounds (between 1 and 2 kHz) are not anticipated because the components that generate these sounds would not be present during cable lay operations. Further, it is unlikely that dredging operations will exceed the marine mammal injury thresholds unless animals are within the immediate vicinity of the operating equipment. Therefore, the Proponent is not requesting take for this activity.

1.1.2. Vessel Activity

Construction vessel activity is described in Section 7.8 of COP Volume III and the Navigation Safety Risk Assessment in Appendix III-I of the COP. The current estimates of vessel numbers and vessel trips presented below, which are based on current understanding of a potential Phases 1 and 2 construction schedule, are likely conservative and subject to change.

During each Phase (i.e., during Phases 1 and 2), assuming the maximum design scenario, it is estimated that an average of ~30 vessels would operate at the SWDA or along the OECC at any given time.[4] Commencement of the WTG installation and commissioning phase typically represents the most intense period of vessel traffic in the Offshore Development Area, with foundations, inter-array cables, and WTGs being installed and commissioned in parallel. During the most active period of construction, it is conservatively estimated that a maximum of approximately 60 vessels could operate in the Offshore Development Area at one time. However, the number of vessels present at any given time during Phase 1 or Phase 2 offshore construction is highly dependent on the final construction schedule, the number of WTGs and ESPs installed, the final design of the offshore facilities, the ports ultimately used, and the logistics solution used to achieve compliance with the Jones Act.

Many construction vessels will remain at the SWDA or OECC for days or weeks at a time, potentially making infrequent trips to port for bunkering and provisioning as needed. For example, during foundation and WTG installation, the main installation vessel(s) and any support vessels(s) will likely remain at the SWDA (or in the immediate vicinity) while supply vessels, jack-up vessels, barges, and/or tugs provide a continuous supply of components to the SWDA. Therefore, although an average of approximately 30 vessels would be present in the Offshore Development Area during the construction of each Phase, fewer vessels will transit to and from port each day.

The Proponent has identified several port facilities in Massachusetts, Rhode Island, Connecticut, New York, and New Jersey that may be used for major construction staging activities[5] (see Table 1). The Proponent expects to use one or more of these ports for frequent crew transfer and to offload/load shipments of components, store components, prepare them for installation, and then load components onto vessels for delivery to the SWDA. In addition, some components, materials, and vessels could come from Canadian and European ports. Each port facility under consideration for New England Wind is either already located within an industrial waterfront area with sufficient existing infrastructure or is identified as an area where other entities intend to develop infrastructure with the capacity to host construction activities under the New England Wind schedule. It is not expected that all the ports identified in Table 2 would be used; it is more likely that only some ports would be used during construction depending upon final construction logistics planning.

Assuming the maximum design scenario for each Phase individually, ~3,200 total vessel round trips (an average of approximately six round trips per day) are expected to occur during offshore construction of Phase 1 and ~3,800 total vessel round trips (an average of approximately seven round trips per day) are

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[4] It is possible that Phase 2 construction could begin immediately following Phase 1 construction in the same year. Under this scenario, there could be some overlap of different offshore activities between Phases 1 and 2 (e.g., Phase 2 foundation installation could occur at the same time as Phase 1 WTG installation). The number of vessels present at the SWDA or along the OECC during Phase 2 construction accounts for the possibility of Phases 1 and 2 vessels being present at the same time.

[5] Some activities such as refueling, restocking supplies, vessel repairs, sourcing parts for repairs, vessel mobilization/demobilization, some crew transfer, and other construction staging activities may occur out of ports other than those listed in Table 2 below. These activities would occur at industrial ports suitable for such uses and would be well within the realm of normal port activities.

expected to occur during offshore construction of Phase 2.[6] Due to the range of buildout scenarios for Phases 1 and 2, the Proponent expects the total number of vessel trips from both Phases of New England Wind combined to be less than the sum of vessel trips estimated for each Phase independently. During the most active month of construction, it is anticipated that an average of approximately 15 daily vessel round trips could occur.

Table 1 provides the estimated number of vessel trips to each port that may be used for major construction staging activities during New England Wind, assuming that Phase 2 construction begins immediately following Phase 1 construction.[7] Please note that the estimates of vessels trips for each individual port are not additive among the ports under consideration.

Table 1. Vessel trips to ports during New England Wind construction.

Ports	Peak construction period		Over construction period	
	Expected average round trips per day	Average round trips per month	Expected Average Round trips per day	Average round trips per month
All ports	15	443	8	215
New Bedford Harbor	15	443	7	209
Bridgeport Vineyard Haven Port of Davisville South Quay Terminal	13	376	6	177
ProvPort Brayton Point Commerce Center Fall River New London State Pier Staten Island Ports South Brooklyn Marine Terminal GMD Shipyard Shoreham	6	162	3	68
Salem Harbor Canadian Ports European Ports	2	46	1	20
Capital Region Ports Paulsboro	1	6	1	3

Table 2 lists the types of vessels that are expected to be used during the construction of New England Wind, along with a description of each vessel's role and approximate typical vessel speed (without implementing mitigation measures). During appropriate time periods, New England Wind-related vessels traveling to/from Salem Harbor will transit at 18.4 km per hour (10 knots) or less within NOAA-designated North Atlantic right whale critical habitat and outside critical habitat.

[6] For the purposes of estimating vessel trips, tugboats and barges are considered one vessel.
[7] In this scenario, each major construction activity would be sequential for the two Phases (e.g., Phase 2 foundation installation would immediately follow Phase 1 foundation installation). However, there could be some overlap of different offshore activities between Phase 1 and Phase 2 (e.g., Phase 2 foundation installation could occur at the same time as Phase 1 WTG installation).

Table 2. Representative vessels used for New England Wind construction.

Vessel role	Expected vessel type	Number of vessels	Description of anticipated activity (subject to change)	Approximate vessel speed	
				Typical operational speed (kn)	Maximum transit speed (kn)
Foundation installation					
Scour Protection Installation	Scour Protection Installation Vessel (e.g. Fall-pipe Vessel)	1	At most, vessel will likely make one round trip from port to the SWDA per foundation to deposit rock material.	10–14	14
Overseas Foundation Transport	Heavy Transport Vessel	2–5	Vessels will likely transport sets of foundations directly to the main foundation installation vessel or to a US port. Vessels will likely remain at the SWDA or port facility for several days at a time to offload foundations.	12–18	12–18
Foundation Installation (Possibly Including Grouting)	Jack-up Vessel or Heavy Lift Vessel	1–2	Vessel(s) will likely remain at the SWDA for the duration of foundation installation, except to travel infrequently to a sheltered area to bunker fuel or seek shelter from weather (if needed).	0–10	6.5–14
Tugboat to Support Main Foundation Installation Vessel(s)	Tugboat	1	Vessel will likely remain at the SWDA for the duration of foundation installation, except to make port calls approximately every two weeks.	10–14	10–14
Transport of Foundations to SWDA	Barge	2–5	If foundations are staged from a US port, pairs of tugboats will likely bring barges loaded with sets of foundation components to the SWDA. Vessels will likely remain at the SWDA for one or more days at a time to offload foundations.	8–10	10–14
	Tugboat	2–5			
Secondary Work and Possibly Grouting	Support Vessel or Tugboat	1	Vessel will likely make one round trip from port to the SWDA per foundation, with each trip to the SWDA lasting approximately one day.	10–14	14
Crew Transfer	Crew Transfer Vessel	1–3	Vessel(s) will likely make daily round trips to the SWDA throughout the duration of foundation installation.	10–25	25
Noise Mitigation	Support Vessel or Anchor Handling Tug Supply vessel	1	Vessel will likely remain at the SWDA for the duration of foundation installation, except to make port calls approximately every two weeks.	10	13

Vessel role	Expected vessel type	Number of vessels	Description of anticipated activity (subject to change)	Approximate vessel speed	
				Typical operational speed (kn)	Maximum transit speed (kn)
Acoustic Monitoring	Support Vessel or Tugboat	1	Vessel will likely remain at the SWDA for the duration of foundation installation, except to make port calls approximately every two weeks.	10–14	14
Marine Mammal Observers and Environmental Monitors	Crew Transfer Vessel	2–6	Vessel(s) will likely make daily round trips to the SWDA throughout the duration of foundation installation.	10	25
ESP installation					
ESP Installation	Heavy Lift Vessel	1	Vessels will remain at the SWDA for the duration of ESP installation, except to travel infrequently to a sheltered area to bunker fuel or seek shelter from weather (if needed).	0–12	6.5–14
Overseas ESP Transport	Heavy Transport Vessel and/or Tugboat	1–2	Vessel(s) will likely transport one ESP at a time to the main ESP installation vessel or to a US port. Vessels will likely remain at the SWDA or port facility for several days at a time to offload ESPs.	10–18	13–18
ESP Transport to SWDA (if required)	Heavy Transport Vessel and/or Tugboat	1–4	If ESPs are staged from a US port, vessel(s) will likely transport one ESP at a time to the SWDA. Vessels will likely remain at the SWDA for one or more days at a time to offload the ESP.	0–14	14
Crew Transfer	Crew Transfer Vessel	1	Vessel will likely make daily round trips to the SWDA throughout the duration of ESP installation and commissioning.	10–25	25
Service Boat	Crew Transfer Vessel or Support Vessel	1	Vessel will likely make one round trip per month lasting one day each to deliver supplies to the accommodation vessel.	10–25	25
Crew Accommodation Vessel During Commissioning	Jack-up	1	Vessel will likely remain in the SWDA for the duration of ESP commissioning.	0–6	6
	Accommodation Vessel			10	13.5
Offshore export cable installation					
Pre-Lay Grapnel Run	Support Vessel	1	At most, vessel will make daily trips to the OECC to perform a pre-lay grapnel run along the offshore export cable alignments.	4–15	15

Vessel role	Expected vessel type	Number of vessels	Description of anticipated activity (subject to change)	Approximate vessel speed	
				Typical operational speed (kn)	Maximum transit speed (kn)
Pre-Lay Survey	Survey vessel or Support Vessel	1	At most, vessel will make daily trips to the OECC to perform a pre-lay survey along the offshore export cable alignments.	4–14	25–30
Boulder Clearance	Support Vessel	1	At most, vessel will make daily trips to the OECC to perform boulder clearance.	5–12	12
Dredging	Dredging Vessel	1	If dredging is needed, vessel will likely perform dredging along the OECC in one or two continuous trips.	10–16	16
Cable Laying (and Potentially Burial)	Cable Laying Vessel	1–2	Vessel(s) will likely remain in the OECC for the duration of offshore export cable installation, except to re-load cables every several weeks (if needed).	5–8	14
Support Main Vessel with Anchor Handling	Tugboat or Anchor Handling Tug Supply Vessel	1–3	Vessel(s) will likely remain at the OECC for the duration of offshore export cable installation, except to make infrequent port calls every several weeks (if needed).	5–14	10–14
Trenching	Cable Laying Vessel or Support Vessel	1	If trenching is needed, vessel will likely remain at the OECC for the duration of offshore export cable installation, except to make infrequent port calls every several weeks (if needed).	10	15
Cable Landing	Tugboat or Jack-up Vessel	1	Vessel will likely make trips to the OECC once every one or two weeks, with each trip lasting approximately one day.	10–14	10–14
Shallow Water Cable Burial	Cable Laying Vessel	1	Vessel will likely make one round trip to the OECC per cable, with each trip lasting approximately one or two weeks.	0–10	10
Install Cable Protection	Cable Protection Installation Vessel (e.g. Fall-pipe vessel)	1	Vessel will likely remain at the OECC for several days at a time to install cable protection and will return to port (as needed) to reload cable protection.	10–14	14
Crew Transfer	Crew Transfer Vessel	1	Vessel will likely make daily round trips to the OECC throughout the duration of offshore export cable installation.	10–25	25

Vessel role	Expected vessel type	Number of vessels	Description of anticipated activity (subject to change)	Approximate vessel speed	
				Typical operational speed (kn)	Maximum transit speed (kn)
Safety Vessel	Crew Transfer Vessel	1	Vessel will likely remain at the OECC for the duration of offshore export cable installation, except to make port calls approximately every two weeks.	10–25	25
Inter-array cable installation					
Pre-Lay Grapnel Run	Support Vessel	1	Vessel will likely perform the pre-lay grapnel run along the entire length of the inter-array cables in one continuous trip, but may make port calls during the campaign.	4–15	15
Pre-Lay Survey	Survey Vessel or Support Vessel	1	Vessel will likely survey the entire length of the inter-array cables in one continuous trip, but may make port calls during the survey campaign.	4–14	25–30
Cable Laying (and Potentially Burial)	Cable Laying Vessel	1	Vessel will likely remain at the SWDA for the duration of inter-array cable installation, except to re-load cables every few weeks (if needed).	5–8	14
Cable Installation Support	Support Vessel	1	Vessel will likely remain at the SWDA for the duration of inter-array cable installation, but may make port calls every few weeks (if needed).	5–12	12
Crew Transfer	Crew Transfer Vessel	2	Vessels will likely make daily round trips to the SWDA throughout the duration of inter-array cable installation.	10–25	25
Cable Termination and Commissioning	Support Vessel	1	Vessel will likely remain at the SWDA for the duration of inter-array cable installation, but may make port calls every few weeks (if needed).	10–12	12
Trenching	Cable Laying Vessel or Support Vessel	1	Vessel will likely remain at the SWDA for the duration of inter-array cable installation, but may make port calls every few weeks (if needed).	10–15	15
Install Cable Protection	Cable Protection Installation Vessel (e.g. Fall-pipe vessel)	1	Vessel will likely remain at the SWDA for one or more days at a time to install cable protection and will return to port (as needed) to reload cable protection.	10–14	14

Vessel role	Expected vessel type	Number of vessels	Description of anticipated activity (subject to change)	Approximate vessel speed	
				Typical operational speed (kn)	Maximum transit speed (kn)
Safety Vessel	Crew Transfer Vessel	1	Vessel will likely remain at the SWDA for the duration of inter-array cable installation, except to make port calls approximately every two weeks.	10–25	25
WTG installation and commissioning					
Overseas WTG Transport	Heavy Transport Vessel	1–5	Vessel(s) will likely transport sets of WTG components to a US port. Vessels will likely remain at the port facility for several days at a time to offload WTGs.	14–18	14–18
Overseas Transport of WTG Installation Vessel(s)	Heavy Transport Vessel	1	Vessel will likely make a limited number of overseas trips to transport the WTG installation vessel(s), if needed. Vessels will likely remain at the SWDA or at a sheltered location nearby for several days at a time to offload the vessel.	10–11.5	11.5
WTG Transport to SWDA	Jack-up Vessels[8] or Tugboat	2–6	Vessels will likely take turns transporting one or more WTGs at a time to the main WTG installation vessel(s). Vessels will likely remain at the SWDA for one or more days at a time to offload WTG components.	0–10	13–14
WTG Transport Assistance	Tugboat	1–6	Vessel(s) will likely remain at the SWDA for the duration of WTG installation, except to make port calls approximately every two weeks.	0–10	13–14
WTG Installation	Jack-up Vessel or Heavy Lift Vessel	1–2	Vessel(s) will likely remain at the SWDA for the duration of WTG installation, except to travel infrequently to a sheltered area to bunker fuel or seek shelter from weather (if needed).	0–10	8–13
Crew Transfer	Crew Transfer Vessel	3	Vessels will likely remain at the SWDA for the duration of WTG installation and commissioning, making port calls approximately every four days.	10–25	25

[8] Jacking-up in ports may occur.

Vessel role	Expected vessel type	Number of vessels	Description of anticipated activity (subject to change)	Approximate vessel speed	
				Typical operational speed (kn)	Maximum transit speed (kn)
WTG Commissioning Vessel	Service Operation Vessel	1	Vessel(s) will likely remain at the SWDA for the duration of WTG commissioning, except to make port calls approximately every two weeks.	10–12	13
Miscellaneous construction activities					
Crew Transfer	Crew Transfer Vessel or Service Operation Vessel	1–4	Crew transfer vessel(s) would likely make daily round trips to the SWDA throughout the duration of construction (weather permitting) whereas the service operation vessel(s) would likely remain at the SWDA for the duration of construction, except to make port calls approximately every two weeks.	10–25	25
Refueling	Crew Transfer Vessel or Support Vessel	1	Vessel will travel to the SWDA or a nearby sheltered area (as needed) to refuel vessels.	10–25	25
Geophysical, Geotechnical, and UXO Survey Operations	Survey Vessel or Support Vessel	1–3	Vessel(s) will likely remain at the SWDA for the duration of survey works, except to make port calls approximately every two weeks.	4–14	25–30

All vessel descriptions and values are subject to change.

Sound levels associated with vessels vary with vessel class, speed, and activity. High speeds and the use of thrusters increase noise levels significantly (Richardson et al. 1995). According to the Navigational Safety Risk Assessment, the Massachusetts Wind Energy Area (MA WEA) currently experiences moderate levels of vessel traffic, with some increased vessel traffic during the summer months (see Appendix III-I of the COP). However, according to the BOEM environmental assessment (BOEM 2014a, NMFS 2018), coastal vessel traffic in the vicinity of the MA WEA is relatively high. Therefore, marine mammals in the Offshore Development 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 2014a). Many of the proposed New England Wind-related vessels have dedicated protected species observers (PSOs), are smaller than cargo ships that frequently transit the area and, for mitigation purposes, will typically transit at slower speeds. Additionally, takes of marine mammals by vessel collision are not expected, given the monitoring and mitigation plans proposed for New England Wind. This LOA application requests incidental takes of marine mammals that may result from exposure to sound associated with foundation installation, HRG surveys, and UXO detonation.

During construction related activities, including cable laying and construction material delivery, dynamic positioning (DP) thrusters may be used to maneuver and maintain station. Thrusters generate underwater sound with apparent sound levels (SLs) ranging from SPL 150 to 180 dB re 1 µPa depending on vessel operations and thruster use (BOEM 2014b). Sound produced by 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; 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 by marine mammals. Monitoring of past projects that used DP thrusters has shown a lack of observed marine mammal responses as a result of exposure to sound from DP thrusters (NMFS 2018). 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. Foundation Design and Piling Equipment

Three foundation types are proposed for New England Wind: monopiles, jackets, and bottom-frame foundations (the latter is for Phase 2 only). WTGs and ESPs may be placed on either monopiles or jacket foundations; bottom-frame foundations are only proposed for WTGs.

A monopile is a single, hollow cylinder fabricated from steel that is secured in the seabed. The base of the monopile will have j-shaped steel tubes (J-tubes) or an opening to allow the inter-array cables to enter and exit the foundation safely. Typically, a separate transition piece (TP) will be installed between the monopile and WTG tower. Monopile dimensions are shown on Figures 3 and 4. Monopiles are a proven foundation design used successfully at many offshore wind farms. They account for more than 80% of the installed foundations in Europe, with more than 4680 units installed (Wind Europe 2021).

The jacket foundation design consists of 3 to 4 piles, a large lattice jacket structure, and a TP (Figure 5). The piles may be driven through pile "sleeves" or guides mounted to the base of each leg. Alternatively, the piles may be pre-installed prior to the installation of the jacket structure. Jackets accounted for 19% of the number of foundations installed in 2020 in Europe, which brings their total market share to 9.9% (Wind Europe 2021). Jackets are also widely used for other offshore applications, including oil and gas production platforms.

The Phase 2 Envelope includes bottom-frame foundations. The bottom-frame foundation is similar to a conventional jacket foundation, but generally has fewer, larger structural tubular members, has a triangular space frame, no small-diameter lattice cross-bracing, and a single central vertical tubular column. At each foot, the structure would be secured to the seafloor using one of two methods: (1) driven piles, which are long slender piles similar to those used by piled jacket foundations (see Figure 6); or (2) suction buckets similar to those used for suction bucket jackets (see Figure 4.2-7 of the COP in the COP Volume I). Suction bucket jackets are not acoustically analyzed in this LOA because this application reflects worst case-scenario (e.g., installation of all monopile and pin piles), and suction bucket jackets are not expected to cause harassment.

New England Wind is proposing to install 41 to 62 WTGs and one or two electrical service platforms (ESPs) in Phase 1 of the SWDA and 64 to 88 WTG/ESPs in Phase 2 of the SWDA. Two types of foundations were considered in the acoustic modeling study conducted to estimate the potential number of incidental marine mammal exposures:

- Monopile foundations with either 12 m (39.4 ft) or 13 m (42.7 ft) diameter piles, and
- Jacket-style foundation using 4 m (13.1 ft) diameter (pin) piles.

The bottom-frame foundation (for Phase 2 only) is similar to the jacket foundation, with the same maximum 4 m pile diameter, but with shorter piles and shallower penetration (Figure 6) and was therefore not modeled separately in the acoustic assessment. It is assumed that the potential acoustic impact of the bottom-frame foundation installation is equivalent to or less than that predicted for the jacket foundation.

The 12 m (39.4 ft) and 13 m (42.7 ft) monopiles will be installed at specific locations for both Phases 1 and 2 of the SWDA. Jacket foundations each require the installation of three to four jacket securing piles, known as pin piles, of ~4 m (13.1 ft) diameter. The piles for the 12 m and 13 m monopile foundations are up to 95 m (311.7 ft) in length and will be driven to a penetration depth of 40 m (131.2 ft). The 4 m (13.1 ft) diameter jacket piles for the jacket foundations are up to ~100 m (328.1 ft) in length and will be driven to a penetration depth of 50 m (164.0 ft). A MENCK 5500 hammer was modeled for driving piles for the monopile foundations and a MENCK 3500 hammer was used in hydroacoustic modeling for driving the 4 m (13.1 ft) pin piles. Representative hammering schedules of increasing hammer energy with increasing penetration depth were modeled, resulting in, generally, longer distances to regulatory sound thresholds as the hammer energy and penetration increases. Acoustic modeling details and summary are provided in Appendix A. Table 3 summarizes the modeled foundation pile diameters and the maximum rated hammer energies. Initial source modeling showed minimal difference between the 12 m and 13 m monopile (Appendix A). Although the project may install the 13 m monopiles at a maximum of 6,000 kJ during Phase 2, this was not modeled beyond sound source modeling (i.e., animal movement modeling was not conducted for this scenario) for this acoustic assessment because this scenario is unlikely and the 12 m monopile with 6,000 kJ hammer energy was assumed to be a reasonable replacement in exposure calculations given their similarities. The modeled broadband source level was predicted to be 1.2 dB higher for the 13 m monopile installed at 6,000 kJ compared to the 12 m monopile installed at 6,000 kJ, which is within the expected measured variance of approximately 2 dB (Bellmann et al. 2020). A source level and impact hammering schedule comparison between the 12 m and 13 m monopiles can be found in Appendix A. Exposure estimates for most species associated with the jacket foundation are higher than for all modeled monopile scenarios and the use of jackets (particularly in Year 2 and/or Year 3 of construction) is included as a conservative assumption (see Section 6.2.1.5 for further explanation). Therefore, given (1) the minimal difference in the source levels between the 12 m monopile installed at 6,000 kJ and the 13 m monopile installed at 6,000 kJ, (2) the small predicted difference in species' exposure estimates when comparing Level A and B exposures for the 12 m monopile installed at 5,000 kJ and the 12 m monopile installed at 6,000 kJ, and (3) that exposure estimates for most species associated with the jacket foundation are higher than for all modeled monopile scenarios and that the use of jackets is assumed (particularly in Year 2 and/or Year 3), the takes requested in this application are conservative and would accommodate the 13 m monopile installed at 6,000 kJ scenario.

Table 3. Modeling foundation pile diameters and hammer maximum rated energies.

Foundation type	Pile diameter (m)	Hammer maximum rated energy (kJ)
Jacket	4	3,500
Monopile	12	5,000
Monopile	12	6,000
Monopile	13	5,000
Monopile	13	6,000

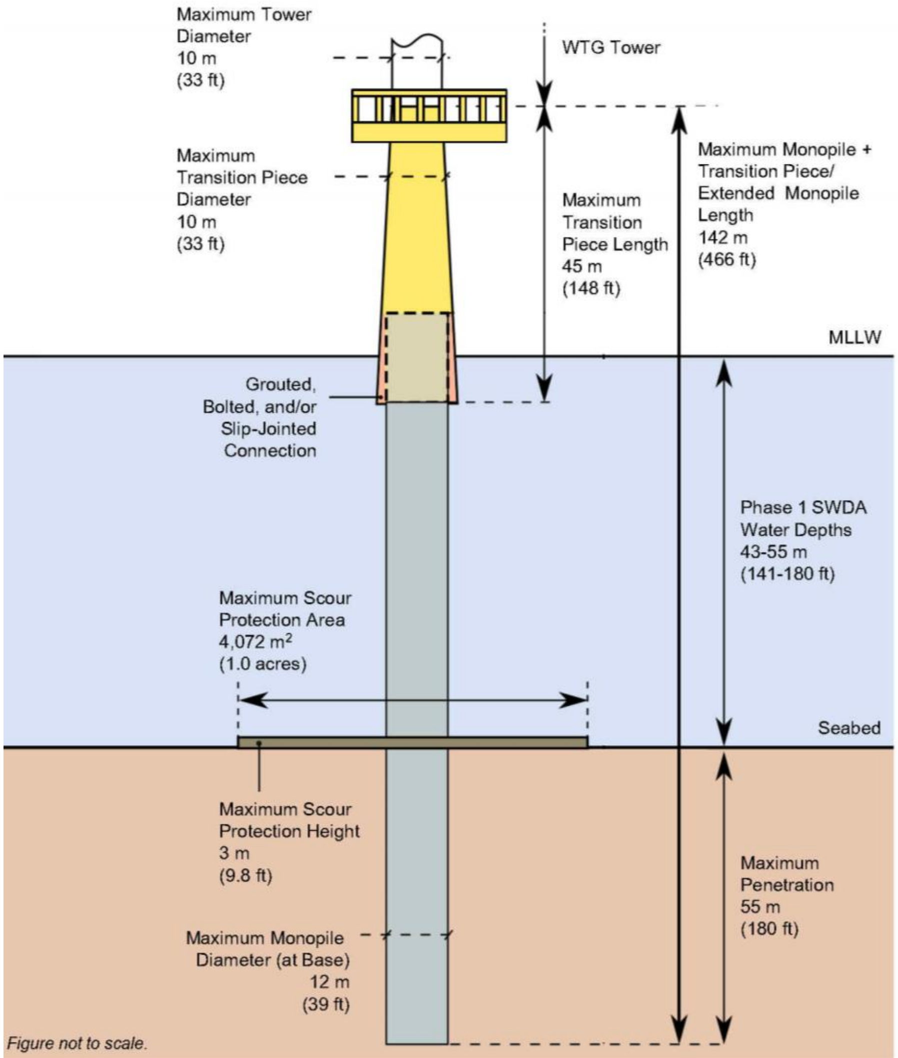

Figure 3. Schematic drawing of a Phase 1, 12 m WTG monopile foundation (Figure 3.2-2 of the New England Wind Draft Construction and Operations Plan Volume 1, Epsilon 2021).

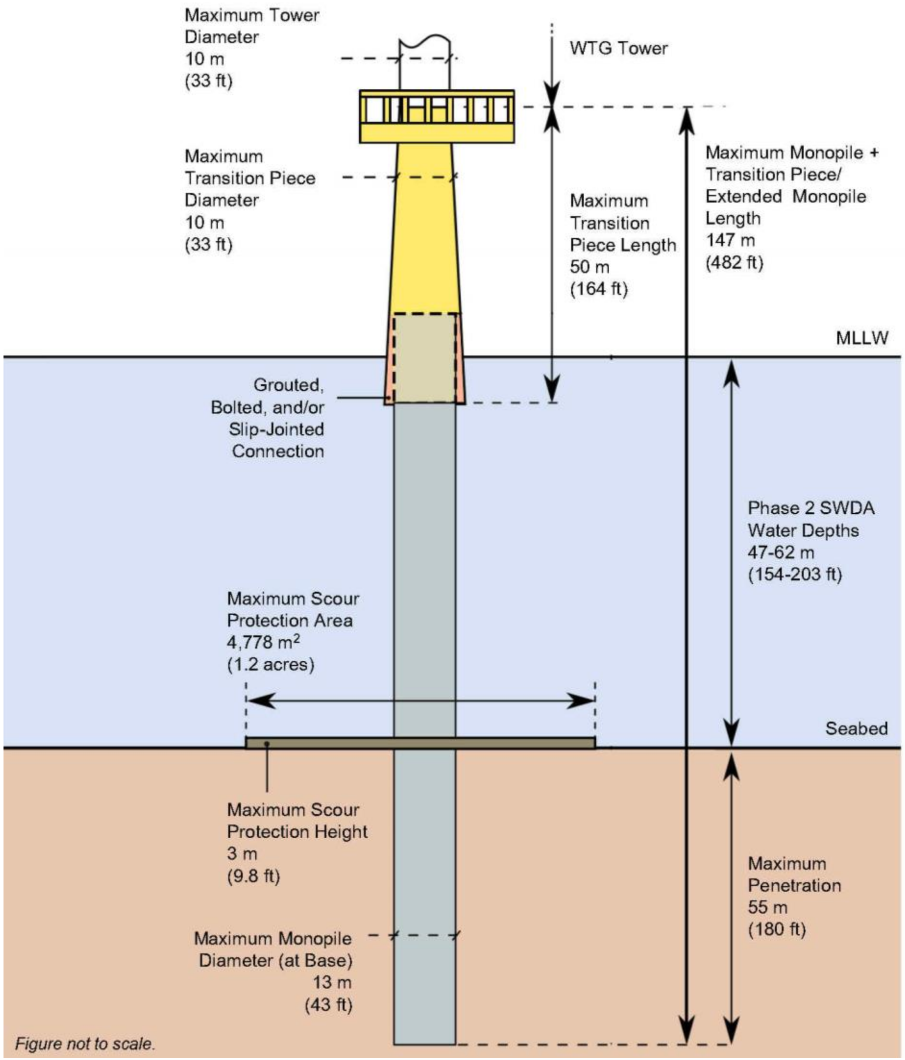

Figure 4. Schematic drawing of a Phase 2, 13 m WTG monopile foundation (Figure 4.2-2 of the New England Wind Draft Construction and Operations Plan Volume 1, Epsilon 2021).

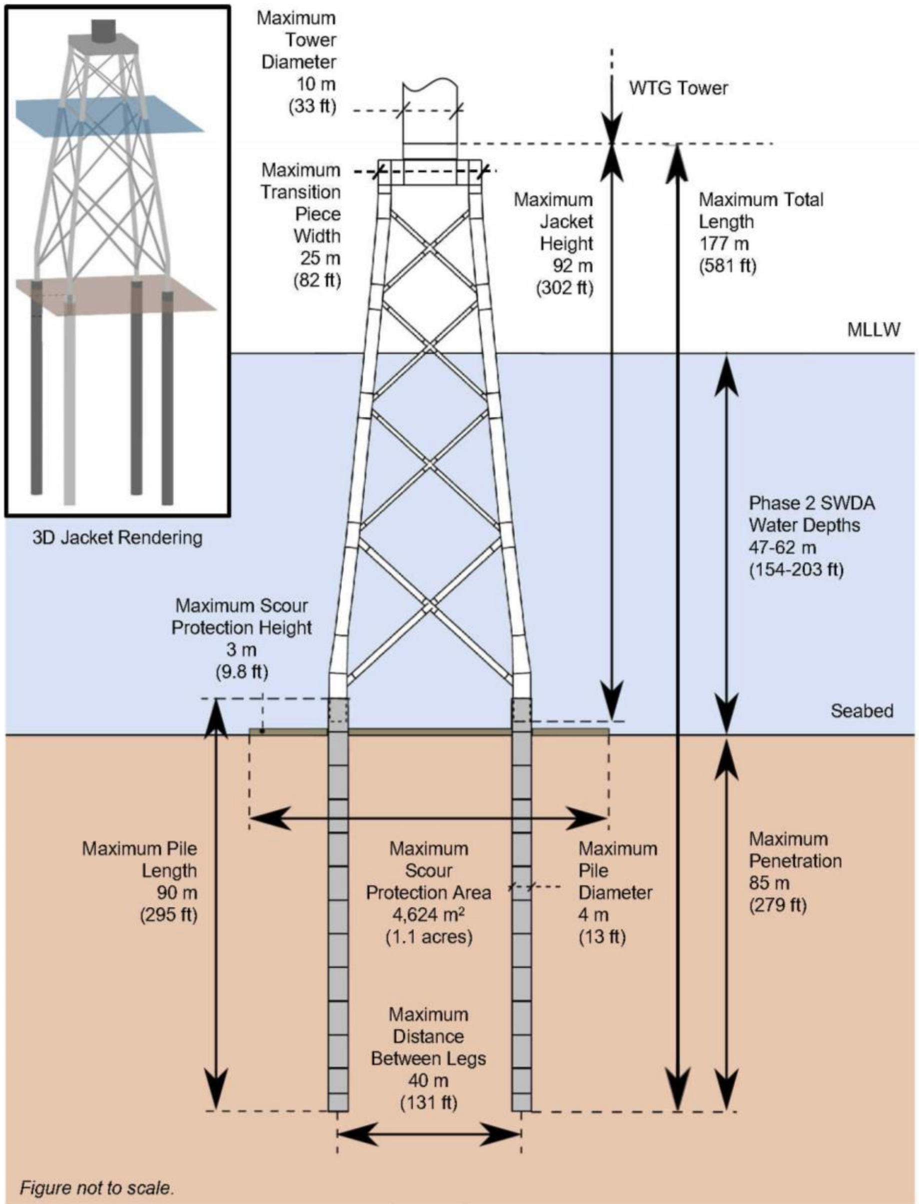

Figure 5. Schematic drawing of a jacket foundation (Figure 4.2-3 of the New England Wind Draft Construction and Operations plan Volume 1, Epsilon 2021).

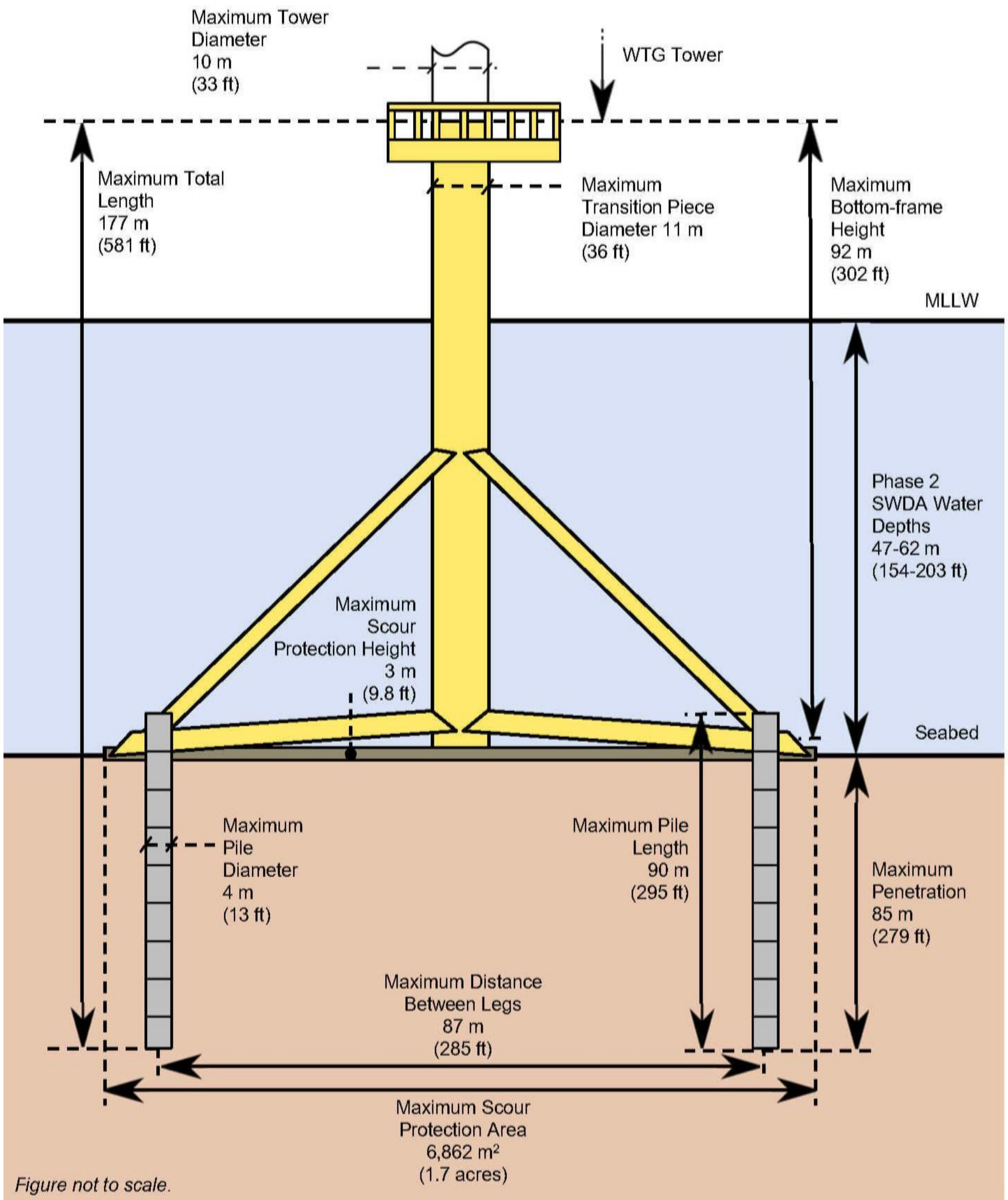

Figure 6. Schematic drawing of a bottom-frame foundation (Figure 4.2-5 of the New England Wind Draft Construction and Operations Plan Volume 1, Epsilon 2021).

1.1.4. Monopile and Jacket Installation

Seabed preparation may be required prior to foundation installation or scour protection installation (see Section 3.3.1.2 and 4.3.1.2 of the COP Volume I). This could include the removal of large obstructions and/or leveling of the seabed.

During Phase 1 and 2 construction and installation, the monopiles and jacket foundations will be installed by one or two DP, anchored, or jack-up vessel(s). The main monopile and jacket foundation installation vessel(s) will likely remain at the SWDA (or in the immediate vicinity) during foundation installation and supply vessels, jack-up vessels, barges, and/or tugs will provide a continuous supply of foundations to the SWDA. In addition, a tugboat may remain at the SWDA to assist feeder vessels' approach to the main installation vessel. The foundation components could be picked up directly in a US port (if Jones Act compliant vessels are available) or Canadian port by the main installation vessel(s).

At the SWDA, the main installation vessel will use a crane to upend and lower the monopile to the seabed. It is anticipated that the monopile will be lifted directly off the transportation vessel, which would be moored to the main installation vessel. To stabilize the monopile's vertical alignment before and during piling, a pile frame may be placed on the seabed (atop the scour protection) or a pile gripper may extend from the side of the installation vessel. After the monopile is lowered to the seabed through the pile gripper/frame, the weight of the monopile will enable it to "self-penetrate" a fraction of the target penetration depth into the seafloor. The crane hook will then be released, and the hydraulic hammer will be lifted and placed on top of the monopile. Figure 7 shows a vessel lowering a monopile and typical jack-up installation vessels. Alternatively, a vibratory hammer could be used for a limited period of time as the monopile is lifted to slowly install the monopile through the surficial sediments in a controlled fashion. The use of a vibratory hammer to install the monopile through the surficial sediments avoids the potential for a "pile run," where the pile could potentially drop quickly through the looser surficial sediments and destabilize the installation vessel. A discussion of the sound produced by vibratory setting of piles is provided in Section 1.2.2. Once the pile has penetrated the surficial sediments with the vibratory hammer, an impact hammer would be used for the remainder of the installation.

The WTG jacket piles are expected to be pre-piled (i.e., the jacket structure will be set on pre-installed piles). Alternatively, the up to three ESP jackets are expected to be post-piled (i.e., the jacket is placed on the seafloor and piles are subsequently driven through guides at the base of each leg). Once delivered to the SWDA, the jacket will be lifted off the transport or installation vessel and lowered to the seabed with the correct orientation. The piles will be driven to the engineered depth, following the same process described above for monopiles. For the ESP post-piled jackets, piling will be initiated during daylight hours (no later than 1.5 hours prior to civil sunset) and will need to continue until all piles are installed in order to maintain asset integrity at the sea floor and to alleviate health and safety concerns. If the up to three ESP jackets require nighttime piling, breaks between piles will be limited to the shortest duration possible, noise abatement systems (NAS) will be utilized, and PAM systems will be deployed.

Foundation installation will begin with a soft-start to ensure that the monopile or jacket foundation pile remains vertical and to 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 energy for monopiles is up to 6,000 kilojoules (kJ) and 3,500 kJ for jacket foundation piles.

For New England Wind, it is expected that each monopile installation will last less than 6 hours, with most installations anticipated to last between 2–4 hours. Jacket foundation installation times will vary, depending on whether the jacket is pre- or post-piled (Table 4). Pile driving activities could occur within the 8-month period of May through December in all years of either schedule.

Table 4. Duration of time (hours) to install the different pile types for various installation schedules (i.e., 1 per day, 2 per day, 4 per day) used to predict exposures in the animal movement modeling.

Duration (h)	12 m Monopile 5,000 kJ		13 m Monopile 5,000 kJ		12 m Monopile 6,000 kJ		4 m Pin Pile 3,500 kJ
	1 Pile/Day	2 Piles/Day	1 Pile/Day	2 Piles/Day	1 Pile/Day	2 Piles/Day	4 Pin Piles/Day
Time per pile	3.57	3.57	3.87	3.87	3.77	3.77	5.43
Time between piles	NA	1.0	NA	1.0	NA	1.0	0.5
Total time per day	3.57	8.14	3.87	8.74	3.77	8.54	23.22

This table includes active impact pile driving time and handling time in between piles only, it does not include potential vibratory setting or drilling time.

There may be instances during construction of New England Wind where a large sub-surface boulder or pile refusal is encountered. In these cases, drilling is required to pass through these objects. A discussion of the sound produced by this drilling is provided in Section 1.2.3.

Once the pile has reached its target penetration depth, the hydraulic hammer will be recovered from the pile and placed on the vessel deck. Next, an anode cage (a steel structure with anodes that provide corrosion protection) will likely be installed. When accounting for pre-piling preparatory work and post-piling activities, installation of a single monopile or jacket pile will take approximately 6–13 hours. There will also be time between piling events to mobilize to the next foundation location. As such, a maximum of two monopiles or one jacket (up to four pin piles) is expected to be installed in a 24-hour period. While pre-piling preparatory work and post-piling activities could be ongoing at one foundation position as pile driving is occurring at another position, there is no concurrent/simultaneous pile driving of foundations planned. The pile driving schedule is further discussed in Section 2.2.

As described in Section 11.2, noise attenuation systems are expected to be applied during pile driving. Some noise attenuation systems are deployed directly from the main foundation installation vessel during the installation process. For example, an AdBm encapsulated bubble sleeve or Hydro Sound Damper would likely be integrated into the pile gripper/frame and would be lowered around the pile after the pile is placed in the pile gripper/frame. An Integrated Pile Installer would be deployed simultaneously with the hydraulic hammer. Other noise attenuation systems require a separate vessel for deployment. For example, bubble curtains would likely be installed by a support vessel prior to the main installation vessel arriving at the foundation position. The support vessel would pay out the bubble curtain hose in a pre-determined ring around the foundation position (which takes approximately 2–4 hours) and then test the bubble curtain (for approximately 30 minutes). The support vessel would remain onsite until the main installation vessel arrives, activate the bubble curtain prior to pile driving, and recover the bubble curtain once pile driving is complete. Reeling the bubble curtain hose back onto the support vessel deck will take approximately 2 hours.

Figure 7. Typical monopile and jacket foundation installation vessels (Figure 3.3-4 of the New England Wind Draft Construction and Operations Plan Volume 1, Epsilon 2021).

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

Sounds from construction activities such as Project-related vessel activity, topside installation, scour protection, and cable laying were considered in the Project COP. These activities are not expected to contribute significantly to the acoustic footprint of New England Wind construction activities and are therefore not considered in the analysis. Section 1.1 provides a description of these activities.

The following subsections describe the activities that could result in the potential incidental take of marine mammals. These activities are the basis for this LOA application and include 1) impact pile driving, 2) vibratory pile driving, 3) drilling, 4) potential UXO detonation, and 5) HRG surveys.

1.2.1. Impact Pile Driving

Impact pile driving during foundation installation for New England Wind could result in incidental take of marine mammals through potential exposure to acoustic threshold levels of sound associated with Level A and Level B harassment. Piles deform when driven with impulsive impact hammers, creating a bulge that travels down the pile and radiates sound into the surrounding air, water, and seabed. This sound may be received as a direct transmission from the sound source to biological receivers (such as marine mammals, sea turtles, and fish) through the water or as the result of reflected paths from the surface or re-radiated into the water from the seabed (Figure 8). Sound transmission depends on many environmental parameters, such as the sound speeds in water and substrates; sound production parameters of the pile and how it is driven, including the pile material and 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 Levels A or B harassment depending on proximity to the sound source and a variety of environmental and biological conditions (Nedwell et al. 2007a, Dahl et al. 2015). Illingworth & Rodkin (2007) measured an unattenuated peak sound pressure of 220 dB re 1 μPa within 10 m (33 ft) of a 2.4 m (96 inch [in]) steel pile driven by an impact hammer, and Brandt et al. (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 1 to 3 kHz, with broadband sound energy near the source (40 Hz to >40 kHz) and only low-frequency energy (<~400 Hz) at longer ranges (Illingworth & Rodkin 2007, Erbe 2009, Bailey et al. 2010a). There is typically a decrease in sound pressure and an increase in pulse duration the greater the distance from the sound source (Bailey et al. 2010a). Maximum sound levels from pile driving usually occur during the last stage of driving a pile where the highest hammer energy levels are used (Betke 2008). A summary of the acoustic modeling and results for impact pile driving are reported in Section 6 and the full acoustic modeling report is included in this LOA application as Appendix A.

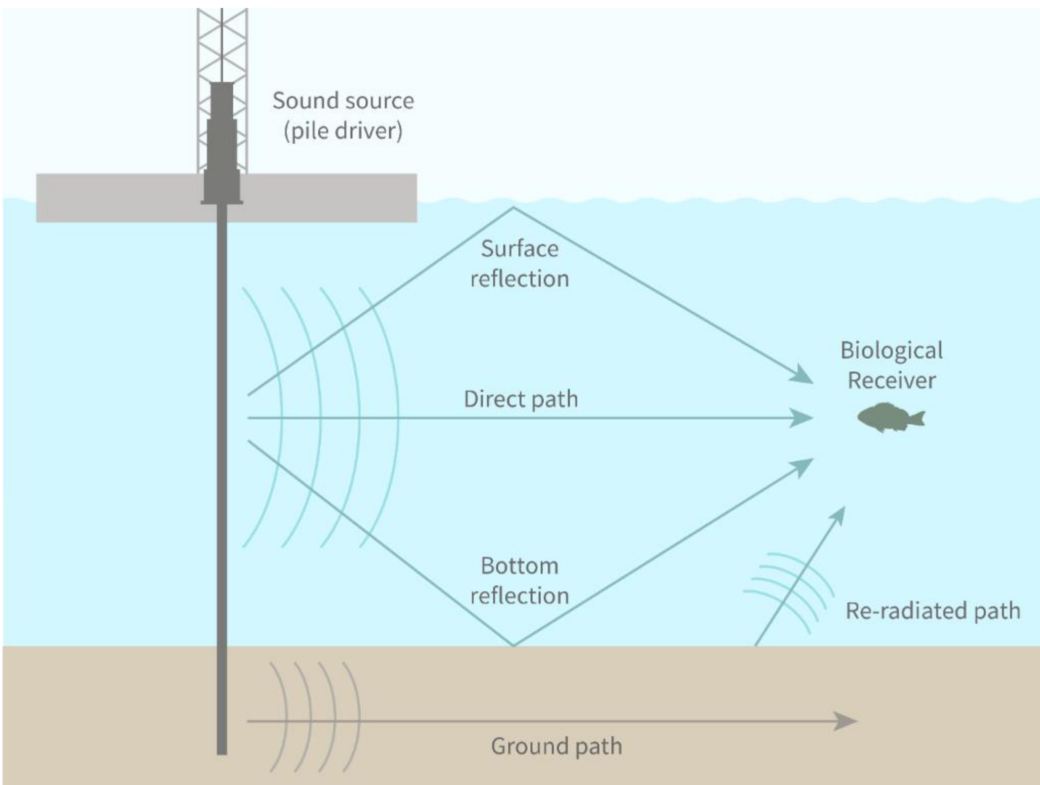

Figure 8. Sound propagation paths associated with pile driving (adapted from Buehler et al. 2015).

1.2.2. Vibratory Pile Setting

As noted above, vibratory hammering could be used during installation before impact hammering begins to mitigate the risk of “pile run,” an effect where due to unstable soil conditions, the pile begins to move under its own self weight through the soil in an uncontrolled manner. Piles which experience pile run can be difficult to recover and pose significant safety risks to the personnel and equipment on the construction vessel. The vibratory hammer mitigates this risk by forming a hard connection to the pile using hydraulic clamps, thereby acting as a lifting/handling tool as well as a vibratory hammer. The tool is inserted into the pile on the construction vessel deck, and the connection made. The pile is then lifted, upended and lowered into position on the seabed using the vessel crane.

After the pile is lowered into position, vibratory pile installation will commence. Vibratory pile installation is a technique where piles are driven into soil using a longitudinal vibration motion. The motion is produced by a vibratory hammer, which contains a system of rotating eccentric weights, powered by electric or hydraulic motors. The characteristics of the weights allow only vertical vibrations to be transmitted into the pile (Deep Foundations Institute and Gavin & Doherty Geo Solutions 2015). The hard-clamped connection between the vibratory hammer and pile through the hydraulic clamps allows the direct transmission of longitudinal vibratory motion into the pile. Both the hydraulic connection clamps and the vibratory motion motors are controlled remotely from a control cabin on the construction vessel deck. The vibratory effect then begins to push the pile through the soil strata by unsettling the soil locally surrounding the pile. The pile is kept vertical through the vibratory installation as it is still connected to the vessel crane. The crane continues to slowly lower the pile, and once a certain depth of penetration has been achieved (the penetration depth will be pre-determined using pile drivability engineering studies to ascertain the pile stability in the soil without exposure to pile run risk), the vibratory motion will be stopped from the control cabin on the construction vessel, and the hard clamped connection between the vibratory hammer and the pile will be released. The vibratory hammer is then recovered to the vessel. At this point the pile will be self-stable and standing vertically in the soil without any connection or support from the vessel crane and is safe to lift the impact hammer onto the pile and commence impact hammer driving. The use of vibratory hammering will decrease the amount of impact hammering required.

Comparisons of vibratory pile installation versus impulsive hammer pile installation indicate that vibratory pile installation typically produces lower amplitude sounds in the marine environment than impact hammer installation (Rausche and Beim 2012). Received peak sound pressure levels (PK) and sound exposure levels (SEL) near impact hammer pile installation can exceed 200 dB, even for piles <2 m diameter, while measured sound levels near similar sized piles driven with a vibratory hammer ranged from 177 to 195 dB PK and 174.8 to 190.6 dB SEL (Hart Crowser and Illingworth and Rodkin (2009), Houghton et al. (2010)). Vibratory driving of 72-inch steel pipe piles has an apparent source level of SPL ~167–180 dB re 1 μPa at 10 m (Molnar et al. 2020). Exposure to vibratory hammer sounds is unlikely to induce injury because of lower sound exposure levels combined with a higher threshold for PTS onset, and typically brief duration (an average of approximately 30 minutes per pile) of vibratory pile driving. However, Level B harassment is possible during vibratory setting of piles and is included in this LOA request.

1.2.3. Drilling

Drilling is a contingency measure that may be required to remove soil and/or boulders from inside the pile in cases of pile refusal during installation. A pile refusal can occur if the total frictional resistance of the soil becomes too much for the structural integrity of the pile and the capability of the impact hammer. Continuing to drive in a refused condition can lead to overstress in the pile and potential to buckle (tear) the pile material. The use of an offshore drill can reduce the frictional resistance by removing the material from inside the pile and allowing the continuation of safe pile driving. An offshore drill is an equipment piece consisting of a motor and bottom hole assembly (BHA). The drill is placed on top of the refused pile using the construction vessel crane, and the BHA is lowered down to the soil inside the pile. On the bottom face of the BHA is a traditional "drill bit," which slowly rotates (at 4 or 5 revolutions per minute or approximately 0.4 m per hour) and begins to disturb the material inside the pile. As the disturbed material mixes with seawater which is pumped into the pile, it begins to liquify. The liquified material is pumped out to a pre-designated location, leaving only muddy seawater inside the pile instead of a solid "soil plug," and largely reducing the frictional resistance generated by the material inside the pile. When enough material has been removed from inside the pile and the resistance has reduced sufficiently, the drill is then lifted off the pile and recovered to the vessel. The impact hammer is then docked onto the pile and impact pile driving commences. It may be necessary to remove and replace the drill several times in the driving process to achieve sufficiently low frictional resistance to achieve the design penetration through impact driving. Engineering techniques are used to ascertain how much material is required to be removed in order to sufficiently reduce the frictional resistance, and thereby optimize the process by reducing drilling time.

The Proponent conducted a seabed drivability analysis to estimate the number of foundation positions that could potentially require drilling during pile installation. This analysis suggested that up to 30% of foundations (~40) could require drilling. Adding 20% conservatism to this estimate results in approximately 48 foundations requiring drilling. The Proponent is not aware of acoustic measurements of very large drills specifically for this purpose, but comprehensive measurements of large seabed drills are available from projects in the Alaskan Chukchi and Beaufort Seas. In particular, measurements were made during use of a mudline cellar drilling with a 6 m diameter bit (Austin et al. 2018). Based on proxy measurements of offshore hydrocarbon exploration drilling, sound levels could reach the 120 dB acoustic threshold for Level B harassment from this continuous sound so incidental take is also being requested for this activity. However, exposure to drilling sounds is unlikely to induce injury because of lower sound exposure levels combined with a higher threshold for PTS onset, so the Proponent is not requesting any Level A take for this activity.

1.2.4. Potential Detonation of UXO

The Proponent is currently assessing the risk of encountering UXO within the SWDA and OECCs. Several strategies may be available to mitigate the presence of confirmed UXO in the wind development and export cable corridor areas:

- Avoidance: relocating the construction activity away from the UXO
- Lift and Shift: Moving the UXO away from the activity
- Cut and Capture: Cutting the UXO open to apportion large ammunition or deactivate fused munitions
- Low-Order Disposal: Using shaped charges to reduce the net explosive yield of a UXO
- Deflagration: Using shaped charges to ignite the explosive materials and allow them to burn at a slow rate rather than detonate instantaneously
- High-order disposal: Using a bulk charge to execute a controlled disposal of the UXO

In instances where these options are not feasible due to layout restrictions or considered safe for project personnel, UXOs may need to be detonated in situ to conduct seabed-disturbing activities such as foundation installation and cable laying during construction of New England Wind. The selection of the disposal method will be determined by the size, location, and condition of each individual UXO that the project may encounter. If detonation of UXOs is necessary, detonation noise has the potential to cause take marine mammals by both Level A and Level B harassment. Therefore, Level A and Level B take is being requested for this activity.

Evaluation of the risk of encountering potential UXO is ongoing, with geophysical and camera surveys planned to identify the location, number and type of potential UXO within the SWDA and OECC. Initial survey data suggests that there are potential areas of moderate risk for UXO presence (Figure 9). Water depth at these locations range from approximately 2 m to 62 m (Mills 2021).

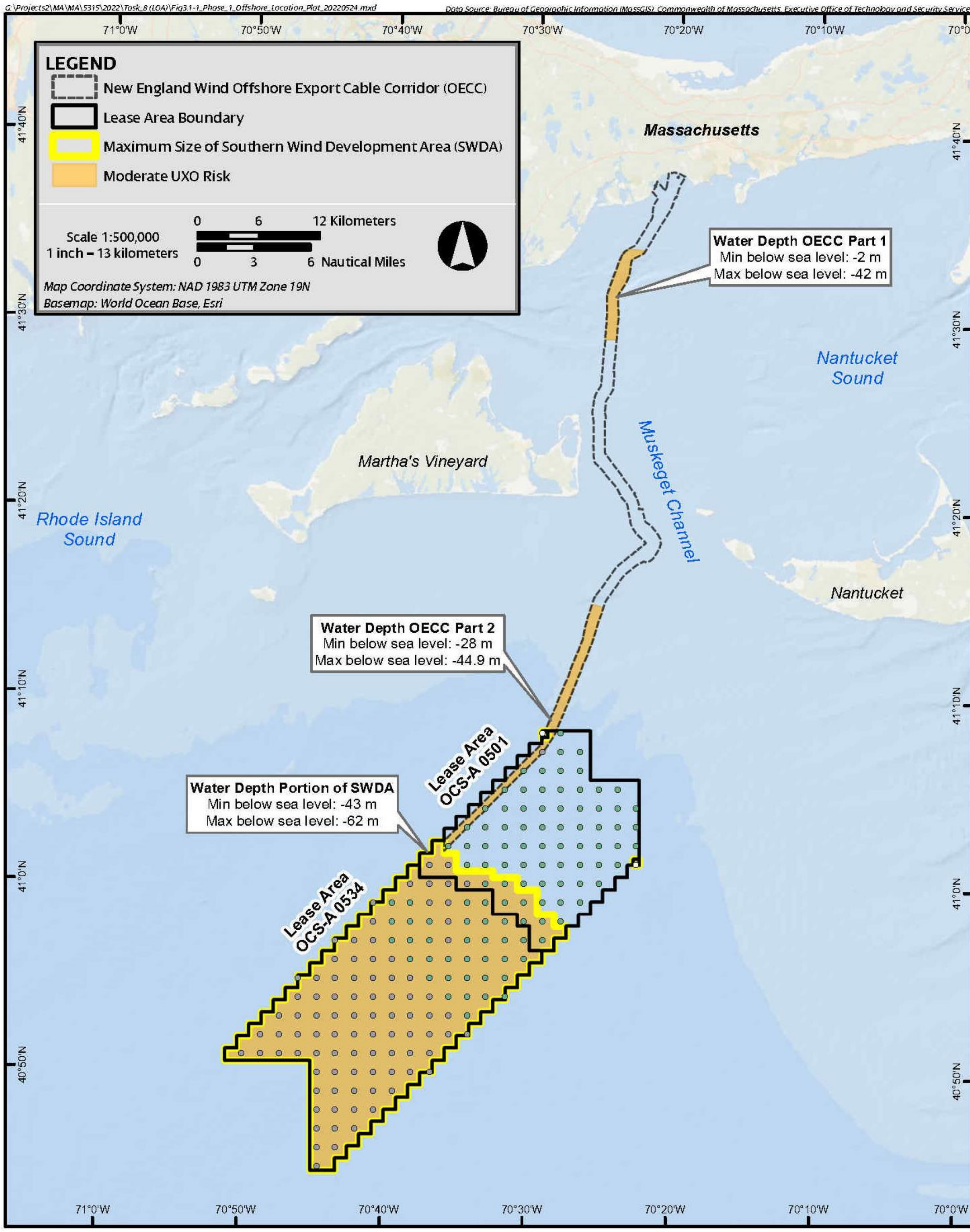

Figure 9. Areas of moderate UXO risk.

Geophysical survey operations and the development of UXO risk analysis and mitigation strategy for New England Wind are currently in line with requirements for COP development and will be further matured as the project timeline progresses towards construction.

The Proponent has commissioned a UXO desktop study in which a comprehensive historic analysis of all activities which may have contributed to potential UXO-related contamination have been considered and are summarized. The conclusion of this historical research is presented in the Tables 5 and 6. The probability of encounter of UXOs within the entire New England Wind project area is classified as possible to improbable for all but one classification of UXO.

Table 5. Probability levels.

Probability Assessment Levels		
Grade	**Probability level**	**Rationale**
A	Highly Probable	Clear evidence that this type of munition would be encountered.
B	Probable	Significant evidence to indicate that this type of munition would be encountered.
C	Possible	Evidence suggests that this type of munition could be encountered.
D	Remote	Evidence suggest that these munitions have been found in the wider area but not specifically on the site.
E	Improbable	Not considered likely to encounter this type of munition on site, but not possible to discount completely.
F	Highly Improbable	No evidence that this type of munition would be encountered on site or the immediate vicinity.

Source: Mills (2021)

Table 6. Probability of encounter for each ordnance type.

UXO		Probability	
Small Arms Ammunition		E	Improbable
Land Service Ammunition		E	Improbable
≤155 mm Projectiles		D	Remote
≥155 mm Projectiles		D	Remote
HE Bombs	Allied Origin	B	Probable
	Axis Origin	E	Improbable
Sea Mines	Allied Origin	E	Improbable
	Axis Origin	D	Remote
	Axis Origin (Non-Ferrous)	E	Improbable
Torpedoes		C	Possible
Depth Charges		C	Possible
Dumped Conventional Munitions		C	Possible
Dumped Chemical Munitions		E	Improbable
Missiles/Rockets		D	Remote

Source: Mills (2021)

The following steps will be taken in the event that a UXO is encountered and avoidance is not feasible:

1. **Identify location of UXO**

   The target UXO will have been previously mapped through geophysical survey operations and/or visual inspection using remotely operated vehicle (ROV) mounted cameras. If necessary, any covering sediments will be removed at the recorded location of the target UXO and the updated position and orientation of the UXO will be established.

2. **Confirmation on clearance strategy**

   Once the target is visually located, the mitigation strategy will be confirmed on the basis of updated information regarding the environmental conditions and context surrounding the target UXO.

3. **Deploy bubble curtain**

   Where low-order disposal, deflagration, cut and capture or high-order disposal are employed, noise-attenuating bubble curtains may be deployed. Bubble curtains are most useful in the case of high-order disposal, but they may also be deployed in the case of low-order disposal, deflagration, and cut and capture, as these methodologies are still comparatively immature; in the event that a planned e.g., low-order disposal fails and becomes a high-order disposal, the appropriate mitigation would already be in place.

   The deployment of bubble curtains is planned for all UXO disposals. Deployment may be impeded by certain bottom conditions, particularly in areas of high slope.

4. **Initiate environmental monitoring and measurement equipment**

   Described in Section 13 and Appendix C.

5. **Deploy charges**

   For low-order disposals and deflagration, shape charges are positioned, using a working class ROV, to open the case of the target UXO.

   For high-order disposals, explosive bulk charges are placed next to the target UXO using a working class ROV. The type and size of bulk charge are tailored to target UXO following advice from the appointed explosive ordnance disposal (EOD) export. The bulk charge is attached to an offshore detonation frame (ODF) to facilitate safe and streamlined deployment as near to the target UXO as possible. A detonator is placed within the frame and attached to a buoy that is released to the surface once the frame is positioned.

6. **Initiate bubble curtain**

   Where relevant, the deployed bubble curtains will be operated.

7. **Initiate clearance**

   All safety distances, as advised by the appointed EOD export will be cleared of all non-critical equipment (ROVs, vessels, etc.).

   Environmental monitoring will be maintained.

8. **Detonate**

   For low order disposals and deflagration, the net explosive yield of the target UXO is reduced or slowly burned away by a process of heat transfer (deflagration) rather than explosion.

For cut and capture, a hole would be cut in the casing of the target UXO and the explosive content would be removed and recovered to deck. This is the least matured of the mitigation strategies for UXO in the marine environment and may not be achievable in the field for New England Wind.

For high order disposals, the detonation can be physically triggered by a surface vessel using the detonator connected to the buoy attached to the ODF, or the detonation can be triggered remotely using a transceiver.

Where lift and shift is the selected mitigation action, the target UXO will be relocated using an air bag lift system and working class ROV to transport the UXO underwater to the wet storage location with as little disturbance as possible.

9. **Post-survey**

Following disposal or relocation, a geophysical or video survey will be conducted at the disposal site to identify remaining debris ≥0.3 m; any identified debris will be removed.

If, during post-survey, the target UXO is not confirmed to be completely neutralized, continuing mitigation activities will be advised by the appointed EOD export.

1.2.5. HRG Surveys

Offshore and nearshore high resolution geophysical (HRG) surveys will be conducted just prior to construction, during construction, and post-construction for activities such as pre-lay surveys (see Section 1.1.1), verifying site conditions, ensuring proper installation of New England Wind components, conducting as-built surveys, inspecting the depth of cable burial, and inspecting foundations. UXO surveys may also be conducted prior to the installation of the offshore facilities. Geophysical survey instruments may include side scan sonar, synthetic aperture sonar, single and multibeam echosounders, and magnetometers/gradiometers, which are all high frequency devices that operate above 180 kHz. Sub-bottom profilers and seismic reflection systems (i.e., single channel and multi-channel seismic profilers), which operate at frequencies below 180 kHz, may also be used to a lesser extent.

NOAA has determined that some types of HRG sources that operate at and below 180 kilohertz (kHz) have the potential to cause Level B harassment within a short distance of the sound source. JASCO conducted acoustic modeling for several types of geophysical equipment. Details of that modeling effort are included as Appendix D. The Proponent is requesting approval for the incidental Level B harassment of marine mammals for sound exposure from two deep seismic profilers: the Applied Acoustics AA251 boomer and GeoMarine’s Geo Spark 2000 (400 tip) sparker system.

New England Wind proposes to use multiple vessels to acquire the HRG survey data. Up to three HRG vessels are currently proposed to operate concurrently within the SWDA and OECC area. HRG survey activities will be conducted by vessels that can accomplish the survey goals in specific survey areas. Each vessel will maintain both the required course and a survey speed required to cover approximately 80 km (43 nm) per day during line acquisition, with consideration to weather delays, equipment maintenance, and crew availability. Vessel survey speed is anticipated to be approximately 4 knots (2.1 m/s).

The Proponent assumes that HRG surveys would be conducted for 24 hours per day for 25 days each year (125 days total over the 5 years), beginning in the first year of foundation installation and extending two years beyond the estimated 3-year duration of foundation installation. For the purpose of the LOA, it is assumed that HRG surveys would begin in January 2025. A distance of 80 km/day is assumed to be the maximum HRG survey distance possible in a 24-hour period.

The HRG surveys may occur in four areas of interest (see Figure 2):

1. Phase 2 South Coast Variant Offshore Routing Envelope
2. New England Wind Offshore Export Cable Corridor
3. Phase 2 OECC Western Muskeget Variant
4. Maximum Size of the Southern Wind Development Area

To maximize efficiency and minimize the duration of HRG survey activities and the period of potential impact on marine fauna, New England Wind proposes to conduct HRG survey activities 24 hours per day, weather dependent, while acquiring data in the Lease Area and along the OECC route. While the HRG survey activities are estimated to occur for 25 days each year, the actual survey duration will be shorter given the use of multiple vessels.

2. Dates, Duration, and Specified Geographic Region

2.1. Dates of Construction Activities

The five activities which could result in potential take of marine mammals under this LOA request (see Section 1.2) are expected to begin in 2025. HRG surveys and detonation of UXOs may occur during any month of the year; therefore, the requested effective start date for this LOA is **January 2025**.

Pile installation activities (i.e., impact pile driving, vibratory pile driving, and drilling) are scheduled to commence in May 2025. No pile driving or drilling will occur between January 1 and April 30 per the mitigation protocol (see Section 11.1). To provide the Proponent with flexibility, two potential construction schedules were evaluated for this request because the exact construction start dates and schedules are unknown at this time. Construction schedule A is a two-year, offshore, pile installation construction plan for the entire buildout of New England Wind (i.e., both Phases). Construction schedule B is a three-year offshore, pile installation construction plan for the full buildout of New England Wind. Both pile installation schedules are described in more detail below.

2.2. Pile Installation Schedule

As described in Section 1, New England Wind includes a maximum of 130 total WTG/ESP positions within the SWDA, which will be developed in two Phases. Phase 1 will include 41 to 62 WTGs and one or two ESPs for a total of 42 to 64 WTG/ESP positions in the northeast portion of the SWDA. Phase 2 will be immediately southwest of Phase 1 and will occupy the remainder of the SWDA. Therefore, the footprint and total number of positions in Phase 2 depends upon the final footprint of Phase 1. Phase 2 is expected to contain 64 to 88 WTG/ESP positions (up to three of those positions will be occupied by ESPs), such that the combined number of positions for Phase 1 and Phase 2 does not exceed 130. Of those 130 WTG/ESP positions, two positions may potentially have co-located ESPs (i.e., two foundations installed at one grid position), resulting in a maximum of 132 foundations. However, the hydroacoustic modeling was conservatively conducted for 133 foundations.[9]

As noted above, the planned duration of offshore construction activities for the full buildout of New England Wind (i.e., up to 132 foundations) is approximately 2 or 3 years, depending on which construction schedule is chosen. Pile driving activities could occur within the 8 month period of May through December in all years of either schedule. However, poor weather days will prevent piling on some days. As described in Section 1.1.4, piling of a single pile is anticipated to last less than 6 hours at a maximum, and most installations are anticipated to last 2–4 hours. There will also be time between piling events to mobilize to the next location and prepare for the next installation. As such, a maximum of two monopiles or one jacket (up to four pin piles) is expected to be installed per day. No concurrent/simultaneous pile driving of foundations is planned for New England Wind.

[9] A total of 132 foundations are presently proposed, which includes 130 WTG/ESP grid positions with two positions potentially having co-located ESPs (i.e., two foundations installed at one grid position). An earlier plan for New England Wind included one additional foundation for a potential reactive compensation station (RCS), bringing the total to 133 foundations. Therefore, hydroacoustic modeling presented in this application includes 133 foundations (completed prior to the elimination of the potential RCS), resulting in a conservative estimate of animal exposures for a project with 132 foundations.

The projected numbers of pile-driving days per month under a two-year construction schedule (Construction schedule A) and a three-year construction schedule (Construction schedule B) are shown in Table 7 and Table 8, respectively. The estimated pile driving schedules were provided by the Proponent's engineers and created based on the number of expected suitable weather days available per month in which pile driving could occur as well as potential construction vessel sequencing. The number of suitable weather days per month was obtained from historical weather data. Also shown in Tables 7 and 8 are the number of days of vibratory setting as well as the number of days of drilling that could occur each month during pile installation.

Construction schedule A assumes a conservative, yet realistic two-year construction scenario where 54 Phase 1 WTGs are installed on monopiles, 53 Phase 2 WTGs are installed on monopiles, 23 Phase 2 WTGs are installed on jackets, and each Phase includes one ESP on a jacket foundation.[10] Construction schedule A also assumes that foundations for all of Phase 1 (Park City Wind) and a portion of Phase 2 (Commonwealth Wind) are installed in Year 1, and that the remaining Phase 2 foundations are installed in Year 2. Overall, under this schedule, 89 monopile foundations and two jacket foundations would be installed in Year 1 and 18 monopile and 24 jacket foundations would be installed in Year 2 (Table 7).

Construction schedule B assumes a conservative, yet realistic three-year construction scenario where 55 Phase 1 WTGs are installed on monopiles, 75 Phase 2 WTGs are installed on jackets, and each Phase includes one ESP on a jacket foundation.[11] The conservative assumption that all Phase 2 (Commonwealth Wind) foundations are jackets was used in the model since jacket foundations are the most impactful in terms of the Level A cumulative sound exposure metric. Thus, the assumption of all jackets provides an envelope for an up to 13 m monopile installed with a 5,000 or 60,00 kJ hammer. Construction schedule B assumes that all ESP foundations and Phase 1 (Park City Wind) WTG foundations are installed in Year 1 and that the Phase 2 (Commonwealth Wind) WTG foundations are installed in Years 2 and 3. Overall, under this schedule, 55 monopiles and three jacket foundations would be installed in Year 1, 53 jacket foundations would be installed in Year 2 and 22 jacket foundations would be installed in Year 3 (Table 8).

[10] Construction schedule A also includes one additional jacket foundation for an RCS, which has been eliminated from the design of New England Wind.
[11] Construction schedule B also includes one additional jacket foundation for an RCS, which has been eliminated from the design of New England Wind.

Table 7. Construction Schedule A: The number of potential days of pile installation per month under the maximum design scenario used to estimate the total number of marine mammal acoustic exposures for New England Wind.

Month	Year 1[a]								Year 2						Schedule A Total		
	12 m Monopile 5,000 kJ		13 m Monopile 5,000 kJ		4 m Pin pile 3,500 kJ	Year 1 total days of impact piling	Days with vibratory hammer[b]	Days with drilling[b,c]	12 m Monopile 6,000 kJ		4 m Pin Pile 3,500 kJ	Year 2 total days of impact piling	Days with vibratory hammer[b]	Days with drilling[b]	Total days of impact piling	Days with vibratory hammer[b]	Days with drilling[b]
	One per day	Two per day	One per day	Two per day	Four per day				One per day	Two per day	Four per day						
May	4	0	0	0	0	4	2	2	4	0	0	4	1	1	8	4	5
June	2	5	0	0	0	7	4	4	0	3	0	3	2	2	10	7	6
July	0	9	0	0	0	9	5	7	0	4	0	4	3	2	13	8	9
August	0	9	0	0	0	9	9	7	0	0	8	8	4	4	17	13	11
September	0	1	1	6	2	10	7	8	0	0	7	7	4	2	17	11	10
October	0	0	0	6	0	6	2	3	0	0	6	6	3	2	12	5	5
November	0	0	0	3	0	3	2	2	0	0	2	2	2	2	5	4	4
December	0	0	4	0	0	4	0	0	0	0	1	1	0	0	5	0	0
	6	**24**	**5**	**15**	**2**	**52**	**31**	**33**	**4**	**7**	**24**	**35**	**19**	**15**	**87**	**50**	**48**
Total Days	**52 days**								**35 days**						**87 days**		
Total Foundations	**89 monopiles and 2 jackets**								**18 monopiles and 24 jackets**						**133 foundations**		
Total Piles	**89 monopiles and 8 pin piles**								**18 monopiles and 96 pin piles**						**211 piles**		

[a] For the purpose of this LOA request, Year 1 is assumed to be 2025 and Year 2 is assumed to be 2026. These dates reflect the currently projected construction start year and are subject to change because exact project start dates and construction schedules are not currently available. No concurrent/simultaneous pile driving of foundations is planned.

[b] The number of days with vibratory hammering or drilling is based on a percentage of the number of days of pile installation and includes installation of a mix of monopiles at a rate of both 1 per day and 2 per day as well as installation of jacket foundations at a rate of four pin piles per day. The number of piles driven per day is not relevant in the context of Level B takes, because these takes are based on single daily exposures above the SPL 120 dB threshold (not a cumulative metric). Only Level B takes are being requested for drilling and vibratory hammering, which are based only on the number of days each month for these activities.

[c] During year 1, the sum of days with vibratory hammering (31) plus days with drilling (33) is 64, which exceeds the 52 days of pile installation. Therefore, for the 12 days when pile installation includes both vibratory setting and drilling, the Level B estimated takes for drilling were not included in the total to avoid double counting.

Table 8. Construction Schedule B: The number of potential days of pile installation per month under the maximum design scenario used to estimate the total number of marine mammal acoustic exposures for New England Wind.

Month	Year 1[a]						Year 2				Year 3				Schedule B Total		
	12 m Monopile 5,000 kJ		4 m Pin pile 3,500 kJ	Year 1 total days of impact piling	Days with vibratory hammer[b]	Days with drilling[b]	4 m Pin pile 3,500 kJ	Year 2 total days of impact piling	Days with vibratory hammer[b]	Days with drilling[b,c]	4 m Pin pile 3,500 kJ	Year 3 total days of impact piling	Days with vibratory hammer[b]	Days with drilling[b]	Total days of impact piling	Days with vibratory hammer[b]	Days with drilling[b]
	One per day	Two per day	Four per day				Four per day				Four per day						
May	4	0	0	4	2	2	1	1	1	1	1	1	1	1	6	5	6
June	6	4	0	10	4	4	9	9	4	4	4	9	1	2	23	11	10
July	0	7	0	7	7	3	14	14	8	4	5	14	3	2	26	18	9
August	1	5	1	7	7	4	14	14	8	4	5	14	3	1	26	18	9
September	0	3	1	4	4	4	8	8	7	4	5	8	3	1	17	14	9
October	1	1	1	3	3	2	4	4	3	1	1	4	1	1	8	7	4
November	2	0	0	2	1	1	2	2	1	1	1	2	1	1	5	3	3
December	1	0	0	1	0	0	1	1	0	0	0	1	0	0	2	0	0
	15	**20**	**3**	**38**	**28**	**20**	**53**	**53**	**32**	**19**	**22**	**22**	**13**	**9**	**113**	**73**	**48**
Total Days	**38 days**						**53 days**				**22 days**				**113 days**		
Total Foundations	**55 monopiles and 3 jackets**						**53 jackets**				**22 jackets**				**133 foundations**		
Total Piles	**55 monopiles and 12 pin piles**						**212 pin piles**				**88 pin piles**				**367 piles**		

[a] For the purpose of this LOA request, Year 1 is assumed to be 2025, Year 2 is assumed to be 2026, and Year 3 is assumed to be 2027. These dates reflect the currently projected construction start year and are subject to change because exact project start dates and construction schedules are not currently available. No concurrent/simultaneous pile driving of foundations is planned.

[b] The number of days with vibratory hammering or drilling is based on a percentage of the number of days of pile installation and includes installation of a mix of monopiles at a rate of both 1 per day and 2 per day as well as installation of jacket foundations at a rate of four pin piles per day. The number of piles driven per day is not relevant in the context of Level B takes, because these takes are based on single daily exposures above the SPL 120 dB threshold (not a cumulative metric). Only Level B takes are being requested for drilling and vibratory hammering, which are based only on the number of days each month for these activities.

[c] During year 1, the sum of days with vibratory hammering (28) plus days with drilling (20) is 48, which exceeds the 38 days of pile installation. Therefore, for the 10 days when pile installation includes both vibratory setting and drilling, the Level B estimated takes for drilling were not included in the total to avoid double counting

2.3. Specific Geographical Region of Activity

Pile driving and drilling will occur in the SWDA (Figure 1), potential detonation of UXO may occur along the OECCs and SWDA, and HRG surveys will occur in the SWDA, along the OECCs, and within the Phase 2 South Coast Variant Offshore Routing Envelope (Figure 2), as described in Section 1. The SWDA is just over 32 kilometers (km) from the southwest corner of Martha's Vineyard and approximately 38 km from Nantucket. Water depths in the SWDA generally range from approximately 43–62 m (141–203 ft). Water depths in the OECC generally range from approximately <2 to 46 meters(<7–151 ft).

Part of the mid-Atlantic Bight, this area is characterized by a shelf break that separates continental waters and those of the slope sea near the 200-m isobath (Linder and Gawarkiewicz 1998). Circulation at the front of the shelf break leads to an upwelling that supports an increase in primary productivity (Marra et al. 1990). As a result, the area is biologically significant to a number of marine mammal species and is considered to be an important seasonal foraging area (Stone et al. 2017).

3. Species and Numbers of Marine Mammals

Descriptions of marine mammals, their distribution, and abundance are based on a review of existing published and gray literature, as well as public reports (e.g., press releases), where relevant, to describe recent events not yet published. Examples of primary data sources referenced in this assessment include the following:

- **Marine Mammal Stock Assessment Reports**

  NMFS releases Stock Assessment Reports (SARs) for marine mammals that occur within the US Atlantic EEZ as required under the 1994 amendments to the MMPA. All stocks are reviewed at least every 3 years or as new information becomes available. Stocks that are designated as strategic are reviewed annually. Each report contains a description of a stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, an estimate of the potential biological removal (i.e., maximum number of animals that may be removed from a marine mammal stock without reducing numbers below the optimum sustainable population) for each species, the status of the stock, estimates of annual human-caused mortality and serious injury by source, and descriptions of other factors that may be causing a decline or impeding the recovery of strategic stocks (Hayes et al. 2021).

- **The Northeast Large Pelagic Survey Collaborative (NLPSC) Aerial and Acoustic Surveys for Large Whales and Sea Turtles**

  Multiple surveys were conducted for the Massachusetts Clean Energy Center and Bureau of Ocean Energy Management (BOEM) by the NLPSC (comprised of the New England Aquarium, Cornell University's Bioacoustics Research Program, the University of Rhode Island, and the Center for Coastal Studies) (Kraus et al. 2016). This study was designed to provide a comprehensive baseline characterization of the abundance, distribution, and temporal occurrence of marine mammals, with a focus on large, Endangered whales and sea turtles in the MA WEA, and the RI/MA WEA and surrounding waters. Information was collected using visual line-transect aerial surveys and passive acoustic monitoring (PAM) from October 2011 to June 2015 and from December 2012 to June 2015 in the RI/MA WEA. Seventy-six aerial surveys were conducted, and Marine Autonomous Recording Units were deployed for 1010 calendar days during the study period. Survey methodologies and details are described in Kraus et al. (2016).

- **Megafauna Aerial Surveys in the Wind Energy Areas of Massachusetts and Rhode Island with Emphasis on Large Whales Summary Report Campaign 5, 2018–2019:**

  NEAq and Woods Hole Oceanographic Institution (WHOI), in coordination with the Provincetown Center for Coastal Studies, conducted oceanographic surveys to assess the physical and biological characteristics of waters used by right whales in this study area. These reports include the sightings and data information, plus analyses of effort corrected data, and includes maps of sightings per unit effort (SPUE), sighting rates, and calculations of density and abundance. This report also includes analysis of right whale prey species and oceanographic conditions near right whale aggregations during Campaign 4 and 5 (O'Brien et al. 2020a).

- **Megafauna Aerial Surveys in the Wind Energy Areas of Massachusetts and Rhode Island with Emphasis on Large Whales: Interim Report Campaign 6A, 2020**

  This report summarizes results from a subset of the ongoing Campaign 6 surveys, funded by BOEM. Campaign 6A surveys were conducted in the MA and RI/MA WEAs between March and October 2020 (with an interruption to allow for development of safety protocols related to COVID-19). Specifically, this report contains summaries of survey effort, summaries of sightings (e.g., sightings maps), and analyses of effort-corrected data, including sighting rates and calculations of density and abundance (O'Brien et al. 2020b).

- **Atlantic Marine Assessment Program for Protected Species (AMAPPS)**

  The AMAPPS Phase I surveys were conducted from 2010–2014 (NEFSC and SEFSC 2011b, 2011a, 2012, 2014a, 2014b), and Phase II surveys from 2015–2020 (NEFSC and SEFSC 2015, 2016, 2018, 2019). Phase III will acquire data through 2023. AMAPPS surveys include aerial and shipboard observations, biological and oceanographic sampling, satellite-telemetry, and PAM conducted in all four seasons of the year. AMAPPS reports provide updated information on the abundance and distribution of marine mammals, sea turtles, and sea birds and assess recent changes in seasonal habitat use by these species. These data can be used to quantify changing species' abundance and distributions and assess the potential impact of human activities on protected species. The abundance estimates used by NMFS for many of the marine mammal species within the US Atlantic EEZ are based on the AMAPPS surveys (NOAA Fisheries 2020b). At least one survey was conducted in the MA WEA and the RI/MA WEA in each survey year.

- **Duke University Habitat-based Marine Mammal Density Models for the US Atlantic**

  The Duke University habitat-based density models were originally published in 2016 for 26 cetacean species and three cetacean species guilds for US waters of the North Atlantic and northern Gulf of Mexico (Roberts et al. 2016a). Under an ongoing research agreement with the US Navy, the models were subsequently updated for the Atlantic (the East Coast [EC] models) using the same methods but incorporating additional data, including NOAA Fisheries' AMAPPS surveys, North Atlantic right whale Early Warning System (EWS) surveys, and other data (Roberts et al. 2016b). Later revisions to the EC models under this research agreement included updates to 11 cetacean taxa in 2017 and an additional ten cetacean taxa in 2018 (Roberts et al. 2017, 2018). The 2018 update also included the addition of seals as a guild (Roberts et al. 2018). More recent updates have focused on the North Atlantic right whale, including the latest revision in February 2021. The animal modeling undertaken in support of this LOA application used this most recent EC model versions, downloaded in July 2021 from the model home page (https://seamap.env.duke.edu/models/Duke/EC/).

Thirty-eight marine mammal species (whales, dolphins, porpoise, and seals) comprising 39 stocks have been documented as present (some year-round, some seasonally, and some as occasional visitors) in the Northwest Atlantic Outer Continental Shelf (OCS) region (CeTAP 1982, USFWS 2014, Roberts et al. 2016a, Hayes et al. 2020, Hayes et al. 2021). All thirty-eight marine mammal species identified in Table 9 are protected by the MMPA and some are also listed under the ESA. The five ESA-listed marine mammal species known to be present year-round, seasonally, or occasionally in southern New England waters are the sperm whale (*Physeter macrocephalus*), North Atlantic right whale (NARW; *Eubalaena glacialis*), fin whale (*Balaenoptera physalus*), blue whale (*Balaenoptera musculus*), and sei whale (*Balaenoptera borealis*). The humpback whale (*Megaptera novaeangliae*) is assessed globally under the ESA using 14 Distinct Population Segments (DPSs). Although five of these DPSs are ESA listed as Endangered or Threatened, humpback whales occurring in the feeding area off the NE US belong to the West Indies DPS, which is considered Not at Risk under the ESA.

Palka et al. (2017) modeled temporal trends for several species and predicted that the abundance estimates for the period April to June were larger than those predicted for the period August to September. This pattern was observed for humpback whales, sei whales, minke whales (*Balanenoptera acutorostrata*), sperm whales, Atlantic white-sided dolphins (*Lagenorhynchus acutus*), and common dolphins (*Delphinus delphis*). In contrast, within the AMAPPS study area, some species appeared to have fairly consistent abundance estimates in all seasons (fin whales, long-finned [*Globicephala melaena*] and short-finned [*G. macrorhynchus*] pilot whales, and Atlantic spotted dolphins [*Stenella frontalis*]), while others have higher abundance in US waters in late summer (Risso's dolphins [*Grampus griseus*] and harbor porpoises [*Phocoena phocoena*]).

The AMAPPS results (Palka et al. 2017) indicate that pygmy/dwarf sperm whales (*Kogia breviceps/K. sima*), beaked whales (*Ziphiidae*), and striped dolphins (*Stenella coeruleoalba*) are nearly always found in deep offshore waters, at least during summer. Of the species that were detected year-round, various distribution/abundance patterns were observed. For example, seasonal migrations were documented for species like sei whales that spent spring in US Atlantic waters, and then nearly completely disappeared in other seasons.

Southern New England waters (including the Offshore Development Area in Figure 1) are important feeding habitats for several species of baleen whales, including NARW, humpback, fin, and minke whales (Hayes et al. 2020) with seasonal abundance differences in New England waters. Most of these species undertake yearly migrations between their winter breeding grounds in southern latitudes and spring/summer feeding grounds in the US Atlantic. Sei whales have been sighted in summer in continental shelf waters of the Northeastern US and seem to be distributed closer to the 2000 m (approximately 6562 ft) depth contour than fin whales (Waring et al. 2016). Minke whales have a strong seasonal component to their distribution on both the continental shelf (spring to fall) and in deeper, off-shelf waters (fall to spring) (Hayes et al. 2019). Humpback whales can be found in New England waters throughout the year, but their numbers decrease in winter when most animals migrate to their more southerly calving and breeding grounds. Sperm whales have been observed during scientific surveys conducted in summer over the continental shelf edge, over the continental slope, and into mid-ocean regions and have occasionally been sighted in shelf waters in or near the SWDA (Halpin et al. 2009, Waring et al. 2015). Sperm whales may occur in the Offshore Development Area, though movements will vary based on prey availability and other habitat factors.

Along with cetaceans, seals are protected under the MMPA. The four species of phocids (true seals) that have ranges overlapping the Offshore Development Area are harbor seals (*Phoca vitulina*), gray seals (*Halichoerus grypus*), harp seals (*Pagophilus groenlandicus*), and hooded seals (*Cystophora cristata*) (Hayes et al. 2021).

The expected occurrence of each species in the Offshore Development Area is listed in Table 9, and is based on Hayes et al. (2021). Many of the marine mammal species that inhabit the Northwestern Atlantic are not likely to be found in the SWDA (Figure 1), as they do not commonly occur in this region of the Atlantic Ocean. Species categories include:

- Common - Occurring consistently in moderate to large numbers;
- Regular - Occurring in low to moderate numbers on a regular basis or seasonally;
- Uncommon - Occurring in low numbers or on an irregular basis; and
- Rare - Records for some years but limited; range includes the Offshore Development Area but due to habitat preferences and distribution information, species are generally not expected to occur in the SWDA, though rare sightings are a possibility.

The protection status, stock identification, occurrence, and abundance estimate of the species listed in Table 9 that are categorized as common, regular, and uncommon are discussed in more detail in Section 4. Species listed as rare are not described in detail here but are considered in the take request as a conservative measure to account for potential rare sightings (see Section 6). Abundance estimates are based on the most recent information available, including the yearly updated SARs (Hayes et al. 2021). Density estimates are also used in this report to calculate the number of animals potentially exposed to threshold levels of sound (Roberts et al. 2016a, 2016b, 2017, 2018, 2021b). The likelihood of this incidental exposure for each species based on its presence, density, and overlap with proposed activities is described in detail in Section 6.

Table 9. Marine mammal species that may occur in the marine waters of Southern New England.

Species	Scientific name	Stock	Regulatory status[a]	SWDA occurrence	Abundance[b]
Baleen whales (Mysticeti)					
Blue whale	*Balaenoptera musculus*	Western North Atlantic	ESA-Endangered	Rare	402
Fin whale	*Balaenoptera physalus*	Western North Atlantic	ESA-Endangered	Common	6,802
Humpback whale	*Megaptera novaeangliae*	Gulf of Maine	MMPA	Common	1,396
Minke whale	*Balaenoptera acutorostrata*	Canadian Eastern Coastal	MMPA	Common	21,968
North Atlantic right whale	*Eubalaena glacialis*	Western North Atlantic	ESA-Endangered	Common	368[c]
Sei whale	*Balaenoptera borealis*	Nova Scotia	ESA-Endangered	Common	6,292
Toothed whales (Odontoceti)					
Sperm whales (Physeteroidae)					
Sperm whale	Physeter macrocephalus	North Atlantic	ESA-Endangered	Uncommon	4,349
Dwarf sperm whale	*Kogia sima*	Western North Atlantic	MMPA	Rare	7,750[d]
Pygmy sperm whale	*Kogia breviceps*	Western North Atlantic	MMPA	Rare	7,750[d]
Dolphins (Delphinidae)					
Atlantic spotted dolphin	Stenella frontalis	Western North Atlantic	MMPA	Uncommon	39,921
Atlantic white-sided dolphin	Lagenorhynchus acutus	Western North Atlantic	MMPA	Common	93,233
Bottlenose dolphin	Tursiops truncatus	Western North Atlantic, offshore[e]	MMPA	Common	62,851
Clymene dolphin	Stenella clymene	Western North Atlantic	MMPA	Rare	4,237
False killer whale	Pseudorca crassidens	Western North Atlantic	MMPA	Rare	1,791
Fraser's dolphin	Lagenodelphis hosei	Western North Atlantic	MMPA	Rare	Unknown
Killer whale	Orcinus orca	Western North Atlantic	MMPA	Rare	Unknown
Melon-headed whale	Peponocephala electra	Western North Atlantic	MMPA	Rare	Unknown
Pantropical spotted dolphin	*Stenella attenuata*	Western North Atlantic	MMPA	Rare	6,593
Pilot whale, long-finned	*Globicephala melas*	Western North Atlantic	MMPA	Uncommon	39,215
Pilot whale, short-finned	*Globicephala macrorhynchus*	Western North Atlantic	MMPA	Uncommon	28,924
Pygmy killer whale	Feresa attenuata	Western North Atlantic	MMPA	Rare	Unknown
Risso's dolphin	Grampus griseus	Western North Atlantic	MMPA	Uncommon	35,215
Rough-toothed dolphin	Steno bredanensis	Western North Atlantic	MMPA	Rare	136
Short-beaked common dolphin	*Delphinus delphis*	Western North Atlantic	MMPA	Common	172,974
Spinner dolphin	Stenella longirostris	Western North Atlantic	MMPA	Rare	4,102
Striped dolphin	Stenella coeruleoalba	Western North Atlantic	MMPA	Rare	67,036
White-beaked dolphin	*Lagenorhynchus albirostris*	Western North Atlantic	MMPA	Rare	536,016

Species	Scientific name	Stock	Regulatory status[a]	SWDA occurrence	Abundance[b]
Monodontid whales (Monodontidae)					
Beluga whale	*Delphinapterus leucas*	None defined for US Atlantic	MMPA	Rare	Unknown[f]
Beaked whales (Ziphiidae)					
Cuvier's beaked whale	*Ziphius cavirostris*	Western North Atlantic	MMPA	Rare	5,744
Blainville's beaked whale	*Mesoplodon densirostris*	Western North Atlantic	MMPA	Rare	10,107[g]
Gervais' beaked whale	*Mesoplodon europaeus*	Western North Atlantic	MMPA		
Sowerby's beaked whale	*Mesoplodon bidens*	Western North Atlantic	MMPA		
True's beaked whale	*Mesoplodon mirus*	Western North Atlantic	MMPA		
Northern bottlenose whale	*Hyperoodon ampullatus*	Western North Atlantic	MMPA	Rare	Unknown
Porpoises (Phocoenidae)					
Harbor porpoise	*Phocoena phocoena*	Gulf of Maine/Bay of Fundy	MMPA	Common	95,543
Earless seals (Phocidae)					
Gray seal	*Halichoerus grypus*	Western North Atlantic	MMPA	Common	27,300[h]
Harbor seal	*Phoca vitulina*	Western North Atlantic	MMPA	Regular	61,336
Harp seal	*Pagophilus groenlandicus*	Western North Atlantic	MMPA	Uncommon	Unknown[i]
Hooded seal	*Cystophora cristata*	Western North Atlantic	MMPA	Rare	Unknown

[a] Denotes the highest federal regulatory classification. A strategic stock is defined as any marine mammal stock: 1) for which the level of direct human-caused mortality exceeds the potential biological removal level; 2) that is declining and likely to be listed as Threatened under the ESA; or 3) that is listed as Threatened or Endangered under the ESA or as depleted under the MMPA (NOAA Fisheries 2019).

[b] Best available abundance estimate is from NOAA Fisheries Stock Assessment Reports (NOAA Fisheries 2021aa).

[c] Best available abundance estimate is from NOAA Fisheries Stock Assessment (NOAA Fisheries 2021aa). NARW consortium has released the 2021 report card results estimating a NARW population of 336 for 2020 (Pettis et al. 2022). However, the consortium "alters" the methods of Pace et al. (2017, Pace et al.) to subtract additional mortality. This method is used in order to estimate all mortality, not just the observed mortality, therefore the NOAA Fisheries (2021aa) SAR will be used to report an unaltered output of the Pace et al. (2017, 2021) model (DoC and NOAA 2020).

[d] This estimate includes both dwarf and pygmy sperm whales. Source: NOAA Fisheries (2021aa).

[e] Bottlenose dolphins occurring in the Offshore Development Area likely belong to the Western North Atlantic Offshore stock (NOAA Fisheries 2021aa). The known range of the Western North Atlantic Northern Coastal Migratory Stock of this species is limited to waters <20 m deep off Long Island, New York, and southward (Hayes et al. 2021).

[f] NMFS does not provide abundance estimates of beluga whales in US waters because there is no stock defined for the US Atlantic. Belugas occurring off the US Atlantic coast are likely vagrants from one of the Canadian populations (COSEWIC 2020).

[g] This estimate includes all undifferentiated Mesoplodon spp. beaked whales in the Atlantic. Sources: Kenney and Vigness-Raposa (2009), Rhode Island Ocean Special Area Management Plan (2011), Waring et al. (2011, 2013, 2015), Hayes et al. (2017, 2018, 2019, 2020)

[h] Estimate of gray seal population in US waters. Data are derived from pup production estimates; NOAA Fisheries (2021aa) notes that uncertainty about the relationship between whelping areas along with a lack of reproductive and mortality data make it difficult to reliably assess the population trend.

[i] NOAA Fisheries (2021aa) report insufficient data to estimate the population size of harp seals in US waters; the best estimate for the entire western North Atlantic population is 7.6 million.

4. Affected Species Status and Distribution

All marine mammal species are protected under the MMPA. Some marine mammal stocks may be designated as strategic under the MMPA (2015), which requires the jurisdictional agency (NMFS for the Atlantic offshore species considered in this application) to impose additional protection measures. A stock is considered strategic if:

- Direct human-caused mortality exceeds its Potential Biological Removal (PBR) level (defined as the maximum number of animals, not including natural mortality, that can be removed from the stock while allowing the stock to reach or maintain its optimum sustainable population level);
- It is listed under the ESA;
- It is declining and likely to be listed under the ESA; or
- It is designated as depleted under the MMPA.

A depleted species or population stock is defined by the MMPA as any case in which:

- The Secretary, after consultation with the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals established under MMPA Title II, determines that a species or population stock is below its optimum sustainable population;
- A State, to which authority for the conservation and management of a species or population stock is transferred under Section 109 of the MMPA, determines that such species or stock is below its optimum sustainable population; or
- A species or population stock is listed as an Endangered or Threatened species under the ESA.

Some species are further protected under the ESA (2002). Under the ESA, a species is considered Endangered if it is "in danger of extinction throughout all or a significant portion of its range." A species is considered Threatened if it "is likely to become an Endangered species within the foreseeable future throughout all or a significant portion of its range" (ESA 2002). There are 17 marine mammal species that are Endangered, strategic, and/or can be reasonably expected to reside, traverse, or visit the SWDA (Figure 1), and thus may experience some level of exposure to sound from New England Wind construction and installation activities. The NARW, fin whale, sei whale, and sperm whale are all considered Endangered under the ESA. These four species are also considered strategic under the MMPA.

The following subsections provide additional information on the biology, habitat use, abundance, distribution, and existing threats to the non-ESA-listed and ESA-listed marine mammal species for which incidental harassment is being requested. Species considered common, uncommon, and regular (i.e., have the likelihood of occurring at least seasonally in the Offshore Development Area) include the NARW, humpback whale, fin whale, sei whale, minke whale, bottlenose dolphin, short- and long-finned pilot whales, Risso's dolphin, short-beaked common dolphin, sperm whale, Atlantic white-sided dolphin, Atlantic spotted dolphin, harbor porpoise, gray seal, harbor seal, and harp seal (BOEM 2014b). These species were included in the acoustic modeling assessment described in Section 6. While the potential for interactions with pilot whales, Atlantic white-sided dolphins, Atlantic spotted dolphins, Risso's dolphins, and harp seals is low, small numbers of these species may transit the Offshore Development Area and are therefore included in this analysis. In general, the remaining species listed in Table 9 range outside the Offshore Development Area, usually in deeper water, and are considered rare. For example, beaked whales are likely to occur in regions further offshore along the continental shelf-edge but not within 74 km (40 NM) of shore (Hayes et al. 2020). However, based on sightings of some rare species during HRG site characterization surveys in the Offshore Development Area, The Proponent is also requesting approval of Level B incidental harassment of rare species, so descriptions of these species are also included below. .

4.1. Mysticetes

4.1.1. Blue Whale (*Balaenoptera musculus*)

Blue whales are the largest animal to have ever lived on earth, reaching a maximum length of 33.5 m (110 ft) (NOAA Fisheries 2022f). These whales have a blue-gray, slender body that appears light blue under water. Their mottling pattern is unique and can be used for individual identification. Antarctic blue whales are generally larger than other blue whale subspecies, such as those in the North Atlantic, but females of all blue whale subspecies are generally larger than males. Blue whales primarily feed on krill and occasionally feed on fish and copepods. Blue whales are most often found alone or in pairs but sometimes swim in small groups.

Blue whales are low frequency cetaceans, producing long, stereotypical series of sounds, typically in the 15–40 Hz range (Cummings and Thompson 1971, Mellinger and Clark 2003). Blue whales are among the loudest animals, emitting sounds that can be heard by other whales up to 1609 km (1,000 mi) away (NOAA Fisheries 2022f). Blue whales respond to military sonar, although the scale of the responses vary greatly and appear to be influenced by the whale's feeding mode (deep versus shallow), received sound levels, and the exposed animal's distance to the sound source (Goldbogen et al. 2013, Southall et al. 2019a). In the presence of vessels, blue whales are more likely to increase their vocalizing rates (McKenna 2011), a pattern also observed in the presence of sounds produced by a seismic sparker (Di Iorio and Clark 2009).

4.1.1.1. Distribution

Blue whales are widely distributed throughout the world's oceans, both in coastal and pelagic areas, and are most frequently sighted in the waters off eastern Canada (Sears et al. 1987). Blue whales have been detected and tracked acoustically in much of the North Atlantic, indicating the potential for long-distance movements, although the southern limit of the species' range is unknown (Clark 1995). Observations made by Reeves et al. (2004) show a broad longitudinal distribution during the winter months, with a narrower, more northerly distribution in summer. Yochem and Leatherwood (1985) suggest an occurrence of blue whales south to Florida. Blue whales calls were recently detected by passive acoustic devices in areas offshore the New York Bight, mostly during the winter (Muirhead et al. 2018). The blue whale is best considered as an occasional visitor in US Atlantic EEZ waters ([CeTAP] Cetacean and Turtle Assessment Program 1982, Wenzel et al. 1988, Kenney and Vigness-Raposa 2010). Sigurjónsson and Gunnlaugsson (1990) attribute the depletion of North Atlantic blue whales in formerly important habitats, such as the northern and northeastern North Atlantic, to commercial whaling. Blue whales often aggregate near the continental shelf edge where upwelling produces concentrations of krill (Yochem and Leatherwood 1985, Fiedler et al. 1998, Gill et al. 2011).

Kraus et al. (2016) conducted aerial and acoustic surveys between 2011–2015 in the Massachusetts and Rhode Island/Massachusetts Wind Energy Areas (MA and RI/MA WEAs) and surrounding areas. During this study period, blue whales were not visually observed and were only sparsely acoustically detected in the MA and RI/MA WEAs. Although blue whales were acoustically detected in the winter, the range to the WEAs was not estimated, and the vocalizing whale(s) may have been distant from the WEAs. These data suggest that blue whales are rarely, if at all, present in the MA and RI/MA WEAs (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of blue whales in MA and RI/MA WEAs (O'Brien et al. 2020a)(O'Brien et al. 2020b).

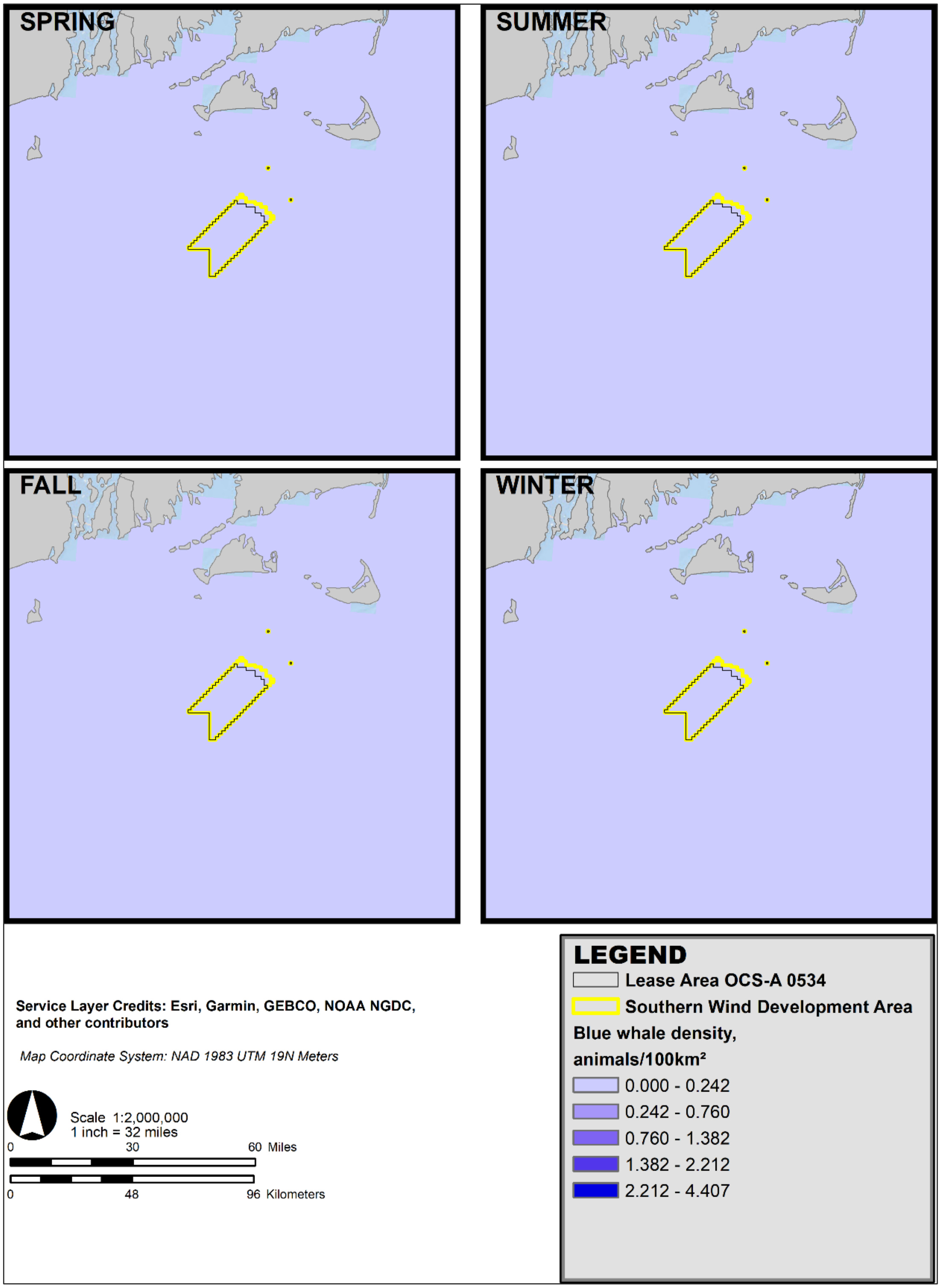

Figure 10. Blue whale maximum seasonal density from Roberts et al. (2016a).

4.1.1.2. Abundance

The best available minimum population estimate for the Western North Atlantic blue whale stock from NMFS stock assessments is 402 individuals (NOAA Fisheries 2021aa). This estimate comes from the catalogue count of recognizable individuals from the Gulf of St. Lawrence (Ramp and Sears 2013). There are insufficient data to determine population trends for this species (NOAA Fisheries 2021aa). Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.10 because the blue whale is listed as endangered under the Endangered Species Act (ESA). PBR for the Western North Atlantic stock of blue whale is 0.8.

4.1.1.3. Status

The entire blue whale species is listed as Endangered under the ESA and Massachusetts Endangered Species Act (MA ESA), and NMFS considers this a strategic stock under the MMPA (NOAA Fisheries 2022f). The status of this stock relative to its Optimum Sustainable Population (OSP) in the U.S Atlantic EEZ is unknown (NOAA Fisheries 2021aa). There are currently no critical habitat areas established for the blue whale under the ESA. Internationally, blue whales received complete legal protection from commercial whaling in 1966 under the International Convention for the Regulation of Whaling. Threats for North Atlantic blue whales are not well known, but may include ship strikes, pollution, entanglement, and long-term changes in climate. There are no recent confirmed records of anthropogenic mortality or serious injury to blue whales in the US Atlantic EEZ or in Atlantic Canadian waters (Henry et al. 2020). The total level of human caused mortality and serious injury is unknown, but it is believed to be insignificant and approaching a zero mortality and serious injury rate.

4.1.2. Fin Whale (*Balaenoptera physalus*)

Fin whales are the second largest species of baleen whale in the Northern Hemisphere with a maximum length of about 22.8 m (75 ft) (NOAA Fisheries 2021b). These whales have a sleek, streamlined body with a V-shaped head that makes them fast swimmers. Fin whales have a distinctive coloration pattern: the dorsal and lateral sides of their bodies are black or dark brownish-gray while 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 (Kenney and 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 et al. 1992, Kenney et al. 1997).

Fin whales are low-frequency cetaceans producing short duration, down sweep calls between 15 and 30 hertz (Hz), typically termed “20-Hz pulses”, as well as other signals up to 1 kHz (Southall et al. 2019b). The SL of fin whale vocalizations can reach 186 dB re 1 μPa, making it one of the most powerful biological sounds in the ocean (Charif et al. 2002).

4.1.2.1. 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 named the Western North Atlantic stock. The current understanding of stock boundaries, however, remains uncertain

Fin whales are common in waters of the US Atlantic EEZ, principally from Cape Hatteras northward. There is evidence that fin whales are present year-round throughout much of the US EEZ north of 35° N, but the density of individuals in any one area changes seasonally (NOAA Fisheries 2021b). Fin whales are the most commonly observed large whales in continental shelf waters from the mid-Atlantic coast of the US to Nova Scotia (Sergeant 1977, Sutcliffe and Brodie 1977, CeTAP 1982, Hain et al. 1992). The range of fin whales in the Western North Atlantic extends from the Gulf of Mexico and Caribbean Sea to the southeastern coast of Newfoundland. While fin whales typically feed in the Gulf of Maine and the waters surrounding New England, their mating and calving (and general wintering) areas are largely unknown (Hain et al. 1992, Hayes et al. 2019). Acoustic detections of fin whale singers augment and confirm these visual sighting conclusions for males. Recordings from Massachusetts Bay, New York Bight, and deep-ocean areas have detected some level of fin whale singing from September through June (Watkins et al. 1987, Clark and Gagnon 2002, Morano et al. 2012). These acoustic observations from both coastal and deep-ocean regions support the conclusion that male fin whales are broadly distributed throughout the Western North Atlantic for most of the year (NOAA Fisheries 2021aa). It is likely that fin whales occurring within 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 (Hayes et al. 2019). Based on an analysis of neonate stranding data, Hain et al. (1992) suggest that calving occurs during October to January in latitudes of the US mid-Atlantic region.

Kraus et al. (2016) suggest that, compared to other baleen whale species, fin whales have a high multi-seasonal relative abundance in the Massachusetts and Rhode Island/Massachusetts Wind Energy Areas (MA and RI/MA WEAs) and surrounding areas. Fin whales were observed in the Massachusetts Wind Energy Area (MA WEA) in spring and summer. This species was observed primarily in the offshore (southern) regions of the MA and RI/MA WEAs during spring and was found closer to shore (northern areas) during the summer months (Kraus et al. 2016). Calves were observed three times and feeding was observed nine times during the Kraus et al. (2016) study. Although fin whales were largely absent from visual surveys in the MA and RI/MA WEAs in the fall and winter months (Kraus et al. 2016), acoustic data indicated that this species was present in the MA and RI/MA WEAs during all months of the year. Low-frequency vocalizing fin whales were acoustically detected in the MA WEA on 87% of survey days (889/1020 days). Acoustic detection data indicated a lack of seasonal trends in fin whale abundance with slightly fewer detections from April to July (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 and MA WEAs; however, arrival patterns of many fin whale vocalizations indicated that received signals likely originated from within the Kraus et al. (2016) study area.

Recent continuations of the surveys in MA and RI/MA WEAs were conducted between October 2018 and August 2019 (O'Brien et al. 2020a).There were 32 sightings of 53 individual fin whales during the survey period, including both on- and off-effort data. Group sizes ranged from 1 to 4 whales. There were seasonal changes in distribution, with most fin whales sighted in May and June and no sightings in January-February, July-August, or October (O'Brien et al. 2020a). Consequently, relative abundance was highest in spring and summer, when whales clustered in the southern and eastern parts of the MA and RI/MA WEAs and was lowest in fall and winter. A continuation of these surveys occurred between March and

October 2020 (O’Brien et al. 2020b). There were 11 fin whale sightings of 17 individuals during this time, with an average group size of 1.55 whales (range 1 to 6). Contrary to the previous surveys, fin whales were only detected in summer months, with only one whale (of 17) not detected in June (O’Brien et al. 2020b).

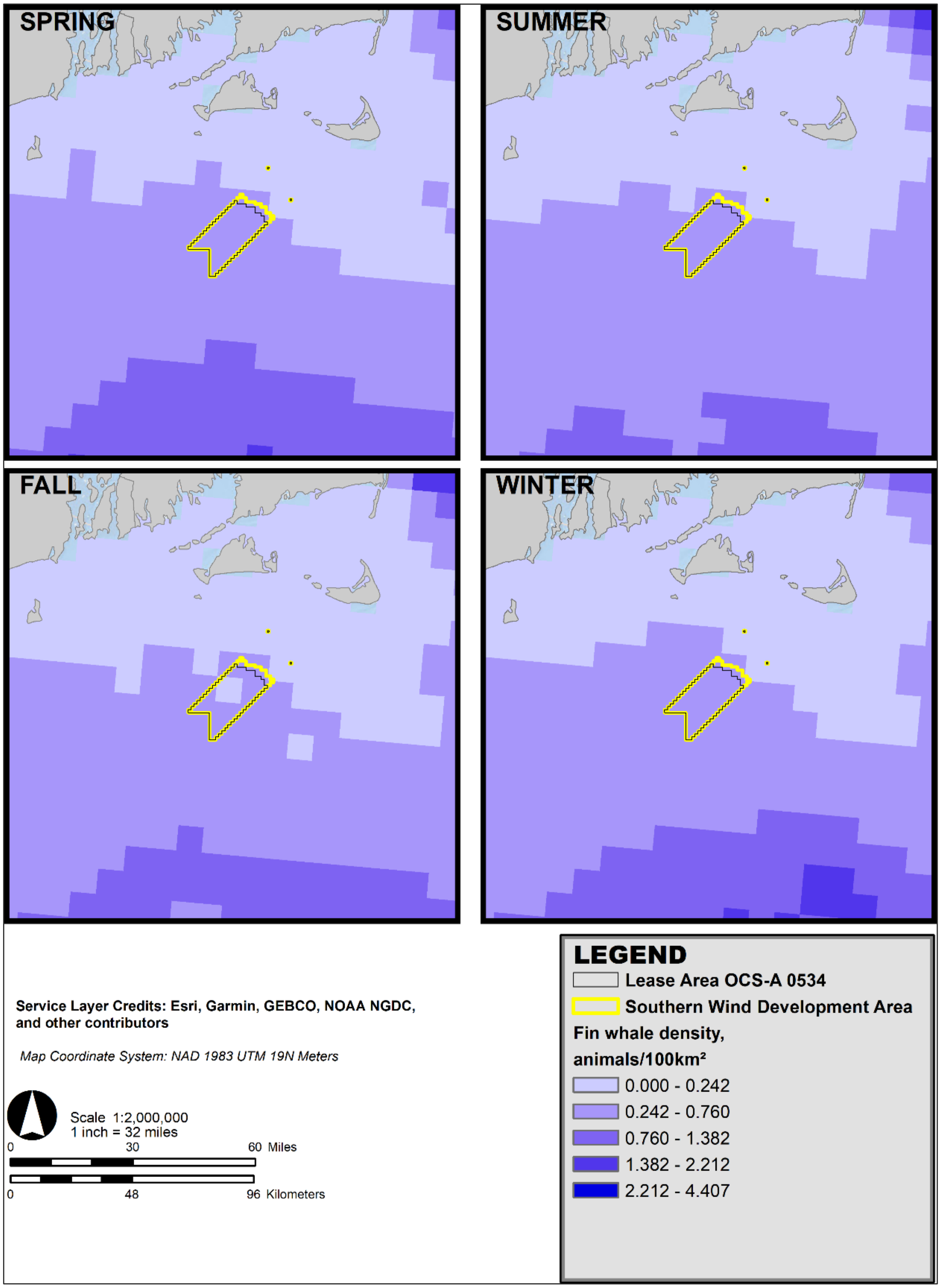

Figure 11. Fin whale maximum seasonal density from Roberts et al. (2016a, 2018).

4.1.2.2. Abundance

The best available abundance estimate for the Western North Atlantic fin whale stock in US waters from NMFS stock assessments is 6802 individuals (NOAA Fisheries 2021aa). Current and maximum net productivity rates and population trends are unknown for this stock due to relatively imprecise abundance estimates and variable survey design (NOAA Fisheries 2021aa).

4.1.2.3. Status

The status of this stock relative to its Optimum Sustainable Population (OSP) in the US Atlantic EEZ is unknown, but the North Atlantic population is listed as Endangered under the ESA and Massachusetts Endangered Species Act (MA ESA), and NMFS considers this a strategic stock under the MMPA. There are currently no critical habitat areas established for the fin whale under the ESA. The minimum population size for the Western North Atlantic fin whale stock (N_{min}) is 5573. The maximum productivity rate is 0.04, the default value for cetaceans. The recovery factor is 0.10 because the fin whale is listed as Endangered under the ESA. PBR for the Western North Atlantic fin whale stock is 11. Because uncertainties exist in stock definition and because the current N_{min} used to calculate PBR is not derived from the full range of the stock as currently defined and is derived from a negatively biased abundance estimate (i.e., not corrected for availability bias), considerable uncertainties exist in this calculated PBR (NOAA Fisheries 2021aa).

From 2014 to 2018, the minimum human-caused mortality rate was approximately two whales per year, caused by incidental fishery interactions and vessel collisions; however, this estimate is biased low due to haphazard detections of carcasses (NOAA Fisheries 2021aa). No critical habitat areas have been established for the fin whale under the ESA. Lease Area OCS-A 0534 is flanked by two Biologically Important Areas (BIAs) for feeding 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).

4.1.3. Humpback Whale (*Megaptera novaeangliae*)

Humpback whale females are slightly larger than males and can reach lengths of up to 18 m (60 ft) (NOAA Fisheries 2018a). 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 (Kenney and 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).

Humpback whales are low-frequency cetaceans but have one of the most varied vocal repertoires of the baleen whales. Male humpbacks will arrange vocalizations into a complex, repetitive sequence to produce a characteristic “song” (Payne and McVay 1971). Songs last upwards of 30 minutes. Songs are predominately produced while on breeding grounds; however, they have been recorded on feeding grounds throughout the year (Clark and Clapham 2004, Vu et al. 2012). Song units are variable but typically occupy frequency bands between 30 and 5,000 Hz (Payne and Payne 1985). Non-song humpback whale calls are also highly variable, with some feeding calls centered at 500 Hz (D'Vincent et al. 1985), and other calls and song units reaching up to 24 kHz. Some humpback calls have been detected across populations and consist of grunt series between 25 and 1900 Hz (Thompson et al. 1986, Dunlop et al. 2007, Stimpert et al. 2011) as well as low frequency harmonic upsweeps with peak frequencies between 80–110 Hz (Dunlop et al. 2007, Stimpert et al. 2011).

4.1.3.1. 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 and Mayo 1987). These populations are found in the Gulf of Maine, Gulf of St. Lawrence, Newfoundland/Labrador, Western Greenland, Iceland, and Norway (Hayes et al. 2020). Most 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 they have been observed feeding in other areas, such as off the coast of New York (Sieswerda et al. 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 winter, where they mate and calve their young (Katona and 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 et al. 1993). There have been several wintertime humpback sightings in coastal waters of the southeastern US, including 46 sightings of humpbacks in the New York-New Jersey Harbor Estuary documented between 2011 and 2016 (Brown et al. 2017).

Kraus et al. (2016) observed humpback whales in the MA and RI/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 ten times and feeding was observed ten times during the Kraus et al. (2016) study. That study also observed one instance of courtship behavior. Although humpback whales were 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 (Kraus et al. 2016). Humpback whales were acoustically detected in the MA WEA on 56% of survey days (566/1010 days). Acoustic detections do not differentiate between individuals, so detections on multiple days could be the same or different individuals. Humpback whales are low-frequency cetaceans with vocalizations that travel long distances in water. The mean detection range for humpback whales using PAM system was 30 to 36 km (16.2 to 19.4 NM). Kraus et al. (2016) estimated that 63% of acoustic detections of humpback whales represented whales within their study area.

Recent surveys (October 2018-August 2019) in the MA and RI/MA WEAs have revealed a similar trend (O'Brien et al. 2020a). Including both on- and off-effort sightings, there were a total of 30 humpback whale sightings of 32 individuals. Humpback whales were sighted in every season, with the highest number of humpback whale sightings and the greatest relative abundance in spring and summer. The majority of sightings were on the eastern side of the RI/MA and MA WEAs, regardless of time of year (O'Brien et al. 2020a). Humpback whales were the most frequently sighted cetacean, although not the most abundant, during the most recent surveys in the MA and RI/MA WEAs from March to October 2020, accounting for 22% of all sightings (O'Brien et al. 2020b). Over the survey period, 44 individual whales were recorded during 22 sightings. Again, humpback whales were sighted in every season, with peaks in the summer. Group sizes ranged from 1–17 (average 1.9). The aggregation of 17 individuals was during a cooperative feeding event recorded in June (O'Brien et al. 2020b). Sightings during the 2020 survey were also concentrated more on the eastern side of the MA and RI/MA WEAs, and just outside the WEAs in the Nantucket Shoals area.

4.1.3.2. Abundance

The Gulf of Maine humpback whale stock consists of approximately 1396 whales and is characterized by a positive trend in abundance with a maximum annual production rate estimate of 6.5% (Barlow and Clapham 1997, NOAA Fisheries 2021aa). The most significant anthropogenic causes of mortality to humpback whales remain incidental fishery entanglements, responsible for roughly eight whale mortalities, while vessel collisions are responsible for four mortalities, both on average annually from 2013–2017 (NOAA Fisheries 2021aa).

4.1.3.3. 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 Gulf of Maine stock is not considered depleted because it does not coincide with any ESA-listed DPS. Humpback whales in the Western North Atlantic have been experiencing an Unusual Mortality Event (UME) since January 2016 that appears to be related to a larger than usual number of vessel collisions (NOAA Fisheries 2018b). In total, 88 strandings were documented between 2016–2018 (Hayes et al. 2020). This most recent UME is ongoing. A BIA for humpback whales for feeding has been designated northeast of the SWDA from March through December (LaBrecque et al. 2015).

4.1.4. Minke Whale (*Balaenoptera acutorostrata*)

Minke whales are a baleen whale species reaching 10 m (33 ft) in length (NOAA Fisheries 2021m). This species has a cosmopolitan distribution in temperate, tropical, and high latitude waters (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 2021m). Its diet is comprised primarily of crustaceans, schooling fish, and copepods. Minke whales generally travel in small groups (1 to 3 individuals), but larger groups have been observed on feeding grounds (NOAA Fisheries 2021m).

Minke whale recordings have resulted in some of the most variable and unique vocalizations of any marine mammal. Common calls for minke whales found in the North Atlantic include repetitive, low-frequency (100 to 500 Hz) pulse trains that may consist of either grunt-like pulses or thump-like pulses. The thumps are very short duration (50 to 70 milliseconds [ms]) with peak energy between 100 and 200 Hz. The grunts are slightly longer in duration (165 to 320 ms) with most energy between 80 and 140 Hz. In addition, minke whales will repeat a 6 to 14 minute-pattern of 40 to 60 second pulse trains over several hours (Risch et al. 2013). Minke whales also produce a unique sound called the “boing”, which consists of a short pulse at 1.3 kHz followed by an undulating tonal call around 1.4 kHz. This call was widely recorded but unidentified for many years and had scientists widely speculating as to its source (Rankin and Barlow 2005).

4.1.4.1. 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 uncertain if separate sub-stocks exist 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 (Hayes et al. 2021). 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 in the winter in lower latitude wintering grounds (NOAA Fisheries 2021m).

Kraus et al. (2016) observed minke whales in the MA and RI/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 SWDA in the spring. Minke whales were not observed between October and February, but acoustic data indicate the presence of this species in the Offshore Development Area in winter months. Calves were observed twice, and feeding was also observed twice during the Kraus et al. (2016) study. Minke whales were acoustically detected in the MA WEA on 28% of survey days (291/1020 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 (Kraus et al. 2016). Although minke whales are low-frequency cetaceans, the acoustic detection range for this species during the study was small enough that over 99% of detections were limited to within the Kraus et al. (2016) study area.

The surveys in the MA and RI/MA WEAs continued between October 2018 and August 2019 (O’Brien et al. 2020a). During this time, 115 individual minke whales were observed from 98 sightings, including both on and off-effort surveys. The average group size was 1.2 individuals (range 1 to 5). Most sightings occurred in June and April, resulting in the highest sighting rates during the summer and spring. Only two sightings occurred during winter, and no minke whales were observed during fall. Minkes were distributed throughout the MA and RI/MA WEAs (O’Brien et al. 2020a). Surveys conducted between March and October 2020 revealed a similar trend, with minke whales observed in all months of the survey except March and October, and distributed throughout the lease area (O’Brien et al. 2020b).

4.1.4.2. Abundance

The best available abundance estimate for the Canadian East Coast minke whale stock is 21,968 individuals as of 2016 (NOAA Fisheries 2021aa). Current population trend and net productivity rates of minke whales in this region are unknown. The average annual human-caused mortality from 2014–2018 is approximately 11 whales per year, with nine deaths attributed to entanglement in fishing gear and approximately 2 attributed to vessel collision (Hayes et al. 2021). These records are not statistically quantifiable and may be negatively bias by focusing on strandings and entanglements. These uncertainties will have little effect on the designation of the status of the entire stock as the estimated human caused mortality is well below the PBR calculated from the abundance estimate.

4.1.4.3. 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 2021m). In total, 57 strandings were documented through 2018 as part of this event (Hayes et al. 2021). The most recent UME is ongoing. A BIA for minke whales for feeding has been designated east of the SWDA from March through November (LaBrecque et al. 2015).

4.1.5. 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 2021n). Members of this species 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 (Hayes et al. 2021). They 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 2021n).

NARWs are low-frequency cetaceans that vocalize using several distinctive call types, most of which have peak acoustic energy below 500 Hz (Parks et al. 2019). However, they are capable of producing calls at higher frequencies. The most stereotypical right whale vocalization is the "upcall", a harmonic upsweep with peak energy below 200 Hz (Parks et al. 2019), but can include harmonics beyond 2.5 kHz (McCordic et al. 2016). The stereotypical nature of upcalls provides an opportunity for remote passive acoustic monitoring (PAM) of species presence (Van Parijs et al. 2009). A characteristic "gunshot" call is believed to be produced primarily by male NARWs. These high-intensity broadband pulses can have SLs of 174 to 192 dB re 1 μPa m with a frequency range from 20 to 22,000 Hz (Parks et al. 2005, Parks and Tyack 2005). Other tonal calls range from 20 to 20,000 Hz and have SLs between 137 and 162 dB re 1 μPa (Parks and Tyack 2005).

4.1.5.1. Distribution

NARWs are comprised of two separate stocks: Eastern North Atlantic 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. 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 et al. 2013). 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 (Hayes et al. 2021).They 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 (Kenney and 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 (Jefferson et al. 2008).

Surveys indicate that there are 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 (Hayes et al. 2021). NMFS has designated two critical habitat areas for the NARW under the

ESA: the Gulf of Maine/Georges Bank region (81 FR 4837, 26 Feb 2016), 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). Davis et al. (2017) recently pooled together detections from a large number of passive acoustic devices and documented broad-scale use of much more of the Atlantic Seaboard than previously believed. Further, there has been an apparent shift in habitat use patterns (Davis et al. 2017), which includes an increased use of Cape Cod Bay (Mayo et al. 2018) and decreased use of the Great South Channel. Movements within and between habitats are extensive (Hayes et al. 2021), and there is a high interannual variability in NARW use of some habitats (Pendleton et al. 2009).

New England waters are important feeding habitats for NARW that must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx 1990). These dense zooplankton patches are likely a primary characteristic of the spring, summer, and fall NARW habitats (Kenney et al. 1986, Kenney et al. 1995). While feeding in the coastal waters off Massachusetts has been better studied than in other areas, NARW feeding has also been observed on the margins of Georges Bank, in the Great South Channel, in the Gulf of Maine, in the Bay of Fundy, and over the Scotian Shelf (Baumgartner et al. 2007). NMFS and Center for Coastal Studies aerial surveys during spring 1999 to 2006 found NARWs along the northern edge of Georges Bank, in the Great South Channel, in Georges Basin, and in various locations in the Gulf of Maine, including Cashes Ledge, Platts Bank, and Wilkinson Basin. Analysis of the sightings data has shown that utilization of these areas has a strong seasonal component (Pace and Merrick 2008, Pace et al. 2014).

In recent years (2012–2015), surveys have detected fewer individuals in the Great South Channel and the Bay of Fundy, indicating an important shift in habitat use patterns. In addition, late winter use of a region south of Martha's Vineyard and Nantucket Islands was recently described (Leiter et al. 2017). A large increase in aerial surveys of the Gulf of St. Lawrence documented at least 36 and 117 unique individuals using the region during the summer in 2015 and 2017, respectively (NMFS unpublished data). A poleward shift in the distribution of NARW's primary source of nutrition, the copepod species *Calanus finmarchicus*, has been attributed as the impetus for the change in distribution of the NARW (Meyer-Gutbrod et al. 2018). Starting in 2012, NARW sightings in several traditional feeding habitats began to decline, causing speculation that a shift in NARW habitat usage was occurring (Pettis et al. 2017).

Kraus et al. (2016) observed NARWs in the MA and RI/MA WEAs in winter and spring. Over 436 hours of aerial surveys were conducted from October 2011 through June 2015, with 93% of the NARW sightings (56 out of 60) occurring in January through April. The greatest sightings per unit effort (SPUE) in the MA and RI/MA WEAs by Kraus et al. (2016) took place in March, with a concentration of spring sightings in the SWDA and winter sightings in the area northeast of the SWDA. Seventy-seven unique individual NARWs were observed in the MA and RI/MA WEAs over the duration of the NLPSC surveys (October 2011 to June 2015) (Kraus et al. 2016). No calves were seen; however, 11 instances of courtship behavior were observed.

Kraus et al. (2016) acoustically detected NARWs with PAM within the MA WEA on 44% of survey days (443/1010 days) and during all months of the year. During 1010 days of acoustic recording, NARW upcalls were detected on 47% of recorded days (478 of 1010 days, 30 of 36 recorded months), with December through April having the highest mean monthly levels of acoustic occurrence (Kraus et al. 2016). 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 winter and spring (January to March), and minimum occurrence in summer (July to September). The mean detection range for NARWs using PAM was 15 to 24 km (8.1 to 13.0 NM), with a mean radius of 21 km (11.3 NM) (95% confidence interval of 3 km [1.6 NM]) for the PAM system).

A continuation of surveys in the MA and RI/MA WEAs between October 2018 through August 2019 revealed 164 individual right whales from 112 sightings during directed surveys. On-effort surveys resulted in a further 24 sightings of 67 right whales, and opportunistic surveys recorded three sightings of three animals (O'Brien et al. 2020a). In contrast with aerial surveys from Kraus et al. (2016), NARWs were observed in the MA and RI/MA WEAs in every season, and in 9 of 11 months, with the highest number of sightings in January. No right whales were observed in June or October. Most (67%) sightings were of single animals; however, larger feeding aggregations did occur (O'Brien et al. 2020a). NARWs were recorded predominately on the eastern side of the survey area. All sightings were within 20 NM of the MA and RI/MA WEAs; however, most were outside of the SWDA. This distribution changed seasonally, with a large aggregation of whales moving north from the southern portion of Nantucket Shoals in winter to an area 10 NM south of Nantucket in April. The aggregation moved south again back to Nantucket Shoals in late July, and persisted in the area until the end of the survey period in August (O'Brien et al. 2020a). The most recent surveys in the MA and RI/MA WEAs occurred between March and October 2020 (O'Brien et al. 2020b). A total of 15 NARWs were observed from ten sightings. Group sizes ranged from 1 to >10, with an average of 1.5 whales. NARWs were observed in summer and fall, with no observations in the reduced spring season. No surveys were conducted in winter. Sighting rates were higher in fall than summer, and the feeding aggregations observed in previous years during summer were absent (O'Brien et al. 2020b). Similar to previous surveys, all sightings were within 15 nm of the RI/MA and MA WEAs; however, no NARWs were observed in the lease areas.

4.1.5.2. Abundance

The estimated abundance for the Western North Atlantic right whale stock is 368 (NOAA Fisheries 2021aa). This is based on a state-space model of the sighting histories of individual whales (Pace et al. 2017). This estimate does not consider that NARWs have been experiencing a UME since June 2017, with 30 documented deaths as of 2019 (NOAA Fisheries 2021aa). The UME appears to be driven by entanglement in fishing gear and blunt force trauma associated with ship strikes mainly in the Gulf of St. Lawrence. Additionally, eight free-swimming whales were documented as entangled with serious injuries increasing the number of whales included in the UME to 38 (NOAA Fisheries 2021aa). Cause of death findings for the UME are based on seven necropsies of dead NARWs found in Canada in the Gulf of St. Lawrence (Daoust et al. 2017, NOAA Fisheries 2021r) and along the Atlantic coast in US water (NOAA Fisheries 2021aa). From 2015 to 2019, annual detected human caused mortality from entanglement records and vessel strike records averaged 7.7 (NOAA Fisheries 2021aa). Total estimated mortality is likely biased low due to irregular and incomplete detections and data suggesting that only 36% of right whale deaths result in a carcass detection (Pace et al. 2021). Using refined methods of the abundance state space model to estimate mortality yields an estimated annual rate of total mortality of 27.4 animals between 2014–2018 (Pace et al. 2021), all of which are assumed to be human-caused (NOAA Fisheries 2021aa).

The Western North Atlantic right whale stock has been in decline since 2011 with an overall abundance decline between 2011 and 2019 of 23.5% (NOAA Fisheries 2021aa). Population growth rates were low between 1990–2011 (2.8%), and the average number of calves born per year from 1990–2019 was 15 and ranged from 0 to 39 with high inter-annual variability. Productivity for NARW lacks any definitive trend which may be attributed to decreased prey species yielding variability in nutrition, larger energy expenditures due to entanglements, and other environmental and anthropogenic stressors causing habitat shift (Davis et al. 2017, NOAA Fisheries 2021aa). It appears as though the decline in NARW birth rates is continuing in more recent years, likely a result of lower female survival rate (Pace et al. 2017, Meyer-Gutbrod et al. 2020). In the four calving seasons since 2017, only five births were observed in 2017, zero in 2018, seven in 2019, and ten in 2020, which is less than one-third the average annual birth rate for the NARW (NOAA Fisheries 2021n). Eighteen mother/calf pairs were reported in 2021, a significant upward trend from 2020. Although encouraging, the interbirth interval remains high and the species continues to be in decline and is still listed by the IUCN as critically endangered (Pettis et al. 2022). The NARW consortium has released the preliminary 2021 report card results predicting a NARW population of 336 in 2020 (Pettis et al. 2022). This represents an 8% decline over the 2019 estimate. The consortium adjusts their estimates (Pace et al. 2017) to subtract additional mortality. This method is used in order to estimate all mortality, not just the observed mortality; therefore, the (NOAA Fisheries 2021aa) SAR is used in this LOA to report an unaltered output of the Pace et al. (2017) model (DoC and NOAA 2005).

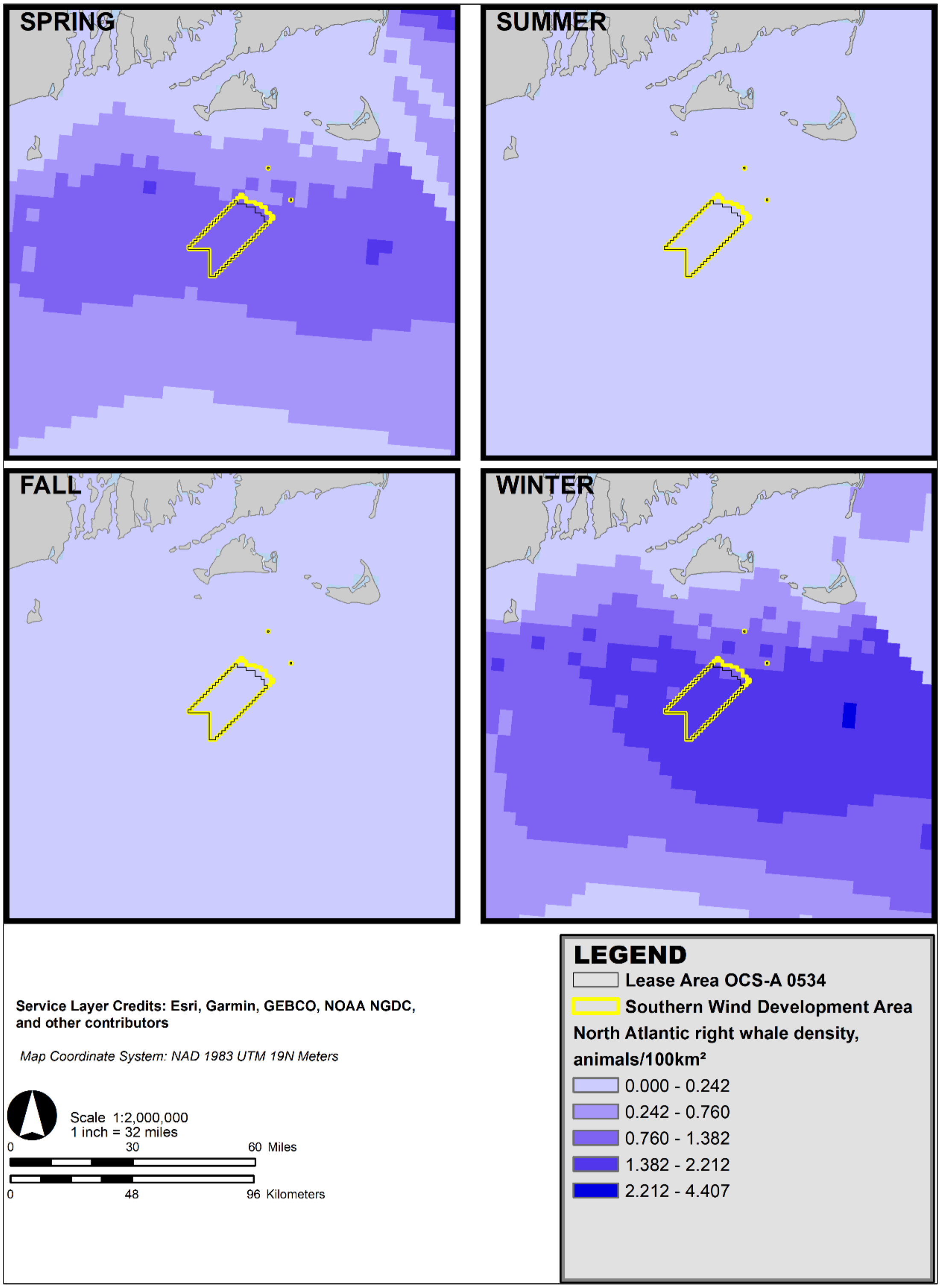

Figure 12. North Atlantic right whale maximum seasonal density from Roberts et al. (2016a, 2021b).

4.1.5.3. Status

The size of the Western Atlantic stock is considered extremely low relative to its OSP in the US Atlantic EEZ (Hayes et al. 2021). 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. The minimum population size is estimated at 364 (NOAA Fisheries 2021aa). The maximum productivity rate is 0.04, the default value for cetaceans, with a recovery factor of 0.1, because this species is listed as Endangered. PBR for the Western Atlantic stock of North Atlantic right whale is 0.7 (NOAA Fisheries 2021aa). Historically, the population suffered severely from commercial overharvesting and has more recently been threatened by incidental fishery entanglement and vessel collisions (Knowlton and Kraus 2001, 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 m/s) or less within these areas during specific time periods. The Block Island Sound Seasonal Management Area (SMA) overlaps with the southern portion of the SWDA and is active between November 1 and April 30 each year. The Great South Channel SMA lies to the northeast of Lease Area OCS-A 0501 and is active April 1 to July 31. NMFS may also establish Dynamic Management Areas (DMAs) when and where NARWs are sighted outside SMAs. DMAs are generally in effect for 2 weeks. During this time, vessels are encouraged to avoid these areas or reduce speeds to 10 knots (5.1 m/s) or less while transiting through these areas.

The SWDA is encompassed by a NARW BIA for migration from March to April and from November to December (LaBrecque et al. 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 MA and RI/MA WEAs and beyond to the continental slope, extending northward to offshore of Provincetown, Massachusetts and southward to halfway down the Florida coast (LaBrecque et al. 2015).

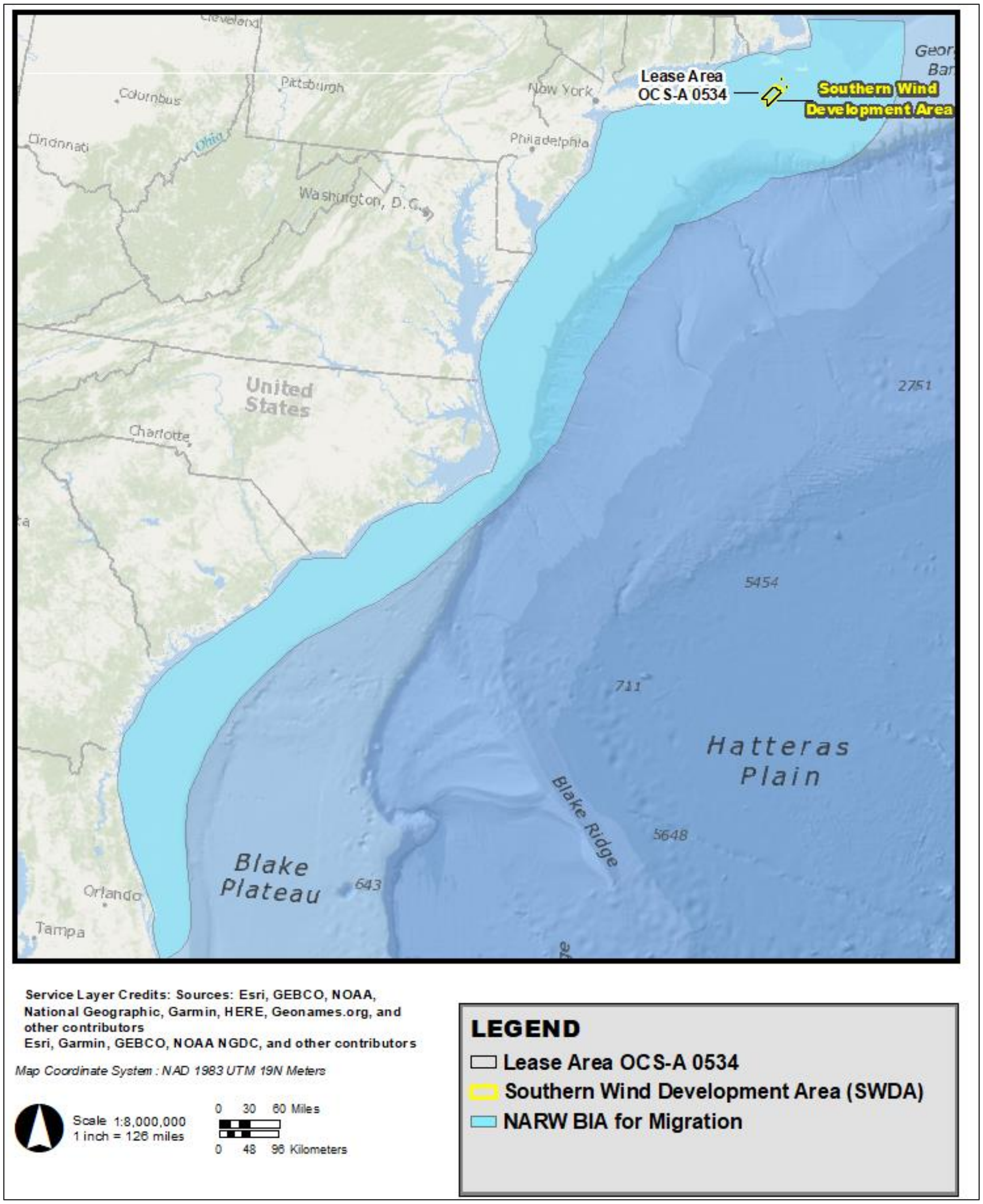

Figure 13. Map showing the location of the NARW BIA and SWDA.

4.1.6. Sei Whale (*Balaenoptera borealis*)

Sei whales are a relatively widespread baleen whale that can reach lengths of about 12 to 18 m (39 to 59 ft) (NOAA Fisheries 2021s). This species has a long sleek body that is dark bluish-gray to black in color and pale underneath (NOAA Fisheries 2021s). Their diet is comprised primarily of plankton, schooling fish, and cephalopods. Sei whales generally travel in small groups (2 to 5 individuals), but larger groups are observed on feeding grounds (NOAA Fisheries 2021s).

Like all baleen whales, sei whales are categorized as low-frequency cetaceans. There are limited confirmed sei whale vocalizations; however, studies indicate that this species produces several, mainly low-frequency (<1000 Hz) vocalizations. Several calls attributed to sei whales include pulse trains up to 3 kHz, broadband "growl" and "whoosh" sounds between 100 and 600 Hz, tonal calls and upsweeps between 200 and 600 Hz, and down sweeps between 34 and 100 Hz (McDonald et al. 2005, Rankin and Barlow 2007, Baumgartner et al. 2008).

4.1.6.1. Distribution

The stock of sei whales 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 (Hayes et al. 2021). Sighting data suggest sei whale distribution is largely centered in the waters of New England and eastern Canada (Roberts et al. 2016a, 2018, Hayes et al. 2021). 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 early fall. During winter, the species is predicted to be largely absent (Roberts et al. 2016a, 2018). This general offshore pattern of sei whale distribution is disrupted during episodic incursions into more shallow and inshore waters (Hayes et al. 2021). In years of reduced predation on copepods by other predators and thus greater abundance of this prey source, sei whales are reported in more inshore locations, such as the Great South Channel (in 1987 and 1989) and Stellwagen Bank (in 1986) areas (Payne and Heinemann 1990, Hayes et al. 2021). An influx of sei whales into the southern Gulf of Maine occurred in summer 1986 (Schilling et al. 1992). Such episodes, often punctuated by years or even decades of absence from an area, have been reported for sei whales from various places worldwide.

Kraus et al. (2016) observed sei whales in the MA and RI/MA WEAs and surrounding areas only between 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. Calves were observed three times and feeding was observed four times during the Kraus et al. (2016) study.

Surveys between October 2018 and August 2019 revealed 28 sightings of 55 individual sei whales (O'Brien et al. 2020a). Sightings only occurred in 2 of the 11 months surveyed, May and June. The average group size was 2 whales, with a range of 1 to 10 individuals. Sei whales were only observed in the southern portion of the survey area, and most were outside the MA and RI/MA WEAs (O'Brien et al. 2020a). No sei whales were observed during the 2020 surveys (O'Brien et al. 2020b). Based on sighting rates in Kraus et al. (2016) and O'Brien et al. (2020a, 2020b), sei whales are expected to be present but much less common than fin whales, minke whales, humpback whales, and NARWs.

4.1.6.2. Abundance

The best available abundance estimate for the Nova Scotia stock of sei whales from NMFS stock assessments is 6292 individuals (NOAA Fisheries 2021aa). Current and maximum net productivity rates and population trends are unknown for this stock due to relatively imprecise abundance estimates and long survey intervals (NOAA Fisheries 2021aa).

4.1.6.3. Status

Sei whales are listed as Endangered under the ESA and MA ESA and the Nova Scotia stock is considered strategic by NMFS. The minimum population size is estimated at 3098. The maximum productivity rate is

0.04, the default value for cetaceans, with a recovery factor of 0.1, because this species is listed as Endangered. PBR for the Nova Scotia stock of sei whales is 6 (NOAA Fisheries 2021aa). For the period 2013 through 2017, the minimum annual rate of human-caused mortality and serious injury to sei whales was 1.0; however, due to haphazard detections this is a minimum estimate which is almost certainly biased low (NOAA Fisheries 2021aa). No critical habitat areas are designated for the sei whale under the ESA. A BIA for feeding for sei whales occurs east of the SWDA from May through November (LaBrecque et al. 2015).

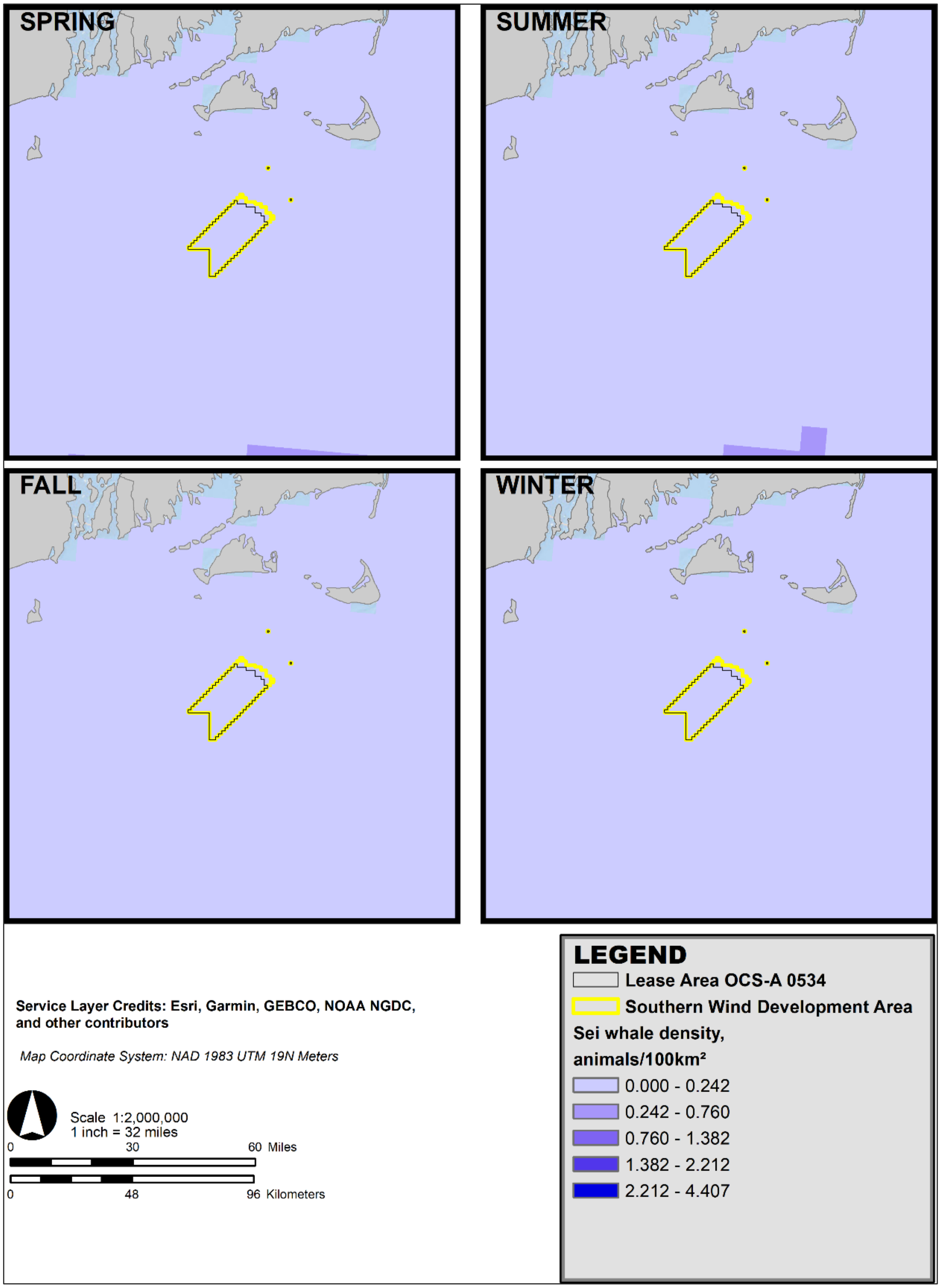

Figure 14. Sei whale maximum seasonal density from Roberts et al. (2016a, 2018).

4.2. Odontocetes

4.2.1. Atlantic Spotted Dolphin (*Stenella frontalis*)

Atlantic spotted dolphins are found in warmer temperate and tropical waters of the Atlantic Ocean (NOAA Fisheries 2021t). They are a smaller moderately slender dolphin and attain a body length of 1.5–2.3 m (5–7.5 ft) (Perrin 2002). They have a tall, curved dorsal fin located midway down their back (NOAA Fisheries 2021t). The Atlantic spotted dolphins' color patterns vary with age and location, with most individuals seen north of Cape Hatteras exhibiting few small dark ventral spots (Perrin et al. 1987, Perrin 2002). They form groups of varying sizes, usually less than 50 individuals, but can be seen traveling in groups of more than 200. In shallower waters, group size is typically 5–15 individuals (NOAA Fisheries 2021t). These dolphins eat small fish, invertebrates, and cephalopods such as squid or octopi (Herzing 1997).

Atlantic spotted dolphins are in the mid-frequency functional hearing group with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Their vocalizations, including signature whistles, range from 5 to 20 kHz (Perrin 2002). Because calls produced by many delphinid species are highly variable and overlap in frequency characteristics, it is challenging to identify to individual species (Oswald et al. 2007) during acoustic studies.

4.2.1.1. Distribution

Atlantic spotted dolphins observed off the eastern US coast are part of the Western North Atlantic stock and range from southern New England south through the Gulf of Mexico and the Caribbean (Hayes et al. 2020). Atlantic spotted dolphins regularly occur along the continental shelf, typically between 33 and 650 ft (10 to 200 m) and deeper slope waters greater than 1640 ft (500 m) deep. Two forms of the Atlantic spotted dolphin exist: one is large, heavily spotted, and usually inhabits the continental shelf, while the other is smaller in size, with fewer spots, and occurs farther offshore (Viricel and Rosel 2014). The offshore form of the Atlantic spotted dolphin and the pantropical spotted dolphin (*Stenella attenuata)* co-occur in some areas, and can be difficult to differentiate (Hayes et al. 2020). It has been suggested that Atlantic spotted dolphins may move inshore seasonally during the spring, but data to support this theory are limited (Caldwell and Caldwell 1966, Fritts et al. 1983). These dolphins can be expected to occur in SWDA waters with the highest likelihoods in the fall, spring, and summer.

Kraus et al. (2016) suggest that Atlantic spotted dolphins occur infrequently in the MA and RI/MA WEAs and surrounding areas. Effort-weighted average sighting rates for Atlantic spotted dolphins could not be calculated, because most small cetaceans sighted during the study could not be identified to species due to their size (Kraus 2016). However, during a 2020 geotechnical and geophysical survey in or adjacent to the Offshore Development Area, Atlantic spotted dolphins were observed in summer months (Vineyard Wind 2020d). It is possible that the NLPSC surveys underestimated the abundance of Atlantic spotted dolphins because these surveys were designed to target large cetaceans. No sightings of Atlantic spotted dolphins occurred during the 2018–2019 and 2020 surveys; however, there were some observations of small delphinids that could not be identified to species (O'Brien et al. 2020a, O'Brien et al. 2020b).

4.2.1.2. Abundance

The best available abundance estimate for the Western North Atlantic stock of Atlantic spotted dolphins is 39,921 individuals, estimated from data collected during summer surveys in 2016 covering waters from central Florida to the lower Bay of Fundy (NOAA Fisheries 2021aa). Distinction between the two Atlantic spotted dolphin ecotypes has not regularly been made during surveys.

4.2.1.3. Status

The total annual estimated human-caused mortality and serious injury to spotted dolphins between 2013 and 2017 was zero; there were no reported deaths from US fisheries observer data (Hayes et al. 2020). The Atlantic spotted dolphin is not listed as Threatened or Endangered under the ESA and the Western North Atlantic stock of Atlantic spotted dolphins is not classified as strategic.

4.2.2. 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) (Jefferson et al. 2008). It is characterized by a strongly “keeled” tail stock and distinctive, white-sided color pattern (BOEM, 2014b). Atlantic white-sided dolphins form groups of varying sizes, ranging from a few individuals to over 500 (NOAA Fisheries 2021p). They feed mostly on small schooling fishes, shrimps, and squids, and they are often observed feeding in mixed-species groups with pilot whales and other dolphin species (Cipriano 2002, Jefferson et al. 2008).

Atlantic white-sided dolphins are in the mid-frequency functional hearing group with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Their vocalizations range from 6 to 15 kHz (DoN 2008). Because calls produced by many delphinid species are highly variable and overlap in frequency characteristics, it is challenging to identify to individual species (Oswald et al. 2007) during acoustic studies.

4.2.2.1. 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 et al. 2008). Sighting data indicate seasonal shifts in distribution (Northridge et al. 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 (Payne and Heinemann 1990).

Kraus et al. (2016) suggest that Atlantic white-sided dolphins occur infrequently in the MA and RI/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 to June 2015). No Atlantic white-sided dolphins were observed during the winter months, and this species was only sighted twice in fall and three times in spring and summer. However, from 2018 to 2020, geotechnical and geophysical surveys in or adjacent to the SWDA observed Atlantic white-sided dolphins 17 times in spring and summer months. Group sizes ranged from

5 to 108 individuals (Vineyard Wind 2018, 2020c, 2020d). It is possible that the NLPSC surveys underestimated the abundance of Atlantic white-sided dolphins because these surveys were designed to target large cetaceans and the majority of small cetaceans were not identified to species.

Surveys in the MA and RI/MA WEAs between October 2018 and August 2019 revealed no sightings of Atlantic white-sided dolphins (O'Brien et al. 2020a). Atlantic white-sided dolphins were only observed between the months of April and July, and only on the Western side of the survey area; however, the small number of sightings precludes broad assessments of distribution patterns (O'Brien et al. 2020a). Between March and October 2020, surveys in the area observed one group of 15 Atlantic white-sided dolphins (O'Brien et al. 2020b). However, as not all small delphinids could be identified to species, this may be an underestimate of abundance.

4.2.2.2. Abundance

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 93,233 individuals, estimated from data collected during the June to September 2016 surveys that covered nearly the entire Western North Atlantic stock (NOAA Fisheries 2021aa).

4.2.2.3. 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.

4.2.3. Beluga Whale (*Delphinapterus leucas*)

Beluga whales are dark grey as calves but lighten as they age, becoming white as they reach physical maturity (Noaa Fisheries 2022c). They can reach up to 4.8 m (16 ft) in length. Beluga whales are known as the "canary of the sea" because of their wide range of vocal sounds. They lack a pronounced beak, and the top of their head is characterized by a round melon. They also lack a dorsal fin, and instead have a dorsal ridge, which allows them to swim easily under ice floes. Belugas' vertebrae are not fused, so they can nod and move their heads from side to side. They feed on a variety of fish, octopus, squid, crabs, shrimp, clams, snails, and sandworms. Groups may range from one or two to several hundred whales.

Beluga whales are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Belugas produce diverse and frequent vocalizations which are used for echolocation including squeals, chirps and clicks. Belugas emit whistles with an average frequency range from 2.0 to 5.9 kHz (Sjare and Smith 1986). Additionally, a captive beluga whale produced echolocation sounds between 40 and 60 kHz in one location and between 100 and 120 kHz after it was transported, demonstrating the adaptive capability of its bisonar system (Au et al. 1985).

4.2.3.1. Distribution

Beluga whales are generally associated with Subarctic and Arctic waters and are found only in high latitude of the northern hemisphere. They often occur in inshore and shallow waters, but are capable of travelling over deep water (Richard et al. 2001). Little is known about the distribution of beluga whales in the winter, but they are believed to occur in offshore waters during this time. Beluga whales may be found in the area of the Labrador Current and are found along the Newfoundland coast and the coast of Greenland but are not usually seen further south. In 2014, a beluga whale was observed in the bays and inlets of Rhode Island and Massachusetts, although occurrences of this species in the Northeast US is rare (Swaintek 2014).

Beluga whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of beluga whales in MA and RI/MA WEAs (O’Brien et al. 2020a, O’Brien et al. 2020b). These data suggest that beluga whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.3.2. Abundance

The only stocks of beluga whales managed under NMFS jurisdiction occur near Alaska. Two recognized stocks of beluga whale that are near the northeastern US Atlantic coast include the Eastern High Arctic/Baffin Bay and the West Greenland (Jefferson et al. 2015). NMFS does not provide abundance estimates of beluga whales in US waters because there is no stock defined for the US Atlantic. Belugas occurring off the US Atlantic coast are likely vagrants from one of the Canadian populations (COSEWIC 2020).

4.2.3.3. Status

Beluga whales in the western North Atlantic are not listed as Threatened or Endangered under the ESA or the MA ESA or designated as a strategic stock under the MMPA because there is no stock defined for the US Atlantic. Threats to this species likely include contaminant effects on health and reproduction, underwater noise, prey limitations, and climate-related changes.

4.2.4. Blainville’s Beaked Whale (*Mesoplodon densirostris*)

Blainville’s beaked whales, sometimes known as the dense-beaked whale, reach lengths of up to 4.5 to 6 m (15 to 20 ft) (NOAA fisheries 2021i). They vary from dark-gray to brownish and blueish, with a pale gray face and underside. Blainville’s beaked whales are often covered with scars and markings, especially as they age, and wrinkles on the dorsal area. They have medium-sized, round bodies with a small, slightly hooked dorsal fin and a low, indistinct melon. Mature males have distinct visible, tusk-like teeth that point forward from their arched lower jaw, whereas females’ and juveniles’ teeth are more hidden. Like other beaked whales, Blainville’s beaked whales are deep divers and feed on small fish and cephalopods. They are usually found alone or in small groups of three to seven individuals but are occasionally found in groups of up to 12.

Blainville’s beaked whale are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Blainville’s beaked whale produce two distinct click types during different phases of their foraging dive that are believed to enhance prey detection and classification (Johnson et al. 2006). The first are search clicks, which are emitted during the approach phase, at intervals of 0.2–0.4 s and a frequency of 26–51 kHz. When the target is 2 to 5 m (6.5 to 16.4 ft) away, they switch to buzz clicks which consists of highly repetitive, short bursts of sound at a frequency of 25–80 kHz or higher. Blainville's beaked whales have been repeatedly involved in strandings associated with naval sonar activities (D'Amico et al. 2009). They have been shown to respond to sonar by vacating sonar exercise areas and/or changing their vocalization rates (Tyack et al. 2011).

4.2.4.1. Distribution

Blainville's beaked whales are the most widely distributed *Mesoplodon* species (Macleod et al. 2005). They tend to occur in deep offshore waters, favoring underwater structures such as canyons and the continental slope. Much of the available characterization for beaked whales is to genus level only and the stock structure for each species is unknown (Hayes et al. 2020). Most of the distributions of *Mesoplodon* spp. in the Northwest Atlantic come from stranding records. Off the US Atlantic coast, beaked whale sightings have principally occurred along the shelf-edge and in deeper waters from southwestern Nova Scotia to Florida (Leatherwood et al. 1976, Mead 1989a, MacLeod et al. 2006, Jefferson et al. 2008). They are considered rare in Canadian waters (Houston 1990).

Blainville's beaked whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of Blainville's beaked whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that Blainville's beaked whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.4.2. Abundance

The best abundance estimate for *Mesoplodon* beaked whales is 10,107 (CV=0.27) (NOAA Fisheries 2021aa). This is the sum of the 2016 survey estimates conducted in US waters of the western North Atlantic (Garrison 2020, Palka 2020). The minimum population estimate for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 8,085 (NOAA Fisheries 2021aa). A population trend analysis has not been conducted for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5. PBR for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 81.

4.2.4.3. Status

Blainville's beaked whales are not listed as threatened or endangered under the ESA or the MA ESA and the western North Atlantic stock of Blainville's beaked whale is not considered strategic under the MMPA. The status of Blainville's beaked whales relative to OSP in US Atlantic EEZ is unknown (NOAA Fisheries 2021aa). During the recent 5-year (2013–2017) period, a total of 4 Blainville's beaked whales stranded along the US Atlantic coast between Florida and Massachusetts, only one of which was determined to have evidence of human interaction due to plastic ingestion. Threats to this species likely include contaminant effects on health and reproduction, underwater noise, and climate-related changes (Hayes et al. 2020). The 150 permanent closure of the pelagic drift gillnet fishery has eliminated the principal known source of incidental fishery mortality. Therefore, total US fishery-related mortality and serious injury rate can be considered to be insignificant and approaching zero.

4.2.5. Bottlenose Dolphin (*Tursiops truncatus*)

Bottlenose dolphins are one of the most well-known and widely distributed species of marine mammals. These dolphins reach 2 to 4 m (7 to 13 ft) in length and are light gray to black in color (NOAA Fisheries 2021g). Bottlenose dolphins are commonly found in groups of 2 to 15 individuals, though aggregations in the hundreds are occasionally observed (NOAA Fisheries 2021g). They are considered generalist feeders and consume a wide variety of organisms, including fish, squid, and shrimp and other crustaceans (Jefferson et al. 2008). There are two distinct morphological forms of bottlenose dolphins in the Western North Atlantic that show significant genetic divergence (Rosel et al. 2009). The smaller coastal morphotype is present in estuarine, coastal and shelf waters from Florida to Long Island. The offshore morphotype is larger, and is distributed further offshore in deeper waters of the continental shelf and slope from Florida to Canada (Hayes et al. 2021). The two morphotypes have some spatial overlap however, and are difficult to differentiate in overlapping areas without genetic testing (Hayes et al. 2020)

Coastal and offshore stocks of bottlenose dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Bottlenose dolphin vocalization frequencies range from 3.4 to 130 kHz (DoN 2008).

4.2.5.1. Distribution

The common bottlenose dolphin is a cosmopolitan species that occurs in temperate and tropical waters worldwide. Common bottlenose dolphins are found in estuarine, coastal, continental shelf, and oceanic waters of the Western North Atlantic. Bottlenose dolphins offshore of New England belong to the Western North Atlantic Offshore stock, which ranges throughout the US Atlantic EEZ and into Canada (Hayes et al. 2021). The Western North Atlantic Offshore stock inhabits the outer continental slope and shelf edge regions from Georges Bank to the Florida Keys (Hayes et al. 2017).

Kraus et al. (2016) observed common bottlenose dolphins during all seasons within the MA and RI/MA WEAs. Common bottlenose dolphins were the second most observed small cetacean species and exhibited little seasonal variability in abundance. They were observed in the MA WEA in all seasons and SWDA in fall and winter. One sighting of common bottlenose dolphins in the Kraus et al. (2016) study included calves, and one sighting involved mating behavior. It is possible that the NLPSC surveys underestimated the abundance of common bottlenose dolphins because these surveys were designed to target large cetaceans and the majority of small cetaceans were not identified to species (Kraus et al. 2016).

During the 2018–2019 surveys in the MA and RI/MA WEAs, bottlenose dolphins were the second most abundant small cetacean, accounting for 15% of sightings, including periods of both on- and off-effort (O’Brien et al. 2020a). Bottlenose dolphins were only observed between April and July, but they were sighted throughout the MA and RI/MA WEAs. The March-October 2020 surveys revealed a similar trend, with sightings of bottlenose dolphins only occurring in summer. This species was again the second-most abundant small cetacean, accounting for 22% of sightings (O’Brien et al. 2020b). The 2020 survey revealed sightings only in the southern end of the RI/MA and MA WEAs, with the largest group (>151 individuals) located on the outside edge of the lease area. Not all small delphinids could be identified to species level in either survey, so the abundance of bottlenose dolphins may have been underestimated (O’Brien et al. 2020a, O’Brien et al. 2020b).

4.2.5.2. Abundance

The best available estimate for the offshore stock abundance is 62,851 individuals (NOAA Fisheries 2021aa). Current population estimates indicate there is no significant trend in abundance. Total annual human-caused mortality is unknown. Total annual fisheries mortality and serious injury is estimated as 28 individuals for the offshore stock from 2013–2017 (Hayes et al. 2020).

4.2.5.3. Status

Bottlenose dolphins of the Western North Atlantic Offshore stock are not federally listed as Threatened or Endangered under the ESA or MA ESA and are not considered strategic.

4.2.6. Clymene Dolphin (*Stenella clymene*)

Clymene dolphins are the smallest dolphin in the genus *Stenella,* and are also known as "short-snouted spinner dolphins" because they often spin while leaping out of the water and have a moderately short beak (NOAA Fisheries 2021e). Clymene dolphins are approximately 1.8 m (6 ft) long and have a streamlined body with a tall, curved dorsal fin midway down their back. Clymene dolphins have a dark gray back, light gray sides, and a white underside. They have distinct black lips and a dark line that extends across the top of their beak. Clymene dolphins dive to catch small fish and cephalopods and sometimes feed at night to catch pray at the water's surface. Clymene dolphins are usually found in groups, sometimes organized by age and sex, of around 70 individuals but sometimes travel in groups of up to 200. They prefer deep waters off the continental shelf and are likely to be strongly influenced by oceanographic features of the Gulf Stream (Fertl et al. 2003).

Clymene dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Wang (Ding 1993) recorded whistles of clymene dolphins in the Gulf of Mexico, and reported the sound energies as between 6.33 and 19.22 kHz, and the mean whistle duration as 0.61 s. During acoustic surveys in the offshore Gulf of Mexico, clymene dolphins' whistles ranged in frequency from 9.25 to 13.62 kHz, with a mean whistle duration of 0.41 s (Mullin et al. 1994).

4.2.6.1. Distribution

Clymene dolphins are generally encountered in tropical and subtropical waters of the Atlantic Ocean. Commonly sighted in the Gulf of Mexico, clymene dolphin sightings in the western North Atlantic are rare, possibly due to a lack of clear identifying characteristics in relation to other dolphin species. In the western North Atlantic, sightings are generally restricted to waters along and beyond the continental shelf edge off North Carolina and Virginia (Hayes et al. 2020), but the species has been recorded as far north as New Jersey (Fertl et al. 2003). This species routinely occurs in the western North Atlantic as evidenced by the sightings and stranding records (Fertl et al. 2003)(Mullin et al. 1994). Sightings of clymene dolphins offshore of Cape Hatteras were documented primarily during the summer and fall months ([DoN] Department of the Navy (US) 2013) and in the northern Gulf of Mexico during the winter, spring, and summer (Hansen et al. 1996, Mullin and Hoggard 2000b).

Clymene dolphins were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of clymene dolphins in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of Clymene dolphins may be underestimated during either survey (Kraus et al. 2016, O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that clymene dolphins are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.6.2. Abundance

The best abundance estimate for clymene dolphins in the western North Atlantic is 4,237 (CV = 1.03) (NOAA Fisheries 2021aa). This estimate was generated from vessel surveys conducted in US waters of the western North Atlantic during the summer of 2016 (Garrison and Stokes 2020, Palka 2020). The minimum population estimates based on the 2016 abundance estimates is 2,071 (NOAA Fisheries 2021aa). Clymene dolphins are rarely sighted and the resulting estimates of abundance are both highly variable and highly uncertain, which limits the ability to assess or interpret trends in population size. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is set to 0.5 because this stock is of unknown status. PBR for the western North Atlantic stock of clymene dolphins is 21.

4.2.6.3. Status

Clymene dolphins are not listed under the ESA and the Western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of clymene dolphins in the US EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). One stranding of a clymene dolphin was reported in New Jersey in 2013, for the US Atlantic Ocean during the 2013–2017 period, and no evidence of human interaction was detected. As for many delphinids, threats include fisheries interactions, underwater noise and chronic effects of contaminants. No fishery-related mortality or serious injury has been observed; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

4.2.7. Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale have a round and robust body, reaching lengths up to 4.5 to 7 m (15 to 23 ft) (NOAA Fisheries 2021d). Their coloration ranges from gray to reddish brown with a paler underside. Cuvier's beaked whales have a whitish coloration in the face and as the species grows older they become paler. Their bodies are often covered in scratches and scars. Their head is concave with no distinctive melon or beak, and a large blowhole. Cuvier's beaked whales are deep divers and feed on mostly cephalopods and sometimes fish and crustaceans (Heyning and Mead 2009). Cuvier's beaked whales rarely breach or display active behavior at the surface (NOAA Fisheries 2021d). They are typically found alone or in small groups of two to seven animals although groups of 25 animals have been reported.

Cuvier's beaked whales are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). These whales are highly vocal during foraging dives. Their vocalizations include clicks, click trains and buzzes. Tagged Cuvier's beaked whales produced short, directional, ultrasonic clicks with little energy below 20 kHz (Johnson et al. 2004). Beaked whales appear to be particularly sensitive to underwater sonar. D'Spain et al. (2005) describes the sound fields during multiple beaked whale mass strandings. A Cuvier's beaked whale exhibited an unusual foraging dive in conjunction with a large ship passing by, calling into question the impact of the ship's noise on the Cuvier's beaked whale's foraging behavior (Aguilar Soto et al. 2006).

4.2.7.1. Distribution

Cuvier's beaked whales are the most widely distributed and possibly the most abundant beaked whale in the world (Macleod et al. 2005). They are normally found in waters deeper than 200 m and are rarely close to the coast unless the continental shelf is particularly narrow and steep. Cuvier's beaked whales' distribution is poorly known and is mainly based on stranding records (Leatherwood et al. 1976). Strandings have occurred from Nova Scotia south to Florida, in the Gulf of Mexico, and the Caribbean (Hayes et al. 2020). Evidence of their presence from North Carolina to Nova Scotia consistently year round has been demonstrated from acoustic recordings (Stanistreet et al. 2017a). Cuvier's beaked whale sightings have mainly occurred along the continental shelf edge in the Mid-Atlantic region off the US east coast (Hayes et al. 2020).

Cuvier's beaked whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of Cuvier's beaked whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that Cuvier's beaked whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.7.2. Abundance

The best abundance estimate for undifferentiated beaked whales is 5,744 (CV=0.36) (NOAA Fisheries 2021aa). This estimate is derived from the sum of the northeast and southeast 2016 surveys. The minimum population estimate for undifferentiated beaked whales in the western North Atlantic is 4,282. A population trend analysis has not been conducted for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5. PBR for Cuvier's beaked whales is 43.

4.2.7.3. Status

The western North Atlantic stock of Cuvier's beaked whale is not listed as threatened or endangered under the ESA or the MA ESA or designated as a strategic stock under the MMPA. The status of Cuvier's beaked whale relative to OSP in the US Atlantic EEZ is unknown (NOAA Fisheries 2021aa). During 2013–2017, 7 Cuvier's beaked whales stranded along the US Atlantic coast, 2 of which were in New York between 2014–2015. Probably the greatest concern for this species is the effect of acoustic stressors, particularly exposures to military sonar. Cuvier's beaked whales have repeatedly been found stranded in association with military exercises (Frantzis 2003, D'Amico et al. 2009, Filadelfo et al. 2009), which highlights their susceptibility to these sound sources. Other threats may include the chronic impacts of contaminants and climate-related changes (NOAA Fisheries 2021aa). The total US fishery mortality and serious injury for this group of species is less than 10% of the calculated PBR and, therefore, can be considered insignificant and approaching a zero mortality and serious injury rate.

4.2.8. Dwarf Sperm Whale (*Kogia sima*)

Dwarf sperm whales have a small compact body and reach lengths of approximately 2.7 m (9 ft) (NOAA Fisheries 2021c). Dwarf sperm whales are brown to blue-gray colored with a paler white or pink underside. They have a small dorsal fin with a shape is unique to the individual, and a flat head and back. Their eyes are dark and bulging and have a marking behind them that looks similar to a gill slit. Dwarf sperm whales can be confused with pygmy sperm whales because of their similar appearances and geographic ranges. They feed on cephalopods, crustaceans, and fish. Similar to squids, dwarf sperm whales can produce a dark, ink-like liquid that helps them escape from predators. They are usually seen alone or in groups of 16 or less individuals.

The dwarf sperm is considered a high-frequency cetacean, with an estimated auditory bandwidth of 200 Hz to 180 kHz (Southall et al. 2007). Malinka et al. (2021) describes the echolocation click parameters and the bisonar behavior of the dwarf sperm whale based on recordings made in the Bahamas. Dwarf sperm whales produce narrow-band high-frequency echolocation clicks. In deep waters, dwarf sperm whales use a directional but short range echolocation system with moderate source levels.

4.2.8.1. Distribution

Dwarf sperm whales are found in deep waters in tropical to warm temperate zones of all oceans (Caldwell and Caldwell 1989, McAlpine 2009). Dwarf sperm whales are possibly distributed in waters slightly warmer than pygmy sperm whales, although their distribution is thought to overlap in many areas and is it difficult to differentiate between them at sea (Hayes et al. 2020). Sightings of *Kogia* whales in the western North Atlantic occur in oceanic waters along the continental shelf break and slope from Canada to Florida (Mullin and Fulling 2003, Roberts et al. 2015a). Stranding records for *Kogia* spp. are common from Canada to Florida (Bloodworth and Odell 2008, Berini et al. 2015). *Kogia* spp. may be found in the Gulf Stream and North Atlantic Gyre open areas. Dwarf sperm whales in the western North Atlantic are managed separately from those in the northern Gulf of Mexico. The population biology of dwarf sperm whales is inadequately known (Staudinger et al. 2014).

Dwarf sperm whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of dwarf sperm whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that dwarf sperm whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.8.2. Abundance

Total numbers of dwarf sperm whales off the US Atlantic coast are unknown. The reported abundance estimates are for both species of *Kogia* combined. The best estimate for *Kogia* spp. in the western North Atlantic is 7,750 (CV=0.38) (NOAA Fisheries 2021aa). This estimate is from summer 2016 surveys covering waters from central Florida to the lower Bay of Fundy (Garrison 2020, Palka 2020).The minimum population estimate for *Kogia* spp. is 5,689. The high level of uncertainty in the abundance estimates limits the ability to detect a statistically significant population trend. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is 0.4 because the CV of the average mortality estimate is greater than 0.8 (Wade and Angliss 1997). PBR for western North Atlantic *Kogia* spp. is 46 (NOAA Fisheries 2021aa).

4.2.8.3. Status

Dwarf sperm whales are not listed as threatened or endangered under the ESA or MA ESA, and the western North Atlantic stock is not considered strategic under the MMPA. The status of dwarf sperm whales in the US Atlantic EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). During 2013–2017, 46 dwarf sperm whales were reported stranded along the US Atlantic coast from New York to Florida. Threats to this species likely include contaminant effects on health and reproduction, interactions with fisheries, underwater noise, and climate-related changes. This species is likely vulnerable to loud anthropogenic sounds, such as those generated by navy sonar. In fact, dwarf sperm whales have repeatedly been found stranded following military sonar exercises (Hohn et al. 2006, Parsons 2017), suggesting increased vulnerability to these types of signals. No fishery-related mortality or serious injury has been observed in recent years; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

4.2.9. False Killer Whale (*Pseudorca crassidens*)

False killer whales are one of the larger members of the family Delphinidae, reaching a maximum length of 4.8 m (16 ft) in females and up to 6 m (20 ft) in males (NOAA Fisheries 2022a). They are slender and dark gray all over except for a small part of their underside which is lighter. Their head is small, conical, and without a beak. The male false killer whale is slightly larger and their head hangs over their lower jaw to a greater extent than the female. The pectoral fins have a distinct hump, creating an S-shape along the outer edge. The dorsal fin is located in the middle of the back and generally curves backwards. Individuals can be photo-identified through unique markings such as scars on dorsal fins. False killer whales form strong social bonds and are often found in small subgroups that are associated with a larger aggregation. False killer whales are top predators that primarily hunt fish and squid during the day and at night. They hunt in dispersed subgroups, and converge when prey is captured. Prey sharing has also been observed among individuals in the group. In some regions, false killer whales are also found with other cetaceans, most notably bottlenose dolphins.

False killer whales are in the mid-frequency functional hearing group (Southall et al. 2007). Underwater audiograms produced in a study by Thomas et al. (1988) showed that the false killer whale’s most sensitive range of hearing was from 16–64 kHz, and above 64 kHz, there was a rapid decrease in sensitivity. In a study done by Nachtigall and Supin (2013), a false killer whale reduced its hearing sensitivity when it anticipated the quick appearance of a loud sound, most likely to protect its hearing. False killer whales have been observed making a variety of vocalizations including ascending whistles, low-frequency pulse trains, high frequency pulse trains, and echolocation clicks. They also make short duration, broadband clicks centered around 40 kHz, with source levels between 201–225 dB re 1 µPa peak-to-peak (Madsen et al. 2004a).

4.2.9.1. Distribution

False killer whales have a worldwide distribution in tropical and subtropical areas (Jefferson et al. 2008). They are usually seen in the open ocean but are also found near the shore of some oceanic islands (Baird 2013). While sightings from the US western North Atlantic have been uncommon, records of sighting, stranding, and bycatch indicate that they routinely occur in the US western North Atlantic (Hayes et al. 2020). There have been sightings of false killer whales from Southern Florida to Maine (Schmidly 1981). False killer whales in the western North Atlantic are managed separately from those in the northern Gulf of Mexico.

False killer whales were not observed during surveys conducted between 2011–2015 in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Kraus et al. (2016) results suggest that false killer whales occur rarely, if at all, in the MA and RI/MA WEAs and surrounding areas. However, during a 2019 geotechnical and geophysical survey in or adjacent to the Offshore Development Area, one group of five probable false killer whales was observed during the summer (Vineyard Wind 2020d). It is possible that the NLPSC surveys underestimated the abundance of false killer whales because these surveys were designed to target large cetaceans. No sightings of false killer whales occurred during the 2018–2019 and 2020 surveys; however, there were some observations of small cetaceans that could not be identified to species (O'Brien et al. 2020a, O'Brien et al. 2020b).

4.2.9.2. Abundance

The best available abundance estimate for western North Atlantic false killer whales is 1,791 (CV=0.56) (NOAA Fisheries 2021aa). This estimate is from vessel surveys covering waters from central Florida to the lower Bay of Fundy during the summer of 2016 (Garrison and Stokes 2020, Palka 2020). The minimum population estimate for false killer whales is 1,154 (NOAA Fisheries 2021aa). False killer whales are rarely sighted during abundance surveys, and the resulting estimates of abundance are both highly variable between years and highly uncertain, which limits the ability to assess trends in population size. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic false killer whale stock is 12.

4.2.9.3. Status

False killer whales are not listed under the ESA and the western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of false killer whales in the US EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). There was one stranding of a false killer whale reported in Florida in 2013, in the US Atlantic Ocean during the 2013–2017 period. There have been intermittent false killer whale strandings throughout history, including a mass stranding in 1970 that may have been as many as 175 individuals (Caldwell et al. 1970, Schmidly 1981). Threats to this species are unknown but likely include fisheries interactions, underwater noise, and contaminants. Insufficient information is available to determine whether the total fishery-related mortality and serious injury for this stock is insignificant and approaching a zero mortality and serious injury rate.

4.2.10. Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphins have a stocky body with a small, distinct beak and reach a length of 1.8 to 2.7 m (6 to 9 ft) (NOAA Fisheries 2021y). Their dorsal fin is small and triangular and their flippers and flukes are smaller than those of other dolphin species. Fraser's dolphins are bluish or brownish-gray with a pale white or pink underside. They have a dark stripe that extends down their side, varying in shape based on geography and sex. Males are slightly longer and heavier than females, with a more distinct color pattern. Fraser's dolphins feed on deep-sea fish, crustaceans, and cephalopods and can dive up to 2,000 feet. Fraser's dolphins are usually found in groups of 10 to 100 individuals, but they have sometimes been seen in groups of up to 1,000 individuals. They are also sometimes seen in mixed groups with other cetacean species.

Fraser's dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Sound recordings from the encounters with Fraser's dolphins in the Gulf of Mexico included two types of whistles: relatively long duration single calls centered at either 11.4–13.4 kHz or 7.64–8.88 kHz and groups of 3–5 relatively short duration calls centered between 11.4 and 12.8 kHz (Leatherwood et al. 1993). Overall, the whistles were relatively stereotyped. Pulsed vocalizations, presumably used for echolocation, were also recorded.

4.2.10.1. Distribution

Fraser's dolphins are a poorly known species and sightings of this species in the western North Atlantic are rare (Hayes et al. 2020). They occur in tropical and subtropical waters worldwide, primarily offshore except where deep water occurs closer to shore such as near oceanic islands (Perrin et al. 1994). In the North Atlantic, the species has been recorded in the Lesser Antilles of the Caribbean Sea (Dolar 2009), off the US mid-Atlantic coast (NMFS 1999), and in the Azores, Cap Verde, and Madeira, as well as several areas along the African coast (Gomes-Pereira et al. 2013). Sightings in the northern Gulf of Mexico are uncommon, but occur regularly in oceanic waters greater than 200 m depth in all seasons (Leatherwood et al. 1993, Hansen et al. 1996, Mullin and Hoggard 2000a, Mullin and Fulling 2004). There are three stocks of Fraser's dolphins: Hawaiian, North Gulf of Mexico, and western North Atlantic (NOAA Fisheries 2021aa). These stocks are managed separately given the evidence for strong population structuring in other areas and the occupation of the in distinct marine ecoregions (Spalding et al. 2007, Moore and Merrick 2011).

Fraser's dolphins were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of Fraser's dolphins in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of Fraser's dolphins may be underestimated during either survey (Kraus et al. 2016, O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that Fraser's dolphins are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.10.2. Abundance

There are currently no abundance estimates for Fraser's dolphins in the western North Atlantic due to the paucity of sightings (NOAA Fisheries 2021aa). A group of an approximately 250 Fraser's dolphins was sighted off Cape Hatteras during a 1999 vessel survey but abundances have not been estimated from this sighting because it was not made during line- transect sampling effort (NMFS 1999). Present data are insufficient to calculate a minimum population estimate and population trends for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04 (NOAA Fisheries 2021aa). The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic Fraser's dolphin stock is unknown.

4.2.10.3. Status

Fraser's dolphins are not listed under the ESA or considered depleted under the MMPA. The status of Fraser's dolphins in the western US Atlantic EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). As for many delphinids, threats include fisheries interactions, underwater noise, chronic effects of contaminants, and climate-related changes. There were no reported strandings of a Fraser's dolphin in the US Atlantic Ocean during the 2013–2017 period. No fishery-related mortality or serious injury has been observed during recent years; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

4.2.11. Gervais' Beaked Whale (*Mesoplodon europaeus*)

Gervais' beaked whales are little known members of the beaked whale family and are difficult to distinguish from others in the genus *Mesoplodon* (NOAA Fisheries 2021x). They have small to medium-sized bodies and can reach lengths of up to 4.5 to 5.2 m (15 to 17 ft); females may be larger than males. They are dark gray or bluish to black, with a paler ventral side, and a pronounced dark patch around the eye. They tend to become darker as they age, however, scarring is not heavy with this species. Gervais' beaked whales have a long beak, an indistinct melon, and a small, triangular, slightly hooked dorsal fin. Mature males have a distinct, visible pair of teeth that point forward from their curved lower jaw; whereas females' and juveniles' teeth are more hidden. Gervais' beaked whales use suction while diving to feed on cephalopods, mysid shrimp, and small fish. They are usually found individually or in small social groups. Gervais' beaked whales are challenging to observe and identify, therefore, much of the available characterization for beaked whales is to the genus level only.

Gervais' beaked whales are in the mid-frequency functional hearing group (Southall et al. 2007). Cook et al. (2006) used auditory evoked potentials to measure the hearing abilities of a juvenile, stranded Gervais' beaked whale. They found that the Gervais' beaked whale was most sensitive to high frequency signals between 40 kHz and 80 kHz, but produced smaller evoked potentials to 5 kHz, the lowest frequency tested. Like other beaked whales, Gervais' beaked whales are known to be sensitive to underwater noise. Gervais' beaked whales were found stranded in the Caribbean in 1998, in association with a military sonar exercise (Filadelfo et al. 2009).

4.2.11.1. Distribution

Gervais' beaked whales are found only in the Atlantic Ocean and primarily in the North Atlantic (Macleod et al. 2005), although there are stranding records for the South Atlantic as far as southern Brazil (Martins et al. 2004). They range from tropical to warm-temperate areas but, compared to other beaked whale species in the Atlantic, relatively little is known about their ecology, possibly due to the difficulty in reliably identifying them at sea. Like other beaked whales, they tend to be found in deep, off-shelf areas. Much of the available characterization for beaked whales is to genus level only and the stock structure for each species is unknown (NOAA Fisheries 2021aa). Most of the distributions of *Mesoplodon* spp. in the Northwest Atlantic come from stranding records. Off the US Atlantic coast, beaked whale sightings have principally occurred along the shelf-edge and in deeper oceanic waters from Cape Cod to Florida, into the Caribbean and the Gulf of Mexico (Leatherwood et al. 1976, Mead 1989a, Moore et al. 2005, MacLeod et al. 2006, Jefferson et al. 2008, McLellan et al. 2018). They have been acoustically detected year round off Cape Hatteras (Stanistreet et al. 2017a). Numerous strandings of this species have also been recorded around Cape Hatteras (McLellan et al. 2018) and they are the most common species of *Mesoplodon* to strand along the US Atlantic Coast (Hayes et al. 2020).

Gervais' beaked whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of Gervais' beaked whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that Gervais' beaked whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.11.2. Abundance

The best abundance estimate for *Mesoplodon* beaked whales is 10,107 (CV=0.27) (NOAA Fisheries 2021aa). This estimate comes from the sum of the 2016 survey estimates conducted in US waters of the western North Atlantic (Garrison 2020, Palka 2020). The minimum population estimate for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 8,085 (NOAA Fisheries 2021aa). A population trend analysis has not been conducted for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5. PBR for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 81.

4.2.11.3. Status

Gervais' beaked whales are not listed as threatened or endangered under the ESA or the MA ESA and the western North Atlantic stock of Gervais' beaked whale is not considered strategic under the MMPA. The status of Gervais' beaked whales relative to OSP in US Atlantic EEZ is unknown (NOAA Fisheries 2021aa). During 2013–2017, 12 Gervais' beaked whales stranded along the US Atlantic coast, three of which were determined to have evidence of human interaction due to trash ingestion. All of these strandings occurred in the southern portion of the US Atlantic coast in either North Carolina, South Carolina, or Florida. Threats to this species likely include contaminant effects on health and reproduction, underwater noise, and climate-related changes (NOAA Fisheries 2021aa). The permanent closure of the pelagic drift gillnet fishery has eliminated the principal known source of incidental fishery mortality, and no fishery-related mortality and serious injury has been observed during the recent 5-year (2013–2017) period. Therefore, the total US fishery mortality and serious injury rate can be considered to be insignificant and approaching zero.

4.2.12. Killer Whale (*Orcinus orca*)

The killer whale, also known as orca, is the largest member of the Delphinidae family, reaching a maximum length of up to 9.7 m (32 ft) (NOAA Fisheries 2022d). They are one of the most recognizable marine mammals with their distinct black body, white underside, and white patches near the eyes and behind the dorsal fin. These markings vary widely between individuals and populations. Adult males develop larger pectoral flippers, dorsal fins, tail flukes, and girths than females. The killer whale is the ocean's top predator and has the most varied diet of all cetaceans. Different populations specialize in their foraging behavior and diet and use a coordinated hunting strategy. Katona et al. (1998) reported the following prey species for killer whales found in the western North Atlantic: fin, humpback, minke, and pilot whales, bluefin tuna, mackerel, squid, herring and sea turtles. Results from Mehta et al. (2007) implied that most killer whale attacks target young baleen whales. Killer whales are highly social, most living in pods consisting of a few to 20 or more animals. Larger groups sometimes form for temporary social interactions, mating, or seasonal concentrations of prey.

Killer whales are in the mid-frequency functional hearing group, (Southall et al. 2007). They rely on underwater sound to feed, communicate, and navigate. Pod members communicate with each other through clicks, whistles, and pulsed calls (Ford 2009). Szymanski et al. (1999) found that the killer whale audiogram extends to at least 120 kHz, with the most sensitive frequency measured at 20 kHz (36 dB). Simon et al. (2007) found that feeding whales produced high rates of clicks and calls. Tyson et al. (2007) documented nonlinearities in killer whale vocalizations. Killer whales respond to military sonar at sound pressure levels lower than the thresholds commonly used by the US Navy (Miller et al. 2014). Killer whales also show avoidance behavior and increased call amplitude when exposed to vessel noise (Holt et al. 2009, Williams et al. 2014).

4.2.12.1. Distribution

Killer whales are found in all the world's oceans, their distribution extending from the Arctic ice edge to the West Indies, and share the sperm whale's distinction of having the largest range of any non-human mammal (Whitehead 2002b, Waring et al. 2015). They are found in all marine habitats, from the coastal zone to deep oceanic basins although they are generally most numerous in coastal waters and at higher latitudes (Dahlheim & Heyning 1999). Killer whales are likely found in Labrador Current, Gulf Stream, and North Atlantic Gyre open ocean areas (DoN 2017). Killer whales are characterized as uncommon or rare in waters of the US Atlantic Exclusive Economic Zone (EEZ) (Katona et al. 1998). The 12 killer whale sightings constituted 0.1% of the cetacean sightings in the 1978–1981 CETAP surveys in the mid- and north Atlantic areas of the outer continental shelf ([CeTAP] Cetacean and Turtle Assessment Program 1982). In the US Atlantic EEZ, while their occurrence is unpredictable, they do occur in fishing areas, perhaps coincident with tuna, in warm seasons (Katona et al. 1998). The species has been described as relatively uncommon and numerically few in eastern Canadian waters as well (Mitchell and Reeves 1988). Most sightings off eastern Canada occur between June and September in coastal waters of Newfoundland and Labrador. However, cases of ice entrapment suggest that some killer whales may be present year round (Lawson et al. 2007). Stock and ecotype definitions are largely unknown but results from other areas suggest that social structure and territoriality may be important (Waring et al. 2015).

Killer whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of killer whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that killer whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.12.2. Abundance

The total number of killer whales off the eastern US coast is unknown (NOAA Fisheries 2021aa). Present data are insufficient to calculate a minimum population estimate and population trends for this species. Current and maximum net productivity rates are not known for this stock. The maximum net productivity rate was assumed to be 0.04 for purposes of this assessment. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic killer whale is unknown.

4.2.12.3. Status

Killer whales are not listed as threatened or endangered under the ESA or MA ESA, and the western North Atlantic stock is not considered strategic under the MMPA. The status of killer whales relative to OSP in US Atlantic EEZ is unknown (Waring et al. 2015). The main threats to killer whales include lethal interactions with fisheries, marine chemical pollution and subsequent toxic effects, and prey depletion. The effects of underwater noise are also of concern. Because there are no observed mortalities or serious injury between 2008 and 2012, the total US fishery-related mortality and serious injury for this stock is considered insignificant and approaching zero mortality and serious injury rate.

4.2.13. Melon-Headed Whale (*Peponocephala electra*)

Melon-headed whales are a robust small whale, reaching lengths of up to 2.7 m (9 ft) (NOAA Fisheries 2021j). Their body is dark gray with darker areas on the sides of the face and beneath the dorsal fin. Melon-headed whales have a small head, a rounded melon, and no discernible beak. They have a large dorsal fin and pointed, tapering pectoral fins. Melon-headed whales can be confused with their close relatives, pygmy killer whales and false killer whales. Their diet consists of squid, small fish, and shrimp (Clarke and Young 1988). Melon-headed whales make fast, low leaps from the water as they swim and tend to rest in the morning, socialize in the afternoon, and forage at night (NOAA Fisheries 2021j). They are social animals and often occur in groups of hundreds to 1,000 individuals and likely maintain a matrilineal social structure. Melon-headed whales are often associated with mixed groups of other delphinids.

Melon-headed whales are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Melon-headed whale vocalizations include clicks, burst-pulsed sounds, and whistles. Watkins et al. (1997) observed melon-headed whales in the southeastern Caribbean and found that clicks and click-bursts had a frequency emphasis between 20–24 kHz and that the dominant frequencies for whistles were 8–12 kHz. Southall et al. (2006) described unusual behavior of melon-headed whales in Hanalei Bay, Kauai, Hawaii, overlapping in time with naval exercises in which ships used active mid-frequency sonar intermittently. A group of 150–200 whales milled in the shallow confined bay and were returned to deeper water with human assistance. One calf was known to have died. Southall et al. (2006) concluded that the sonar transmissions were likely a contributing factor to this event, which was further supported by Brownell et al. (2009).

4.2.13.1. Distribution

Melon-headed whales are distributed worldwide in tropical and subtropical waters. They occur in deep oceanic waters, foraging at 300–500 m depth (Joyce et al. 2017). Melon-headed whales were recorded during NMFS vessel surveys in 1992 and 2006 off of Cape Hatteras in waters deeper than 2500 m (NMFS 1999, 2002). Most stranding records are from Florida and South Carolina, with a few from Virginia and one from New Jersey (Hayes et al. 2020). Sightings of this species in the western North Atlantic are extremely rare. Sightings are also relatively rare over the continental shelf and they have never been recorded in Canadian waters (Brownell et al. 2009). Cape Hatteras is likely close to the northern edge of the species’ range in the western North Atlantic, which may explain the scarcity of sightings (Hayes et al. 2020). Melon-headed whales in the western North Atlantic are managed separately from those in the northern Gulf of Mexico.

Melon-headed whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of melon-headed whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of melon-headed whales may be underestimated during either survey (Kraus et al. 2016, O'Brien et al. 2020a, O'Brien et al. 2020b).These data suggest that melon-headed whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.13.2. Abundance

There are currently no abundance estimates for melon-headed whales in the western North Atlantic due to the paucity of sightings (NOAA Fisheries 2021aa). Present data are insufficient to calculate a minimum population estimate and population trends for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic stock of melon-headed whales is unknown.

4.2.13.3. Status

Melon-headed whales are not listed as threatened or endangered under the ESA or MA ESA, and the western North Atlantic stock is not considered strategic under the MMPA. The status of melon-headed whales in the western US Atlantic EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). There were three reported strandings of melon-headed whales off Florida during the 2013–2017 period, one of which had evidence of human interaction detected in the form of an ingested plastic bag. The main threats to this species are likely underwater noise exposures, effects of contaminants on health and reproduction, and climate-related changes. No fishery-related mortality or serious injury has been observed during recent years; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

4.2.14. Northern Bottlenose Whale (*Hyperoodon ampullatus*)

Northern bottlenose whales are the largest members of the beaked whale family in the North Atlantic Ocean, reaching lengths of 8.5 to 11.2 m (28.2 to 36.7 ft) (NOAA Fisheries 2022b). They vary from dark gray to brownish green, and their skin may appear mottled and covered with markings. The dorsal side is darker and the melon appears light gray. Northern bottlenose whales have a large, long body and a small, triangular dorsal fin. They have a bulbous melon, which becomes flatter with age, and a bottle-shaped beak, Males may be larger than females and they have a distinct pair of teeth that angle forward visibly from the tip of the lower jaw. Mature females may have a white band around the neck. Northern bottlenose whales feed near the ocean bottom on deep-sea cephalopods, fish, shrimp, sea cucumbers, and sea stars. They are usually found alone or in groups of four to ten individuals but are occasionally found in groups of up to 50. Northern bottlenose whales produce small blows at the ocean surface that can be visible from a significant distance.

Northern bottlenose whales are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). They have been described as producing a variety of sounds including clicks, whistles, and chirps (Winn et al. 1970). Hooker and Whitehead (2002) identified two types of clicks produced by northern bottlenose whales. The first type of clicks were higher amplitude click trains, produced by socializing whales at the surface. The second type were low amplitude, regular clicks, likely produced by animals foraging in deep water. Wahlberg et al. (2011) describe the pulses produced by northern bottlenose whales as broadband impulsive vocalizations, the centroid frequency ranging from 31–51 kHz with a mean of 47 kHz. Northern bottlenose whales have been shown to respond to military sonar (Miller et al. 2015, Wensveen et al. 2019)

4.2.14.1. Distribution

Northern bottlenose whales are endemic to the North Atlantic Ocean (Macleod et al. 2005). They occur primarily in cool and subarctic waters, and are seldom found in waters less than 2,000 m deep (Mead 1989b). Northern bottlenose whales' distribution is concentrated in areas of high relief, including shelf breaks and submarine canyons. Northern bottlenose whales are characterized as rare in waters of the US EEZ (Waring et al. 2015). In the western North Atlantic, there are no recent visual sightings or acoustic detections south of the Canadian border (Stanistreet et al. 2017b). The two primary areas of occurrence in the western North Atlantic are the edge of the eastern Scotian Shelf and the Davis Strait (Reeves et al. 1993).

Northern bottlenose whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of northern bottlenose whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that northern bottlenose whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.14.2. Abundance

The total number of northern bottlenose whales off the eastern US coast is unknown (NOAA Fisheries 2021aa). Present data are insufficient to calculate a minimum population estimate and population trends for this species. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic northern bottlenose whale is unknown.

4.2.14.3. Status

Northern bottlenose whales are not listed as threatened or endangered under the US ESA or MA ESA and is not considered strategic under the MMPA. The status of northern bottlenose whales relative to OSP in US Atlantic EEZ is unknown; however, the depletion in Canadian waters in the 1970s may have impacted US distribution and may be relevant to current status in US waters (NOAA Fisheries 2021aa). In 2006, a mother-calf pair of bottlenose whales stranded alive in New Jersey. After refloating, the mother re-stranded dead in Delaware Bay. This is believed to be the southernmost US stranding record for this species. The main threats to northern bottlenose whales are entanglements in fishing gear and the effects of underwater noise. Northern bottlenose whales have been shown to respond to military sonar (Miller et al. 2015, Wensveen et al. 2019). This stock has a marginal occurrence in US waters and there are no documented takes in US waters. The total level of US fishery-caused mortality and serious injury is unknown.

4.2.15. Pantropical Spotted Dolphin (*Stenella attenuata*)

Pantropical spotted dolphins are small, reaching lengths of up to 2.1 m (7 ft), and accumulate spots throughout their lifetime until they are completed covered with patterns (NOAA fisheries 2021q). They have long, slender snouts and are distinguished by a darker area on their backs and a white-tipped beak. Pantropical spotted dolphins feed on mesopelagic cephalopods and fish, spending the day in shallower water and diving into deeper waters at night to search for prey. Pantropical spotted dolphins are social, usually occurring in groups of several hundred to 1,000 animals. They associate with other dolphins and small cetaceans, including the rough-toothed dolphin, short-finned pilot whale, and spinner dolphin.

Pantropical spotted dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). The vocal repertoire of pantropical spotted dolphins includes whistles, clicks, and buzzes. Pantropical spotted dolphins produce pulses ranging up to 150 kHz (Perrin and Hohn 1994b). Their whistles are upsweeps ranging in frequency between 10 and 20 kHz with durations of approximately 0.7 to 0.9 seconds (Silva et al. 2016).

4.2.15.1. Distribution

Pantropical spotted dolphins are distributed worldwide in tropical and some subtropical oceans (Perrin and Hohn 1994a). They can be difficult to differentiate at sea from the Atlantic spotted dolphin, whose distribution overlaps with that of pantropical spotted dolphins in part of their range (Hayes et al. 2020). In the north Atlantic, pantropical spotted dolphins are most frequently sighted in deep oceanic waters, particularly along the continental slope. They likely move inshore in the fall and winter months and offshore in the spring (NOAA fisheries 2021q). There have been records of pantropical spotted dolphins along the US Atlantic coast over the continental slope off of Massachusetts and over the Blake Plateau and in deeper offshore waters off of Cape Hatteras and further south down to Florida (Hayes et al. 2020).

Pantropical spotted dolphins were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of pantropical spotted dolphins in MA and RI/MA WEAs (O’Brien et al. 2020a, O’Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of pantropical spotted dolphins may be underestimated during either survey (Kraus et al. 2016, O’Brien et al. 2020a, O’Brien et al. 2020b). These data suggest that pantropical spotted dolphins are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.15.2. Abundance

The best abundance estimate available for western North Atlantic pantropical spotted dolphins is 6,593 (CV=0.52) (NOAA Fisheries 2021aa). This estimate comes from summer 2016 surveys covering waters from central Florida to the lower Bay of Fundy (Garrison 2020, Palka 2020). The minimum population estimate for pantropical spotted dolphins is 4,367 (NOAA Fisheries 2021aa). The high uncertainty in abundance estimates limits the ability to detect a population trend. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for pantropical spotted dolphins is 44.

4.2.15.3. Status

Pantropical spotted dolphins are not listed as threatened or endangered under the ESA, and the western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of pantropical spotted dolphins in the western US Atlantic EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). As for many delphinids, threats include fisheries interactions, underwater noise, chronic effects of contaminants, and climate-related changes. There were five reported strandings of pantropical spotted dolphins off Florida during the 2013–2017 period, four of which were determined to have no evidence of human interaction and one of which could not be determined. No fishery-related mortality or serious injury has been observed during recent years; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

4.2.16. 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 visually and acoustically due to similarity in appearance at the surface and vocalizations that overlap in frequency range. Consequently, the two species cannot be reliably distinguished (Rone and Pace 2012, Hayes et al. 2017); unless otherwise stated, the descriptions below refer to both species. Pilot whales have bulbous heads, are dark gray, brown, or black in color, and can reach approximately 7.3 m (24 ft) in length (NOAA Fisheries 2021o). 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 2021o, 2021l). Occurrence of short and long-finned pilot whales are considered uncommon in the SWDA.

Pilot whales are mid-frequency acoustic specialists with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Pilot whales echolocate and produce tonal calls. The primary tonal calls of the long-finned pilot whale range from 1 to 8 kHz with a mean duration of about 1 second. The calls can be varied with seven categories identified (level, falling, rising, up-down, down-up, waver, and multi-hump) and are likely associated with specific social activities (Vester et al. 2014).

4.2.16.1. 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 (Abend and Smith 1999; CeTAP 1982; Hamazaki 2002; Payne and 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, Payne and 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 (Payne and Heinemann 1993, Hayes et al. 2019). Long-finned pilot whales have occasionally been observed stranded as far south as South Carolina, and short-finned pilot whales have stranded as far north as Massachusetts (Hayes et al. 2020). 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 Hayes et al. (2020). Based on the distributions described in Hayes et al. (2020) pilot whale sightings in the SWDA are most likely to be long-finned pilot whales.

Kraus et al. (2016) observed pilot whales infrequently in the MA and RI/MA WEAs and surrounding areas. Effort-weighted average sighting rates for pilot whales could not be calculated. No pilot whales were observed during fall or winter, and these species were only observed 11 times in spring and three times in summer. Two of these sightings included calves. From 2018–2020 geotechnical and geophysical surveys in or adjacent to the SWDA detected pilot whales acoustically and/or visually six times during spring and summer months. Group sizes ranged from 4 to 6 individuals (Vineyard Wind 2018, 2020c, 2020d). It is possible that the NLPSC surveys underestimated the abundance of pilot whales because these surveys were designed to target large cetaceans and most small cetaceans were not identified to species (Kraus et al. 2016).

Pilot whales were only observed off effort between April and July in the 2018–2019 survey in the MA and RI/MA WEAs and only in the area south of Nantucket Shoals(O’Brien et al. 2020a). Based on the small number of sightings, no inferences can be made about the distribution of pilot whales in the survey area. No pilot whales were sighted during the 2020 surveys (O’Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of pilot whales may be underestimated during either survey (Kraus et al. 2016, O’Brien et al. 2020a, O’Brien et al. 2020b).

4.2.16.2. Abundance

The best available abundance estimate for the Western North Atlantic stock of long-finned pilot whales is 39,215, and the best available abundance estimate for the Western North Atlantic stock of short-finned pilot whales is 28,924 (Lawson and Gosselin 2018, NOAA Fisheries 2021aa). Estimates of population trend or net productivity rates have not been calculated for long-finned pilot whales as abundance estimates remain highly uncertain due to long survey intervals. From 2013 to 2017, total annual observed fishery-related mortality or serious injury was 21 whales (Hayes et al. 2020). In addition to direct human-induced mortality, mass strandings of long-finned pilot whales have occurred throughout their range. Between 2013 and 2017,16 long-finned pilot whales were found stranded between Maine and Florida. There are three available coastwide abundance estimates from summer surveys in 2004, 2011, and 2016 for short-finned pilot whales. A logistical regression model was used and indicated no significant population trend. Currently net productivity rates are unknown for short-finned pilot whales (NOAA Fisheries 2021aa). The total annual human caused mortality between 2013–2017 is also unknown; however, the mean annual fishery- related mortality and serious injury during this time due to the pelagic long line fishery was 160 short-finned pilot whales (NOAA Fisheries 2021aa).

4.2.16.3. Status

Neither pilot whale species is listed as Threatened or Endangered under the ESA or the MA ESA, and neither Western North Atlantic stock is considered strategic under the MMPA.

4.2.17. Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale is a small member of the dolphin family, reaching up to 1.9 m (6.5 ft) in length (NOAA fisheries 2021k). Pygmy killer whales have a dark gray to black body and small white areas on the lips and belly. They have a narrow cape that dips slightly below the dorsal fin and a light gray ventral band. Pygmy killer whales have a small head with a rounded melon and no discernable rostrum. They have a large dorsal fin and long, pointed, tapering pectoral fins. Pygmy killer whales are easily confused with melon-headed whales because of their similar appearance. Pygmy killer whales primarily feed on squids and fish (Donahue and Perryman 2009) and it has been suggested that they may attack and eat other dolphins (Perryman and Foster 1980). Pygmy killer whales usually occur in groups of 12 to 50 individuals but have been seen in groups up to several hundreds. They are generally less active than other oceanic dolphins and are frequently seen resting in groups at the surface oriented the same way.

Pygmy killer whales are in the mid-frequency functional hearing group (Southall et al. 2007). Acoustic recordings of pygmy killer whales in the northern Indian Ocean indicated that pygmy killer whales produce echolocation clicks (Madsen et al. 2004b). Montie et al. (2011), using auditory evoked potential procedures of live stranded pygmy killer whales, determined that maximum evoked potential responses occurred at modulation frequencies of 500 and 1000 Hz; and that the lowest hearing thresholds occurred between 20 and 60 kHz, with the best hearing sensitivity at 40 kHz. Pygmy killer whales appear to be sensitive to anthropogenic noise. Two mass-strandings of pygmy killer whales occurred in the coastal areas of southwest Taiwan, possibly associated with offshore naval training exercises (Wang and Yang 2006).

4.2.17.1. Distribution

Pygmy killer whales are a poorly known species that occur worldwide in deep, warm waters, generally beyond the edge of the continental shelf and rarely close to shore, except near some oceanic islands with steep bathymetric contours (Hayes et al. 2020). This species is mainly tropical but is occasionally sighted in warm temperate regions (Jefferson et al. 1994). Most observations outside the tropics are associated with strong, warm western boundary currents (Ross and Leatherwood 1994). There have been two sightings during NMFS vessel surveys from 1992 to 2016: a group of six pygmy killer whales off Georgia in 1992 and a single pygmy killer whale in waters 4000 m deep far offshore of Long Island, New York in 2016 (Hansen et al. 1995, [NEFSC] Northeast Fisheries Science Center and [SEFSC] Southeast Fisheries Science Center 2013). Strandings have been recorded from primarily South Carolina and Georgia (Hayes et al. 2020). Pygmy killer whales are not known to occur in high densities in any region (Waring et al. 2013). Sightings of this species in the western North Atlantic are extremely rare and stranding records are also sparse, likely due to the rarity of the species (Baird 2018). Pygmy killer whales in the western North Atlantic are managed separately from those in the northern Gulf of Mexico.

Pygmy killer whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of pygmy killer whales in MA and RI/MA WEAs (O’Brien et al. 2020a, O’Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of pygmy killer whales may be underestimated during either survey (Kraus et al. 2016, O’Brien et al. 2020a, O’Brien et al. 2020b). These data suggest that pygmy killer whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.17.2. Abundance

The number of pygmy killer whales off the US Atlantic coast is unknown since it was rarely seen in any survey (NOAA Fisheries 2021aa). Present data are insufficient to calculate a minimum population estimate and population trends for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic stock of pygmy killer whales is unknown.

4.2.17.3. Status

Pygmy killer whales are not listed as threatened or endangered under the ESA, and the western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of pygmy killer whales in the western US Atlantic EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). Three strandings of pygmy killer whales were reported in Virginia during the 2013–2017 period, one of which was determined to have no evidence of human interaction and the remaining two could not be determined. Threats to this species likely include contaminant effects on health and reproduction, underwater noise, and climate-related changes (NOAA Fisheries 2021aa). No fishery-related mortality or serious injury has been observed during recent years; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

4.2.18. Pygmy Sperm Whale (*Kogia breviceps*)

Pygmy sperm whales have a small, compact body and reach lengths of up to 3.5 m (11.5 ft) (NOAA Fisheries 2021h). Their back is brown to blue-gray and the underside is a paler white or pink and their skin is wrinkled. Their eyes are dark and bulging with a marking behind that looks like a gill slit. Pygmy sperm whales have a small and rounded dorsal fin, which is uniquely shaped for each individual, and a flat head and back. Pygmy sperm whales can sometimes be confused with dwarf sperm whales because they have similar appearances and geographic ranges. Pygmy sperm whales feed on cephalopods, crustaceans, and fish. Pygmy sperm whales are often seen in groups of less than seven individuals. Little is known of the behavior and ecology of this species. Like the dwarf sperm whale and squid, they can release ink to escape predators (NOAA Fisheries 2021h). When seen at sea, they have usually appeared slow and sluggish, and often float at the surface with no visible blow.

The pygmy sperm whale is considered a high-frequency cetacean, with an estimated auditory bandwidth of 200 Hz to 180 kHz (Southall et al. 2007). Marten (2000) recorded vocalizations of a pygmy sperm whale in a holding tank; the whale produced ultrasonic clicks ranging from 60 to 200 kHz and peaking at 125 kHz. Pygmy sperm whales have also been documented producing lower-frequency cries at 1 to 2 kHz (Thomas et al. 1990).

4.2.18.1. Distribution

Pygmy sperm whales are found in deep waters in tropical to warm temperate zones of all oceans. They occur mainly in deeper slope waters along and seaward of the shelf edge, where they feed on mesopelagic squid (McAlpine et al. 1997, Hayes et al. 2020). It is difficult to differentiate between pygmy sperm whales and dwarf sperm whales at sea, and therefore sightings are often categorized as *Kogia* spp. Sightings of *Kogia* whales in the western North Atlantic occur in oceanic waters along the continental shelf break and slope from Canada to Florida (Mullin and Fulling 2003, Roberts et al. 2015a). Stranding records for *Kogia* spp. are common from Canada to Florida (Bloodworth and Odell 2008, Berini et al. 2015). *Kogia* spp. may be found in the Gulf Stream and North Atlantic Gyre open areas. Pygmy sperm whales in the western North Atlantic are managed separately from those in the northern Gulf of Mexico. The population biology of pygmy sperm whales is inadequately known (Staudinger et al. 2014).

Pygmy sperm whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of pygmy sperm whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that pygmy sperm whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.18.2. Abundance

Total numbers of pygmy sperm whales off the US Atlantic coast are unknown. The reported abundance estimates are for both species of *Kogia* combined. The best estimate for *Kogia* spp. in the western North Atlantic is 7,750 (CV=0.38) (NOAA Fisheries 2021aa). This estimate is from summer 2016 surveys covering waters from central Florida to the lower Bay of Fundy (Garrison 2020, Palka 2020). The minimum population estimate for *Kogia* spp. is 5,689. The high level of uncertainty in the abundance estimates limits the ability to detect a statistically significant population trend. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is 0.4 because the CV of the average mortality estimate is greater than 0.8 (Wade and Angliss 1997). PBR for western North Atlantic *Kogia* spp. is 46 (NOAA Fisheries 2021aa)

4.2.18.3. Status

Pygmy sperm whales are not listed as threatened or endangered under the ESA or MA ESA, and the western North Atlantic stock is not considered strategic under the MMPA. The status of pygmy sperm whales in the US Atlantic EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). During 2013–2017, 120 pygmy sperm whales were reported stranded along the US Atlantic coast from Massachusetts to Florida, 10 of which were determined to have evidence of human interaction. Likely threats to this species include fisheries interactions, underwater noise, chronic effects of contaminants, and climate-related changes (NOAA Fisheries 2021aa). There is one record of stranding associated with military sonar exercises (D'Amico et al. 2009). No fishery-related mortality or serious injury has been observed in recent years; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate (NOAA Fisheries 2021aa).

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

Risso's dolphins occur worldwide in both tropical and temperate waters (Jefferson et al. 2008, Jefferson et al. 2014). The Risso's dolphin attains a body length of approximately 2.6 to 4 m (9 to13 ft) (NOAA Fisheries 2021f). 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 2021f). They feed primarily on squid, but they also eat fish such as anchovies (*Engraulidae*), krill, and other cephalopods (NOAA Fisheries 2021f).

Risso's dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Vocalizations range from 400 Hz to 65 kHz (DoN 2008).

4.2.19.1. 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 (Leatherwood et al. 1976, Baird and Stacey 1991). During spring, summer, and fall, Risso's dolphins are distributed along the continental shelf edge from Cape Hatteras northward to Georges Bank (CeTAP 1982, Payne et al. 1984). In winter, the distribution extends outward into oceanic waters (Payne et al. 1984); however, very little is known about movement and migration patterns and they are infrequently observed in shelf waters. The stock may contain multiple demographically independent populations that should themselves be considered stocks because the current stock spans multiple eco-regions (Longhurst 1998, Spalding et al. 2007).

Kraus et al. (2016) results suggest that Risso's dolphins occur infrequently in the MA and RI/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 spring. From 2018 to 2020 geotechnical and geophysical surveys in or adjacent to the SWDA observed Risso's dolphins once in early summer. Group size ranged from 5 to 8 individuals (Vineyard Wind 2018, 2020c, 2020d). It is possible that the NLPSC surveys underestimated the abundance of Risso's dolphins because these surveys were designed to target large cetaceans and most small cetaceans were not identified to species. No Risso's dolphins were observed in either of the most recent surveys in the MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b).

4.2.19.2. Abundance

The best abundance estimate for Risso's dolphins is 35,215 individuals, calculated from surveys conducted by Northeast Fisheries Science Center (NEFSC) and Department of Fisheries and Oceans Canada (DFO) (NOAA Fisheries 2021aa). Estimates of population trend or net productivity rates have not been calculated for Risso's dolphins. Annual average estimated human-caused mortality or serious injury from 2013 to 2017 was 54 dolphins, most of which was likely due to interactions with fisheries

4.2.19.3. Status

Risso's dolphins are not listed as Threatened or Endangered under the ESA and this stock is not considered strategic under the MMPA.

4.2.20. Rough-Toothed Dolphin (*Steno bredanensis*)

Rough-toothed dolphins have a reptilian appearance and are relatively small, reaching up 2.5 m (8.5 ft) in length (NOAA Fisheries 2022g). They have a dark gray body with a white throat and lips and a lighter spotted underside. Rough-toothed dolphins have a small head with a long rostrum and distinctively large dorsal fin and pectoral fins. Their common name is based on the ridges found on their teeth. Rough-toothed dolphins feed on squid and different types of fish and often travel in small groups of two to 20 individuals (Jefferson 2009). They often associate with other cetacean species, including short-finned pilot whales, bottlenose dolphins, pantropical spotted dolphins, and spinner dolphins.

Rough-toothed dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Although little is known about the rough-toothed dolphin, whistles and broadband click sounds have been recorded. Jefferson (2009) described highly directional echolocation clicks. Rough-toothed dolphins' short-duration whistles have been observed to range in frequency, on average, from 2.5 to 10 kHz (Seabra de Lima et al. 2012, Rankin et al. 2015).

4.2.20.1. Distribution

Rough-toothed dolphins are distributed worldwide, generally in warm temperate, subtropical, or tropical waters (Hayes et al. 2020). They have been reported in a range of water depths, from shallow, nearshore areas to deep oceanic waters (West et al. 2011). In the western North Atlantic, rough-toothed dolphins have been sighted along the continental slope and off the coast of North Carolina up to Delaware. Sightings of rough-toothed dolphins are much less common along the East Coast of the US than in the Gulf of Mexico ([CeTAP] Cetacean and Turtle Assessment Program 1982, [NMFS] National Marine Fisheries Service (US) 1999, Mullin and Fulling 2003). For management purposes, rough-toothed dolphins observed off the eastern US coast are considered a separate stock from those in the northern Gulf of Mexico.

Rough-toothed dolphins were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of rough-toothed dolphins in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of rough-toothed dolphins may be underestimated during either survey (Kraus et al. 2016, O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that rough-toothed dolphins are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.20.2. Abundance

The best abundance estimate available for the western North Atlantic rough-toothed dolphin is 136 (CV=1.00) (NOAA Fisheries 2021aa). This estimate is an average from summer 2011 and summer 2016 shipboard surveys covering waters from central Florida to the lower Bay of Fundy (Palka 2012, Garrison 2016). Given the limited number of sightings of rough-toothed dolphins over the years, the abundance estimate for this stock is highly uncertain. The minimum population estimate is 67 (NOAA Fisheries 2021aa). A population trend cannot be estimated for this stock due to the small number of sightings in any single year. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic stock of rough-toothed dolphins is 0.7.

4.2.20.3. Status

Rough-toothed dolphins are not listed as threatened or endangered under the ESA and the Western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of rough-toothed dolphins in the US EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). Although potential sources of human-caused mortality for this stock are poorly understood, threats to this species likely include contaminant effects on health and reproduction. Although there have been several mass strandings of rough-toothed dolphins along the US east coast in the past, from 2012 to 2016 no rough-toothed dolphins were reported stranded between Maine and Florida. No fishery-related mortality or serious injury has been observed between 2012 and 2016; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

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

Short-beaked common dolphins are one of the most widely distributed cetaceans and occur in temperate, tropical, and subtropical regions (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 2021a). This species feeds on schooling fish and squid found near the surface at night (NOAA Fisheries 2021a). These dolphins can gather in schools of hundreds or thousands, although groups generally consist of 30 or fewer individuals (NOAA 1993).

Short-beaked common dolphins are in the mid-frequency functional hearing group. Their vocalizations range from 300 Hz to 44 kHz (Southall et al. 2007).

4.2.21.1. 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 (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 typically between the 100 and 2000 m (328 and 6562 ft) isobaths and is associated with Gulf Stream features (CeTAP 1982, Selzer and Payne 1988, Hamazaki 2002, Hayes et al. 2018). 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 and Payne 1988). Migration onto the Scotian Shelf and continental shelf off Newfoundland occurs when water temperatures exceed 11°C (51.8°F) (Sergeant et al. 1970, Gowans and Whitehead 1995). Breeding usually takes place between the months of June and September with females estimated to have a calving interval of 2 to 3 years (Hayes et al. 2020).

Kraus et al. (2016) suggested that short-beaked common dolphins occur year-round in the MA and RI/MA WEAs and surrounding areas. Short-beaked common dolphins were the most frequently observed small cetacean species within the Kraus et al. (2016) study area. Short-beaked common dolphins were observed in the MA and RI/MA WEAs in all seasons and observed in the SWDA 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 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. Short-beaked common dolphins were the most frequently observed or detected animal during the 2016 survey in the SWDA and one was also visually observed during the 2017 geophysical and geotechnical (G&G) survey (Vineyard Wind 2016, 2017). During the 2016 G&G survey, short-beaked common dolphins were visually observed 123 times and acoustically detected 50 times. It is possible that the NLPSC surveys underestimated the abundance of short-beaked common dolphins because these surveys were designed to target large cetaceans and the majority of small cetaceans were not identified to species (Kraus et al. 2016).

More recent aerial surveys in the MA and RI/MA WEAs took place between October 2018 and August 2019 (O'Brien et al. 2020a) and from March to October 2020 (O'Brien et al. 2020b). Common dolphins accounted for most sightings during both surveys (48% and 41% respectively). This species was observed in all seasons and throughout the MA and RI/MA WEAs during the 2018–2019 surveys; however, they were absent in the months of March and August (O'Brien et al. 2020a). They were again present in all seasons and throughout the survey area in 2020; however, no data on monthly abundance is available (O'Brien et al. 2020b). The largest aggregations of common dolphins occurred on the southern edge of the MA and RI/MA WEAs during both surveys (O'Brien et al. 2020a, O'Brien et al. 2020b).

4.2.21.2. Abundance

The best abundance estimate for the Western north Atlantic stock of common dolphins is 172,974 individuals as of 2016 (NOAA Fisheries 2021aa). Annual total human-caused mortality and serious injury are unknown; however, annual fishery-related mortality between 2013 and 2017 was 419 animals (Hayes et al. 2020).

4.2.21.3. 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 dolphin is not designated as a strategic stock under the MMPA.

4.2.22. Sowerby's Beaked Whale (*Mesoplodon bidens*)

Sowerby's beaked whales, also known as the North Atlantic beaked whale, are small to medium sized and reach lengths of up to 4.4 to 6.4 m (14.5 to 21 ft) (NOAA fisheries 2021z). Their body is mostly charcoal gray with a pale underside and a light gray or white jaw. Calves are generally darker than adults. Sowerby's beaked whales have a long, slender beak and a bulge on their forehead. Their dorsal fin is small and slightly hooked. Males, which are generally larger, have a distinct, visible pair of teeth that point forward from their curved lower jaw; whereas females' and juveniles' teeth are more hidden. Sowerby's beaked whales use suction while diving to feed on small, deep-sea fish and cephalopods. Sowerby's beaked whales are usually found individually or in small groups between three and 10 individuals. They are challenging to observe and identify, therefore, much of the available characterization for beaked whales is to the genus level only.

Sowerby's beaked whales are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Acoustic recordings of groups of Sowerby's beaked whales off the US Atlantic coast included echolocation clicks, the majority of which contained a median peak frequency of 25 kHz (Cholewiak et al. 2013). Beaked whales appear to be particularly sensitive to underwater sonar. There has been overlap between beaked whale stranding events and military mid-frequency sonar (2–10 kHz) and air 59 gun arrays (Barlow and Gisiner 2006).

4.2.22.1. Distribution

Sowerby's beaked whales are endemic to the North Atlantic Ocean (Macleod et al. 2005). This species prefers the cold, temperate and subarctic waters (Hayes et al. 2020). Like other beaked whales, they tend to be found in deep, off-shelf areas. Much of the available characterization for beaked whales is to genus level only and the stock structure for each species is unknown. Most of the distributions of *Mesoplodon* spp. in the Northwest Atlantic come from stranding records. In the western North Atlantic, they have been reported from New England waters north to the ice pack. (Leatherwood et al. 1976, Mead 1989a, MacLeod et al. 2006, Jefferson et al. 2008) Sowerby's beaked whales are the most northerly distributed of Atlantic species of *Mesoplodon*. Recent strandings along the US Atlantic coast have been reported in Maine and Massachusetts and a single stranding occurred off the Florida west coast in 1984 (Mead 1989a).

Sowerby's beaked whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of Sowerby's beaked whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that Sowerby's beaked whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.22.2. Abundance

The best abundance estimate for *Mesoplodon* beaked whales is 10,107 (CV=0.27) (NOAA Fisheries 2021aa). This estimate comes from the sum of the 2016 survey estimates conducted in US waters of the western North Atlantic (Garrison 2020, Palka 2020). The minimum population estimate for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 8,085 (NOAA Fisheries 2021aa). A population trend analysis has not been conducted for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5. PBR for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 81.

4.2.22.3. Status

Sowerby's beaked whales are not listed as threatened or endangered under the ESA or MA ESA and the western North Atlantic stock is not considered strategic under the MMPA. The status of Sowerby's beaked whales relative to OSP in US Atlantic EEZ is unknown (NOAA Fisheries 2021aa). During 2013–2017, a total of 3 Sowerby's beaked whales stranded in Maine and Massachusetts, one of which was determined to have evidence of human interaction due to plastic bag ingestion. Threats to this species likely include contaminant effects on health and reproduction, underwater noise, and climate-related changes (Richardson et al. 1995, Hayes et al. 2020). The permanent closure of the pelagic drift gillnet fishery has eliminated the principal known source of incidental fishery mortality, and no fishery-related mortality and serious injury has been observed during the recent 5-year (2013–2017) period. Therefore, the total US fishery mortality and serious injury rate can be considered to be insignificant and approaching zero.

4.2.23. 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 US tons) (Whitehead 2009). Sperm whales have extremely large heads, which account for 25 to 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 (1312 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 1000 m (3281 ft) (Watwood et al. 2006). Sperm whales have a global distribution in deep water and range from the equator to the edges of the polar pack ice (Whitehead 2002a). 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 2002a, 2003).

The IWC recognizes only one stock of sperm whales for the North Atlantic, and Reeves and Whitehead (1997) and Dufault et al. (1999) suggest that sperm whale populations lack clear geographic structure. Current threats to the sperm whale population include ship strikes, exposure to anthropogenic sound and toxic pollutants, and entanglement in fishing gear (though entanglement risk for sperm whales is relatively low compared to other, more coastal whale species) (Waring et al. 2015, NOAA Fisheries 2020a).

Sperm whales are in the mid-frequency hearing group, with an estimated auditory range of 150 Hz to 160 kHz (Southall et al. 2007). Sperm whales produce short-duration repetitive broadband clicks used for communication and echolocation. These clicks range in frequency from 0.1 to 30 kHz, with dominant frequencies in the 2–4 kHz and 10–16 kHz ranges (DoN 2008). Echolocation clicks from adult sperm whales are highly directional, with a centroid frequency between 8 and 25 kHz (Madsen et al. 2002b) and a SL estimated at up to 223 dB re 1 µPa (Møhl et al. 2000).

4.2.23.1. Distribution

Sperm whales mainly reside in deep-water habitats on the 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 off the coast of Southern New England (Scott and 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, Scott and Sadove 1997). During 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.

Kraus et al. (2016) observed sperm whales four times in the MA and RI/MA WEAs during summer and fall from 2011 to 2015. Sperm whales, traveling singly or in groups of 3 or 4, were observed three times in August and September 2012, and once in June 2015. One sperm whale was observed on the northwestern border of the SWDA and one was observed between the SWDA and Nantucket Island. The frequency of sperm whale clicks exceeded the maximum frequency of PAM equipment used in Kraus et al. (2016), so no acoustic data are available for this species from that study.

More recently, surveys in the MA and RI/MA WEAs in June and July 2019 recorded two groups of sperm whales (O'Brien et al. 2020a). On June 12, a group of four whales was sighted, and a group of two was sighted on July 15. Photographs revealed that these were likely all different individuals. Both groups were observed in relatively shallow water close to shore, with the June 12 sighting 10 NM south of Nantucket Island and the July 15 sighting 13 NM southwest of the island. Both groups were also milling at the surface and diving, with one whale observed sleeping vertically at the surface during the June 12 sighting (O'Brien et al. 2020a). The most recent survey was conducted between March and October 2020. No sperm whales were detected during the survey period (O'Brien et al. 2020b).

From 2018 to 2020, geotechnical and geophysical surveys in or adjacent to the SWDA detected sperm whales acoustically and/or visually twice in spring and summer months. Group size ranged from 1 to 2 individuals (Vineyard Wind 2018, 2020c, 2020d). Sperm whales are expected to be present but uncommon in the SWDA based on survey sightings.

4.2.23.2. Abundance

Though there is currently no reliable estimate of total sperm whale abundance in the entire Western North Atlantic, the most recent and best available population estimate for the US Atlantic EEZ is 4349 (NOAA Fisheries 2021aa).

4.2.23.3. Status

Sperm whales are listed as Endangered under the ESA and MA ESA, and the North Atlantic stock is considered strategic by NMFS under the MMPA. The minimum population size is estimated at 3451 (NOAA Fisheries 2021aa). The maximum productivity rate is 0.04, the default value for cetaceans. The recovery factor is 0.1, because the sperm whale is listed as Endangered. PBR for the Western North Atlantic sperm whale stock is 3.9 (NOAA Fisheries 2021aa). From 2013 through 2017, there are no documented reports of fishery-related mortality or serious injury to this stock (Hayes et al. 2020). No critical habitat areas have been designated for the sperm whale under the ESA.

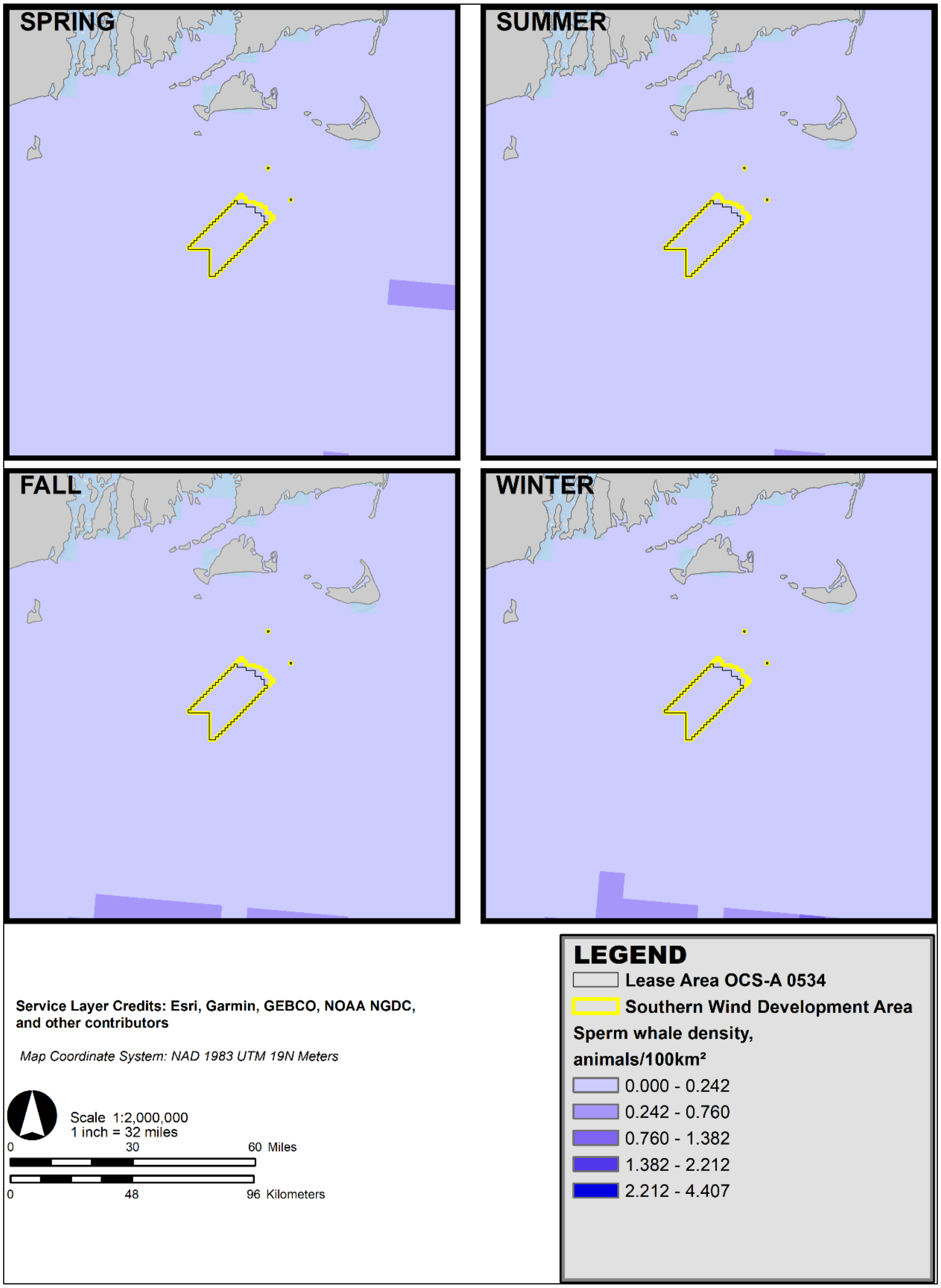

Figure 15. Sperm whale maximum seasonal density from Roberts et al. (2016a, 2016b, 2017).

4.2.24. Spinner Dolphin (*Stenella longirostris*)

Spinner dolphins are relatively small, with thin, recurved flippers, and dorsal fins that usually range from curved to upright and triangular. Spinner dolphins can reach lengths of 1.2 to 2.1 m (4 to 7 ft), males being larger than females. Spinner dolphins received their name because they are often seen leaping and spinning out of the water and have an elongated rostrum. Their color varies greatly depending on the region and subspecies of dolphin, but generally consists of a dark gray back, a light gray side, and a white underside. Individuals can be photo-identified by the shape of and nicks and notches in their dorsal fins. Spinner dolphins feed on small fish, shrimp, and squid. Spinner dolphins feed at night to take advantage of the nightly migration that brings their prey species to shallower depths and closer to shore. Spinner dolphins rest by engaging in group movements, relying on vision, rather than echolocation, to scan their environment. Following their rest period, spinner dolphins greatly increase their activity, swimming in a “zig zag” pattern and synchronizing their acoustic behavior.

Spinner dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Spinner dolphins produce whistles, burst pulses, and echolocation clicks. In a study around Hawaii, spinner dolphin whistles lasted 0.49 s on average, with fundamental frequencies between 2 kHz and 22 kHz (Bazúa-Durán and Au 2002). Burst pulses had approximately 30 clicks per trains with an average peak frequency of 32.3 kHz. The echolocation clicks of spinner dolphins can range up to 65 kHz.

4.2.24.1. Distribution

Spinner dolphins have a worldwide distribution and occur in tropical oceanic and coastal waters (Leatherwood et al. 1976). The species is generally found in deep, offshore waters. However, in the Pacific and the Indian Ocean, some populations remain associated with oceanic islands. The species' distribution in the western North Atlantic is very poorly known. Spinner dolphin sightings have occurred almost exclusively in deeper (greater than 2,000 m) oceanic waters off the northeast US coast ([CeTAP] Cetacean and Turtle Assessment Program 1982, Waring et al. 1992). Sightings were recorded off Cape Hatteras during summer 2011 surveys and off the Virginia coast during summer 2016 surveys in oceanic waters (Palka 2020). Strandings have also been recorded from North Carolina and south thereof (Hayes et al. 2020). They are more commonly sighted in the Gulf of Mexico than the western North Atlantic. Spinner dolphins in the western North Atlantic are managed separately from those in the northern Gulf of Mexico.

Spinner dolphins were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of spinner dolphins in MA and RI/MA WEAs (O’Brien et al. 2020a, O’Brien et al. 2020b). As not all species of small cetacean could be identified to species level, observations of spinner dolphins may be underestimated during either survey (Kraus et al. 2016, O’Brien et al. 2020a, O’Brien et al. 2020b). These data suggest that spinner dolphins are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.24.2. Abundance

The best abundance estimate available for spinner dolphins in the western North Atlantic is 4,102 (CV=0.99) (NOAA Fisheries 2021aa)This estimate is from summer 2016 surveys covering waters from central Florida to the lower Bay of Fundy (Garrison 2020)(Palka 2020). The minimum population estimate for spinner dolphins is 2,045 (NOAA Fisheries 2021aa). There are insufficient data to determine the population trends for this stock because only one estimate of population size is available. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic spinner dolphin is 20.

4.2.24.3. Status

Spinner dolphins are not listed as threatened or endangered under the ESA, and the western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of spinner dolphins in the US western North Atlantic EEZ relative to OSP is unknown (NOAA Fisheries 2021aa). During the 2013–2017 period, two spinner dolphins strandings were reported in Florida, one of which was determined to have no evidence of human interaction and the other one could not be determined. Threats to this species likely include contaminant effects on health and reproduction, underwater noise, and climate-related changes. No fishery-related mortality or serious injury has been observed in recent years; therefore, total fishery-related mortality and serious injury can be considered insignificant and approaching the zero mortality and serious injury rate.

4.2.25. Striped Dolphin (*Stenella coeruleoalba*)

Striped dolphins are known for their unique coloration pattern, which includes bold stripes that extend down the side of the body and from the eye to the flipper (NOAA Fisheries 2022h). The striped dolphin’s rostrum, tapered pectoral fins, tail, and back are dark blue/gray. The area above the side stripe is bluish or light gray and the underside is white to pinkish. The markings and coloration of this species may vary by individual and geographic location. Male striped dolphins can reach lengths of up to 2.7 m (9 ft) and females up to 2.4 m (8 ft). They have a small to medium-sized sleek body, defined rostrum, round forehead, and a hooked and tall dorsal fin. Striped dolphins’ diet consists of fish and squid, and they feed throughout the water column (Archer 2009). They are often characterized as sociable and energetic and can be observed breaching and jumping 6 m (20 ft) above the surface. They are usually found in tight groups of between 25 to 100 individuals, and sometimes up to several hundreds and thousands. Striped dolphins rarely associate with other species of whales and dolphins.

Striped dolphins are in the mid-frequency functional hearing group (Southall et al. 2007). Kastelein et al. (2003) measured the underwater hearing sensitivity of a striped dolphin and found that their hearing capabilities ranged from 500 Hz to 160 kHz maximum sensitivity (42 dB re 1 μPa) occurred at 64 kHz. The range of most sensitive hearing was from 29 to 123 kHz. Kastelein et al. (2006) studied the response of a striped dolphin to an acoustic alarm and found that it did not react to the alarm, despite the sound being within the dolphin’s hearing range.

4.2.25.1. Distribution

Striped dolphins can be found throughout tropical and warm temperate waters worldwide and are the most widely distributed *Stenella* species (Baird et al. 1993). Their preferred habitat seems to be the deep water along the edge and seaward of the continental shelf, particularly in areas influenced by warm currents, like the Gulf Stream (Leatherwood et al. 1976, Schmidly 1981). Striped dolphins are found in the western North Atlantic from Nova Scotia south to at least Jamaica and in the Gulf of Mexico. Sightings of striped dolphins off the northeastern US coast have occurred along the continental shelf edge, often along the 1,000 m depth contour from Cape Hatteras to the southern margin of Georges Bank, and also over the continental slope and rise in the mid-Atlantic region ([CeTAP] Cetacean and Turtle Assessment Program 1982, Mullin and Fulling 2003).

Striped dolphins were not observed during surveys conducted between 2011–2015 in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Kraus et al. (2016) results suggest that striped dolphins occur rarely, if at all, in the MA and RI/MA WEAs and surrounding areas. However, during a 2019 geotechnical and geophysical survey in or adjacent to the Offshore Development Area, one group of three striped dolphins were observed during the fall (Vineyard Wind 2020d). It is possible that the NLPSC surveys underestimated the abundance of striped dolphins because these surveys were designed to target large cetaceans. No sightings of striped dolphins occurred during the 2018–2019 and 2020 surveys; however, there were some observations of small delphinids that could not be identified to species (O'Brien et al. 2020a, O'Brien et al. 2020b).

4.2.25.2. Abundance

The best abundance estimate for striped dolphins is 67,036 (CV=0.29) (NOAA Fisheries 2021aa). This estimate comes from the sum of surveys conducted in US waters of the western North Atlantic during the summer of 2016 (Garrison 2020, Palka 2020). The minimum population estimate for the western North Atlantic striped dolphin is 52,939 (NOAA Fisheries 2021aa). Population trends have not been estimated for this stock due to the relatively imprecise abundance estimates and long survey interval. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is 0.5 because this stock is of unknown status. PBR for the western North Atlantic striped dolphin is 529.

4.2.25.3. Status

Striped dolphins are not listed as threatened or endangered under the ESA, and the western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of striped dolphins, relative to OSP, in the US Atlantic EEZ is unknown (NOAA Fisheries 2021aa). A total of 22 striped dolphins were reported stranded along the US Atlantic coast from Massachusetts to Florida between 2013 and 2017. This includes one record of a mass stranding of 12 animals in North Carolina in 2005 and two strandings in Massachusetts in 2015 and 2017. Threats to this species likely include contaminant effects on health and reproduction, and climate-related changes (Hayes et al. 2020). Average annual human-related mortality and serious injury does not exceed the PBR. The total US fishery-related mortality and serious injury for this stock is less than 10% of the calculated PBR, therefore can be considered insignificant and approaching zero mortality and serious injury rate.

4.2.26. True's Beaked Whale (*Mesoplodon mirus*)

True's beaked whales' coloration varies from gray to brown on their back with a paler underside (NOAA fisheries 2021w). They are distinguished from Gervais' beaked whales by the pale coloration across their melon and the lack of a defined dorsal stripe. True's beaked whales have a relatively small to medium-sized body, reaching lengths of 4.7 to 5.4 m (15.5 to 17.5 ft); females may be larger than males. They have a short beak, a rounded, sloping forehead, and a small, slightly hooked dorsal fin. Males may have linear scarring covering their body and have a distinct, visible pair of teeth on the tip of their slightly curved lower jaw; whereas females' and juveniles' teeth are more hidden. True's beaked whales use suction while diving to feed on small fish and cephalopods in deep waters. They have been known to breach and display surface active behaviors, although this species is difficult to observe and identify at sea. Much of the available characterization for beaked whales is to the genus level only. True's beaked whales are often observed alone or in small groups of five to six animals.

True's beaked whales are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Recordings of True's beaked whales in the western North Atlantic included frequency-modulated clicks with median peak frequencies of 43.1 and 43.5 kHz and median inter-click-intervals of 0.17 s and 0.19 s (DeAngelis et al. 2018). Beaked whales appear to be particularly sensitive to underwater sonar and there has been evidence of overlap between beaked whale strandings and military mid-frequency sonar (2–10 kHz) and air 59 gun arrays (Barlow and Gisiner 2006).

4.2.26.1. Distribution

True's beaked whales occur in temperate waters, and possibly only in warm temperate waters, of the North Atlantic (Macleod et al. 2005). This is where most records have been documented, suggesting a probable relation with the Gulf Stream (Mead 1989a, Macleod 2000). Much of the available characterization for beaked whales is to genus level only and the stock structure for each species is unknown (Hayes et al. 2020). Most of the distributions of *Mesoplodon* spp. in the Northwest Atlantic come from stranding records. Like other beaked whales, they tend to be found in deep, off-shelf areas. True's beaked whales have been reported off the US Atlantic coast from Cape Breton Island, Nova Scotia, to the Bahamas (Leatherwood et al. 1976; Mead 1989; MacLeod et al. 2006; Jefferson et al. 2008). Recent strandings in the US Atlantic coast (2013–2017) have been reported from New York south to Georgia.

True's beaked whales were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of True's beaked whales in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b). These data suggest that True's beaked whales are rarely, if at all, present in the MA and RI/MA WEAs.

4.2.26.2. Abundance

The best abundance estimate for *Mesoplodon* beaked whales is 10,107 (CV=0.27) (NOAA Fisheries 2021aa). This estimate comes from the sum of the 2016 survey estimates conducted in US waters of the western North Atlantic (Garrison 2020, Palka 2020). The minimum population estimate for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 8,085 (NOAA Fisheries 2021aa). A population trend analysis has not been conducted for this stock. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5. PBR for undifferentiated *Mesoplodon* beaked whales in the western North Atlantic is 81.

4.2.26.3. Status

True's beaked whales are not listed as threatened or endangered under the ESA or MA ESA and the western North Atlantic stock is not considered strategic under the MMPA. The status of True's beaked whales relative to OSP in US Atlantic EEZ is unknown (NOAA Fisheries 2021aa). During 2013–2017, six True's beaked whales were reported stranded in New York, Virginia, and Georgia; one of which showed evidence of a fishery interaction. Threats to this species likely include contaminant effects on health and reproduction, underwater noise, and climate-related changes (D'Amico et al. 2009, Filadelfo et al. 2009, Hayes et al. 2020).The permanent closure of the pelagic drift gillnet fishery has eliminated the principal known source of incidental fishery mortality, and only one fishery-related mortality and serious injury has been reported during the recent five-year (2013–2017) period (NOAA Fisheries 2021aa). Therefore, total US fishery-related mortality and serious injury rate can be considered to be insignificant and approaching zero.

4.2.27. White-Beaked Dolphin (*Lagenorhynchus albirostris*)

White-beaked dolphins are mostly dark gray with light gray or white patches on their sides, back and underside (Fisheries 2021). They have a streamlined body and can reach lengths of 2.4 to 3.2 m (8 to 10.5 ft). White-beaked dolphins have a small beak with white "lips" and a large, tall, curved dorsal fin. This species' diet includes squid, octopus, clupeids, gadids, hake, and some benthic crustaceans (Leatherwood and Reeves 1983, Reeves et al. 1999). They typically work together to catch fish at the surface but also feed along the ocean bottom. White-beaked dolphins are active swimmers and often breach and jump at the surface and surf the waves created by vessels (Fisheries 2021). They travel in groups of five to 30 individuals but sometimes are found in groups of up to 1,500 individuals. White-beaked dolphins are sometimes seen in groups with other species, such as fin whales, humpback whales, sei whales and other small dolphins.

White-beaked dolphins are in the mid-frequency functional hearing group (Southall et al. 2007). (Nachtigall et al. 2008) studied white-beaked dolphins in Iceland and demonstrated the species' sensitive high frequency hearing, reporting the audiogram of an adult male audiogram ranged from 16 to 181 kHz. Like many dolphins, this species produces both whistles and clicks (Rasmussen and Miller 2002). White-beaked dolphins' clicks have high peak frequencies of 106 kHz to 115 kHz and are usually produced at rapid rates. Reeves et al. (1999), described "squeals" in the range of 6.5 kHz to 15 kHz. Burst-pulse vocalizations were reported for the white-beaked dolphins near Halifax, Canada with a mean duration of 0.83 s and a mean pulse rate of 765 Hz (Simard et al. 2008)..

4.2.27.1. Distribution

White-beaked dolphins are generally abundant and have an extensive range throughout the temperate and subarctic North Atlantic (Kinze 2009, Hayes et al. 2020). Along the US east coast, they are found from Cape Cod, Massachusetts, north into Canadian waters (Reeves et al. 1999). In waters off the northeastern US coast, white-beaked dolphin sightings are concentrated in the western Gulf of Maine and around Cape Cod ([CeTAP] Cetacean and Turtle Assessment Program 1982). The species' range can overlap with that of the Atlantic white-sided dolphin, but the white-beaked dolphin tends to be a more coastal, cooler-water species. As white-beaked dolphins move north following the movement of colder waters, white-sided dolphins likely expand their range to the north in summer. White-beaked dolphins seem to remain at relatively high latitudes throughout the fall and winter, but not much is known about seasonal movements (Lien et al. 1997). Seasonal movements may also be tied to the spawning concentrations of capelin (Mallotus villosus) (Lien et al. 1997). Ice entrapment may occur in the bays of southern Newfoundland between February and April (Hai et al. 1996).

White-beaked dolphins were not observed during surveys conducted between 2011–2015 in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Kraus et al. (2016) results suggest that white-beaked dolphins occur rarely, if at all, in the MA and RI/MA WEAs and surrounding areas. However, during a 2019 geotechnical and geophysical survey in or adjacent to the Offshore Development Area, one group of 30 white-beaked dolphins were observed during the summer (Vineyard Wind 2020d). It is possible that the NLPSC surveys underestimated the abundance of white-beaked dolphins because these surveys were designed to target large cetaceans. No sightings of white-beaked dolphins occurred during the 2018–2019 and 2020 surveys; however, there were some observations of small delphinids that could not be identified to species (O'Brien et al. 2020a, O'Brien et al. 2020b).

4.2.27.2. Abundance

The best abundance estimate for the western North Atlantic white-beaked dolphin is 536,016 (CV=0.31) (NOAA Fisheries 2021aa). This is an estimate derived from aerial survey data collected during the Canadian Northwest Atlantic International Sightings Survey (NAISS) survey in the summer of 2016 (Lawson and Gosselin 2018). The minimum population estimate for these white-beaked dolphins is 415,344 (NOAA Fisheries 2021aa). There are insufficient data to determine population trends for this species. Current and maximum net productivity rates are unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. The recovery factor is assumed to be 0.5 because this stock is of unknown status. PBR for the western North Atlantic white-beaked dolphin is 4,153.

4.2.27.3. Status

White-beaked dolphins are not listed as threatened or endangered under the ESA, and the western North Atlantic stock is not considered strategic under the Marine Mammal Protection Act. The status of white-beaked dolphins, relative to OSP, in US Atlantic coast waters is unknown (NOAA Fisheries 2021aa). A total of 5 white-beaked dolphin strandings occurred on the US Atlantic coast between 2013–2017, 4 of which were in Massachusetts, and one of which was in North Carolina. Threats to this species likely include contaminant effects on health and reproduction, and climate-related changes (NOAA Fisheries 2021aa). The total documented US fishery-related mortality and serious injury for this stock (0) is less than 10% of the calculated PBR (4.153) and, therefore, is considered to be insignificant and at zero mortality and serious injury rate.

4.2.28. Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise is abundant throughout the coastal waters of the Northern Hemisphere and the only porpoise species found in the Atlantic Ocean. This species is a small, stocky cetacean with a blunt, short-beaked head, dark gray back, and white underside (NOAA Fisheries 2021v). Harbor porpoises reach a maximum length of 1.8 m (6 ft) and feed on a wide variety of small fish and cephalopods (Reeves and Read 2003, Kenney and Vigness-Raposa 2010). Most harbor porpoise groups are small, usually between 5 and 6 individuals, although they aggregate into large groups for feeding or migration (Jefferson et al. 2008).

The harbor porpoise is considered a high-frequency cetacean (Southall et al. 2007). The dominant component of harbor porpoise echolocation signals are narrowband high-frequency clicks within 130 to 142 kHz (Villadsgaard et al. 2007).

4.2.28.1. 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 (656 ft) deep (NOAA Fisheries 2021v). Hayes et al. (2021) 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 (July to September). During fall (October to December) and spring (April to June), they are more widely dispersed from New Jersey to Maine. In winter (January to March), intermediate densities of harbor porpoises can be found in waters off New Jersey to North Carolina with lower densities found in waters off New York to New Brunswick, Canada (Hayes et al. 2021). 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 (Hayes et al. 2021). Harbor porpoises observed within the US Atlantic EEZ are considered part of the Gulf of Maine/Bay of Fundy stock.

Kraus et al. (2016) indicate that harbor porpoises occur within the MA and RI/MA WEAs in fall, winter, and spring. Harbor porpoises were observed in groups ranging in size from 3 to 15 individuals and were primarily observed in the Kraus et al. (2016) study area from November through May, with very few sightings during June through September. During more recent surveys (October 2018-August 2019), harbor porpoises accounted for 15% of small cetacean sightings, and were seen in all seasons except fall (O’Brien et al. 2020a). They were distributed father north in the MA and RI/MA WEAs than the other small cetacean species, and many sightings occurred outside of the lease areas. The most recent surveys between March and October 2020 only revealed two sightings of single harbor porpoises, and both observations were in summer (O’Brien et al. 2020b).

4.2.28.2. Abundance

According to data collected in 2016 by NEFSC and DFO, the best abundance estimate for harbor porpoises is 95,543 individuals (NOAA Fisheries 2021aa). The total annual estimated human-caused mortality and serious injury is 217 harbor porpoises per year based on fisheries observer data (NOAA Fisheries 2021aa).

4.2.28.3. Status

Harbor porpoises are not listed as Threatened or Endangered under the ESA or the MA ESA or designated as a strategic stock under the MMPA.

4.3. Pinnipeds

Four species of pinnipeds are known to occur or could potentially occur in the Atlantic Ocean near the SWDA: the harbor seal, gray seal, harp seal, and hooded seal. Like all pinnipeds, these animals have an amphibious lifestyle and are found nearshore (especially near their haul-out/ breeding sites) as well as in offshore waters. All four seal species are phocids, or true seals, having no external ears. The habitat range of hooded seals is typically outside the SWDA, usually in deeper water, so they are rarely sighted. The remaining three pinniped species are most likely to occur in the region during winter and early spring.

4.3.1. Gray Seal (*Halichoerus grypus*)

Gray seals are the second most common pinniped on the US Atlantic coast (Jefferson et al. 2008). This species inhabits temperate and sub-arctic waters and lives on remote, exposed islands, shoals, and unstable sandbars (Jefferson et al. 2008). Gray seals are large, reaching 2–3 m (7–10 ft) in length, and have a silver-gray coat with scattered dark spots (NOAA Fisheries 2021u). These seals are generally gregarious and live in loose colonies while breeding (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 (Lesage and Hammill 2001, Jefferson et al. 2008). These opportunistic feeders primarily consume fish, crustaceans, squid, and octopus (Bonner 1971, Reeves 1992, Jefferson et al. 2008). They often co-occur with harbor seals because their habitat and feeding preferences overlap (NOAA Fisheries 2021u).

Gray seals, as with all pinnipeds, are assigned to functional hearing groups based on the medium (air or water) through which they are detecting the sounds, and have an estimated auditory bandwidth of 75 Hz to 75 kHz (Southall et al. 2007). Vocalizations range from 100 Hz to 3 kHz (DoN 2008).

4.3.1.1. Distribution

The gray seal ranges from Canada to New York; however, there are stranding records as far south as Cape Hatteras, North Carolina (Gilbert et al. 2005). The eastern Canadian population of gray seals ranges from New Jersey to Labrador and is centered at Sable Island, Nova Scotia (Davies 1957, Mansfield 1966, Richardson and Rough 1993, Lesage and Hammill 2001). There are three breeding concentrations in eastern Canada: Sable Island, Gulf of St. Lawrence, and along the east coast of Nova Scotia (Lavigueur and Hammill 1993). In US waters, gray seals primarily pup at four established colonies: Muskeget and Monomoy islands in Massachusetts, and Green and Seal Islands in Maine. Since 2010, pupping has also been observed at Noman's Island in Massachusetts and Wooden Ball and Matinicus Rock in Maine (Hayes et al. 2019). Although white-coated pups have stranded on eastern Long Island beaches in New York, no pupping colonies have been detected in that region. Gray seals have been observed using the historic pupping site on Muskeget Island in Massachusetts since 1988 (Hayes et al. 2019). Pupping has taken place on Seal and Green Islands in Maine since at least the mid-1990s (Hayes et al. 2019). Pupping was also observed in the early 1980s on small islands in Nantucket-Vineyard Sound and more recently at Nomans Island (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 some of the SWDA, with seasonal occurrence in the offshore areas from September to May (Hayes et al. 2018).

Kraus et al. (2016) observed gray seals in the MA and RI/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 (Kraus et al. 2016). During the continuation of surveys in the MA and RI/MA WEAs between October 2018 and August 2019, three gray seals were observed during three sightings (O'Brien et al. 2020a). A further 77 sightings were made of 3963 unidentified seals however, so it is likely their abundance based on this survey is underestimated. Three unidentified seals were sighted during the March to October 2020 surveys (O'Brien et al. 2020b).

Gray seals were observed on two occasions during the 2016 G &G survey and two additional occasions in the 2017 survey in the SWDA (Vineyard Wind 2016, 2017).

4.3.1.2. Abundance

The gray seal is found on both sides of the North Atlantic, with three major populations: Northeast Atlantic, Northwest Atlantic, and the Baltic Sea (Haug et al. 2013). The Western North Atlantic stock is equivalent to the Northwest Atlantic population, and ranges from New Jersey to Labrador (Mansfield 1966, Scott et al. 1990, Katona et al. 1993, Lesage and Hammill 2001). For US waters alone, there is an estimated an abundance of 27,300 (NOAA Fisheries 2021aa). All seal species were modeled together as one guild (Roberts et al. 2016a, 2018).

4.3.1.3. Status

Gray seals are not listed as Threatened or Endangered under the ESA or the MA ESA and are not considered strategic under the MMPA.

4.3.2. Harbor Seal (*Phoca 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 (Hayes et al. 2021). This species is approximately 2 m (7 ft) in length and has a blue-gray back with light and dark speckling (NOAA Fisheries 2021ab). Harbor seals complete both shallow and deep dives during hunting, depending on the availability of prey (Tollit et al. 1997). This species consumes a variety of prey, including fish, shellfish, and crustaceans (Bigg 1981, Reeves 1992, Burns 2002, Jefferson et al. 2008). Harbor seals commonly occur in coastal waters and on coastal islands, ledges, and sandbars (Jefferson et al. 2008).

Male harbor seals produce underwater vocalizations during mating season to attract females and defend territories. These calls are comprised of "growls" or "roars" with peak energy at 200 Hz (Sabinsky et al. 2017). Captive studies have shown that harbor seals have good (>50%) sound detection thresholds between 0.1 and 80 kHz, with primary sound detection between 0.5 and 40 kHz (Kastelein et al. 2009).

4.3.2.1. Distribution

Harbor seals are year-round inhabitants of the coastal waters of eastern Canada and Maine (Richardson and Rough 1993) and occur seasonally from southern New England to New Jersey between September and late May (Schneider and Payne 1983, Barlas 1999, Schroeder 2000). In the Western North Atlantic, they are distributed from eastern Canada to southern New England and New York, and occasionally as far south as the Carolinas (Payne and Selzer 1989). A general southward movement from the Bay of Fundy to southern New England occurs in fall and early winter (Rosenfeld et al. 1988, Whitman and Payne 1990, Barlas 1999, Jacobs and Terhune 2000). 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 (Richardson 1976, Wilson 1978, Whitman and Payne 1990, Kenney 1994).

Kraus et al. (2016) observed harbor seals in the MA and RI/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 (Kraus et al. 2016). Harbor seals have five major haul-out sites in and near the MA and RI/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 (Payne and Selzer 1989). Increased abundance of seals in the northeast region has also been documented during aerial and boat surveys of overwintering haul-out sites from the Maine/New Hampshire border to eastern Long Island and New Jersey (Payne and Selzer 1989, Rough 1995, Barlas 1999, Hoover et al. 1999, Slocum et al. 1999, deHart 2002). A total of 77 sightings were made of 3963 unidentified seals during the surveys that occurred between October 2018 and August 2019, and three unidentified seals were sighted during the March to October 2020 surveys (O’Brien et al. 2020a, O’Brien et al. 2020b). Based on their known distribution in the MA and RI/MA WEAs and surrounding areas, it is likely that some harbor seals were included in the unidentified seal sightings.

4.3.2.2. 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 (Temte et al. 1991, Andersen and Olsen 2010). The best estimate of abundance for harbor seals in the Western North Atlantic stock is 61,336 (NOAA Fisheries 2021aa). This estimate was derived from a coast-wide survey along the coast of Maine during May and June 2012.

4.3.2.3. 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.

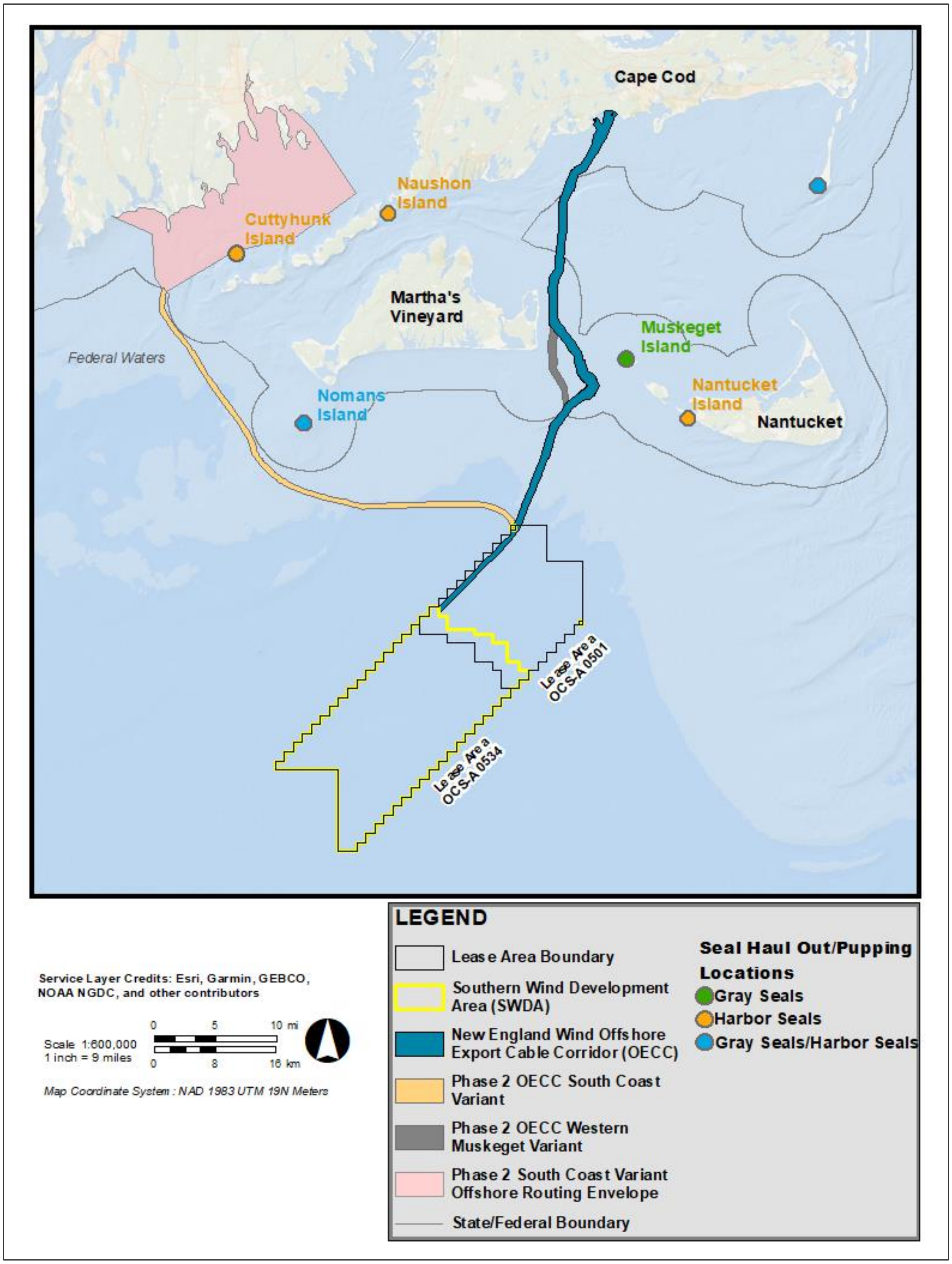

Figure 16. Major haul-outs of harbor seals and pupping locations of gray seals near the SWDA and OECC.

4.3.3. Harp Seal (Pagophilus groenlandicus)

The harp seal is found throughout the North Atlantic and Arctic Oceans (Lavigne and Kovacs 1988). 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 2018c). Harp seals complete shallower dives relative to other pinnipeds (Schreer and Kovacs 1997). This species consumes a variety of species of finfish and invertebrates, mainly capelin, cod (Gadidae), and krill (NOAA Fisheries 2018c).

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 more northern Canadian waters (Sergeant 1965, Lavigne and Kovacs 1988). The most southerly point of observation for this species has been New Jersey, from January through May (Harris et al. 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 2018c). A total of 77 sightings were made of 3963 unidentified seals during aerial surveys in the MA and RI/MA WEAs that occurred between October 2018 and August 2019, and three unidentified seals were sighted during the March to October 2020 surveys (O’Brien et al. 2020a, O’Brien et al. 2020b). It is possible that some harp seals were included in the unidentified seal sightings.

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 (Lavigne and Kovacs 1988, Bonner 1990). The best estimate of abundance for harp seals in the Western North Atlantic stock is 7.6 million (NOAA Fisheries 2021aa).

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.

4.3.4. Hooded Seal (*Cystophora cristata*)

Hooded seals reach lengths of up to 1.9 to 2.6 m (6.5 to 8.5 ft), with males being larger than females (NOAA fisheries 2022e). Adults have silver-gray fur with darker patches across their bodies. Pups have blue-gray fur and whitish bellies. Hooded seals have a stretchy cavity in their nose. Sexually mature males can inflate a partition in their nose, appearing like a red balloon, to attract females during mating season. They feed on fish, squid, starfish and mussels. Hooded seals are not social and remain alone for most of the year, migrating seasonally.

Hooded seals, as with all pinnipeds, are assigned to functional hearing groups based on the medium (air or water) through which they are detecting the sounds, and have an estimated auditory bandwidth of 75 Hz to 75 kHz (Southall et al. 2007). Ballard and Kovacs (1995) recoded the airborne and waterborne vocalization of hooded seals in the Gulf of St. Lawrence during breeding seasons and identified three major classes of sounds containing five call types. Underwater sounds are typically broadband and pulsed. In a more recent study using passive acoustics in the Gulf of St. Lawrence, the most common underwater calls recorded included a repetitive whooping sound centered around 920 Hz and a paired pulsed signal centered around 630 Hz (Frouin-Mouy and Hammill 2021). Another study found that captive hooded seals reacted to 1–7 kHz sonar signals, in part with displacement to the areas of least SPL, at levels between 160 and 170 dB re 1 μPa (Kvadsheim et al. 2010b).

4.3.4.1. Distribution

Hooded seals are found in the Arctic Ocean and in high latitudes of the North Atlantic and prefer deeper and further offshore waters than harp seals (Hayes et al. 2019). Hooded seals are highly migratory and may wander as far south as Puerto Rico (Mignucci-Giannoni and Odell 2001). These extra-limital appearances usually occur between January and May in New England waters, and in summer and autumn off the southeast US coast and in the Caribbean (McAlpine and Rae 1999, Harris et al. 2001, Mignucci-Giannoni and Odell 2001). The hooded seal population has been separated into three stocks, each identified with a specific breeding site (Lavigne and Kovacs 1988, Stenson et al. 1997): Northwest Atlantic, Greenland Sea ("West Ice"), and White Sea ("East Ice") (Hayes et al. 2019). The Western North Atlantic stock whelps off the coast of eastern Canada and is divided into three whelping areas. The Front herd (largest) breeds off the coast of Newfoundland and Labrador. The Gulf herd breeds in the Gulf of St. Lawrence. The third breeding area is in the Davis Strait. Adult hooded seals begin to congregate in thick pack ice in February. After the short breeding season, hooded seals disperse widely, with most individuals moving north and east towards the Denmark Strait (Lavigne and Kovacs 1988). Little is known on this species after the breeding and molting periods.

Hooded seals were not observed during the 2011–2015 surveys conducted in the MA and RI/MA WEAs and surrounding areas (Kraus et al. 2016). Recent continuations of the surveys, conducted between 2018–2020, did not result in any sightings of hooded seals in MA and RI/MA WEAs (O'Brien et al. 2020a, O'Brien et al. 2020b); although these surveys were designed to target large cetaceans.

4.3.4.2. Abundance

Abundance estimates for western North Atlantic hooded seals are unknown (NOAA Fisheries 2021aa). Present data are insufficient to calculate the minimum population estimate for US waters. The total Northwest Atlantic hood seal population size has increased from 478,000 in 1965 to 593,500 in 2005 (Hammill and Stenson 2006), however, uncertainty makes it difficult to reliably assess the population trend. The maximum productivity rate is 0.12, the default value for pinnipeds (Hayes et al. 2019). The recovery factor for this stock is 1.0, the value for stocks of unknown status, but which are known to be increasing. PBR for the portion of the western North Atlantic hooded seal stock in US waters is unknown.

4.3.4.3. Status

The hooded sea is not listed as threatened or endangered under the ESA or MA ESA and is not considered strategic under the Marine Mammal Protection Act. The status of hooded seals relative to OSP in US Atlantic EEZ is unknown (Hayes et al. 2019). From 2012 to 2016, four hooded seal stranding mortalities were reported, three in Massachusetts and one in New York, none of which had evidence of human interaction. Threats to this species likely include fisheries interactions and climate-related changes (Richardson et al. 1995, Hayes et al. 2020). For the period 2012–2016, the average estimated human caused mortality and serious injury to hooded seals was 1,680 per year in the US, Canada, and Greenland. The total US fishery-related mortality and serious injury for this stock is very low relative to the stock's size and can be considered insignificant and approaching zero mortality and serious injury rate.

5. Statement of Request

The Proponent is requesting a letter of Authorization (LOA) pursuant to Section 101(a)(5)(A) of the MMPA for the incidental take by both Level A and Level B harassment of small numbers of marine mammals during the construction activities described in Section 1.2 for a period up to 5 years beginning **January 2025**, when HRG surveys are planned to start. Although exposure estimates predicted from modeling results indicate that Level A takes are zero or negligible when sound attenuation mitigation is employed during pile driving, Level A takes associated with pile driving are being requested for a limited number of species 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, if possible, the operator will power down the hammer energy. Level A take is also being requested for potential UXO detonation, which may be required if they are encountered during construction activities, such as cable laying, and avoidance, physical removal, or alternative combustive removal is not feasible.

The mitigation measures described in Section 11 are designed to minimize the likelihood that Level A takes of any marine mammal species will occur. The Proponent will use two noise abatement systems (NAS) for monopiles and up to two NAS for jackets (such as a bubble curtain and an encapsulated bubble or foam sleeve) to reduce sound levels by a minimum 10 dB with a target of 12 dB or greater. Additional mitigation measures (e.g., clearance zones, shutdown zones) focused on ensuring that no Level A harassment of a NARW will occur include restricting pile driving to months when NARWs are unlikely to be present in the SWDA, and significant NARW monitoring efforts. Monitoring and mitigation to avoid and reduce the potential for Level A harassment will also reduce the risk of Level B harassment during pile driving activities.

NOAA has determined that some types of HRG sources that operate at and below 180 kilohertz (kHz) have the potential to cause Level B harassment within a short distance of disturbance from the sound source. Additionally, vibratory hammering could be used in the setting of piles and drilling may be required in the case of pile refusal. These activities also generate sound that could expose marine mammals to sound levels above acoustic threshold. Level B harassment is also being requested for HRG surveys, vibratory setting of piles should it be required to avoid pile run and drilling of sediments should pile refusal occur. Sounds from other construction activities, including Project-related vessel activity, topside installation, scour protection, and cable laying were considered (Appendix A). These activities are not expected to contribute significantly to the acoustic footprint of New England Wind construction activities (see Section 1.1 for a description of these activities), since most sound associated with these construction activities is likely to be similar to routine vessel traffic sounds, already present in the area.

6. Take Estimates for Marine Mammals

Marine mammal take estimates were calculated for the five sound-producing activities that could result in marine mammal Level A or Level B harassment based on real-world densities of each species, estimates of ensonified areas, and the timing and intensity of the various construction activities. The details of marine mammal occurrence used in the exposure calculations including densities, group sizes, and PSO data are provided in Section 6.1. The methods used to estimate marine mammal exposures are described in detail in the following subsections for impact pile driving (Section 6.2), potential vibratory hammering for setting piles (Section 6.3), potential drilling in the event of pile refusal (Section 6.4), potential UXO detonation (Section 6.5), and HRG surveys (Section 6.6). Section 6.7 describes how the exposure estimates for the various activities were converted into take estimates and section 6.8 compiles the takes into a single request.

6.1. Marine Mammal Occurrence Used in Exposure Estimation

6.1.1. Marine Mammal Densities

Mean monthly marine mammal density estimates (animals per 100 square kilometers [animals/100 km^2]) for all modeled species were calculated using the Duke University Marine Geospatial Ecology Laboratory (MGEL) habitat-based marine mammal density models for the US Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b). Densities in the Duke/MGEL models are provided as the number of animals per 100 km^2 and are given for each 10 km x 10 km grid cell in the US Atlantic for most species, with a cell size of 5 km x 5 km for the North Atlantic right whale (NARW). The 2021 updated NARW model (v11.1) that includes new estimates for NARW abundance in Cape Cod Bay in December (Roberts et al. 2016a, 2021a, 2021b) was used. In the 2021 updated model (Roberts et al. 2016a, 2021a, 2021b), NARW densities are provided for three time periods, 2003–2018, 2003–2009, and 2010–2018, to reflect the apparent shift in NARW distribution around 2010. The modeling conducted in support of this LOA application used the 2010–2018 NARW density predictions from the 2021 model updates (Roberts et al. 2016a, 2021a, 2021b) because these are likely to most accurately reflect current densities given that NARWs appear to have shifted their distribution in the period since 2010.

The mean density for each month was determined by calculating the unweighted mean of all 10 × 10 km (5 × 5 km for NARW) grid cells partially or fully within the analysis polygon. The analysis polygon was defined for each sound-producing activity based on its predicted impact area. These are defined for the different activities in Sections 6.1.1.1 through 6.1.1.5. Where the analysis polygon overlaps with land, grid cells entirely on land were not included but cells that overlapped only partially with land were included. For long- and short-finned pilot whales, monthly densities are unavailable from Roberts et al. (2016a, 2016b, 2017), so annual mean densities were used instead. Additionally, Roberts et al. (2016a, 2016b, 2017) provide density for pilot whales as a guild that includes both species, so their densities were scaled by their relative stock sizes based on the best available abundance estimate from NOAA Fisheries SARs (Hayes et al. 2021). Equation 1 shows an example of how abundance scaling is applied to compute density for short-finned pilot whales.

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned}+a_{long-finned}}\right), \quad (1)$$

where a represents abundance and d represents density. Similarly, the Duke/MGEL densities are provided for seals as a guild consisting primarily of harbor and gray seals (Roberts et al. 2016a, 2018).

Gray and harbor seal densities were scaled by relative abundance. However, density estimates are unavailable for the harp seal in the SWDA, so the lower of the two (i.e., the gray seal density) was used as a surrogate density for that species as a conservative measure. This is likely to overestimate impacts to harp seals because they are thought to be uncommon in the area and generally are only present in New England waters during January through May (Harris et al. 2002).

6.1.1.1. Densities Used for Impact Pile Driving Analysis

For impact pile driving, densities were computed monthly, annually, and for the May through December period to coincide with proposed pile driving activities (Table 10) within a 6.2 km buffered polygon around the SWDA perimeter (Figure 17). The buffer size was selected as the largest 10 dB-attenuated exposure range for all species, scenarios, and threshold criteria (see Table 23 – range to 160 dB SPL behavioral threshold for fin whale, for the installation of one 12 m monopile per day with a 6,000 kJ hammer and with 10 dB attenuation), with the exception of the Wood et al. (2012) thresholds. Wood et al. (2012) exposure ranges were not considered in this estimate since they include a small subset of very long ranges for migrating mysticetes and harbor porpoise.

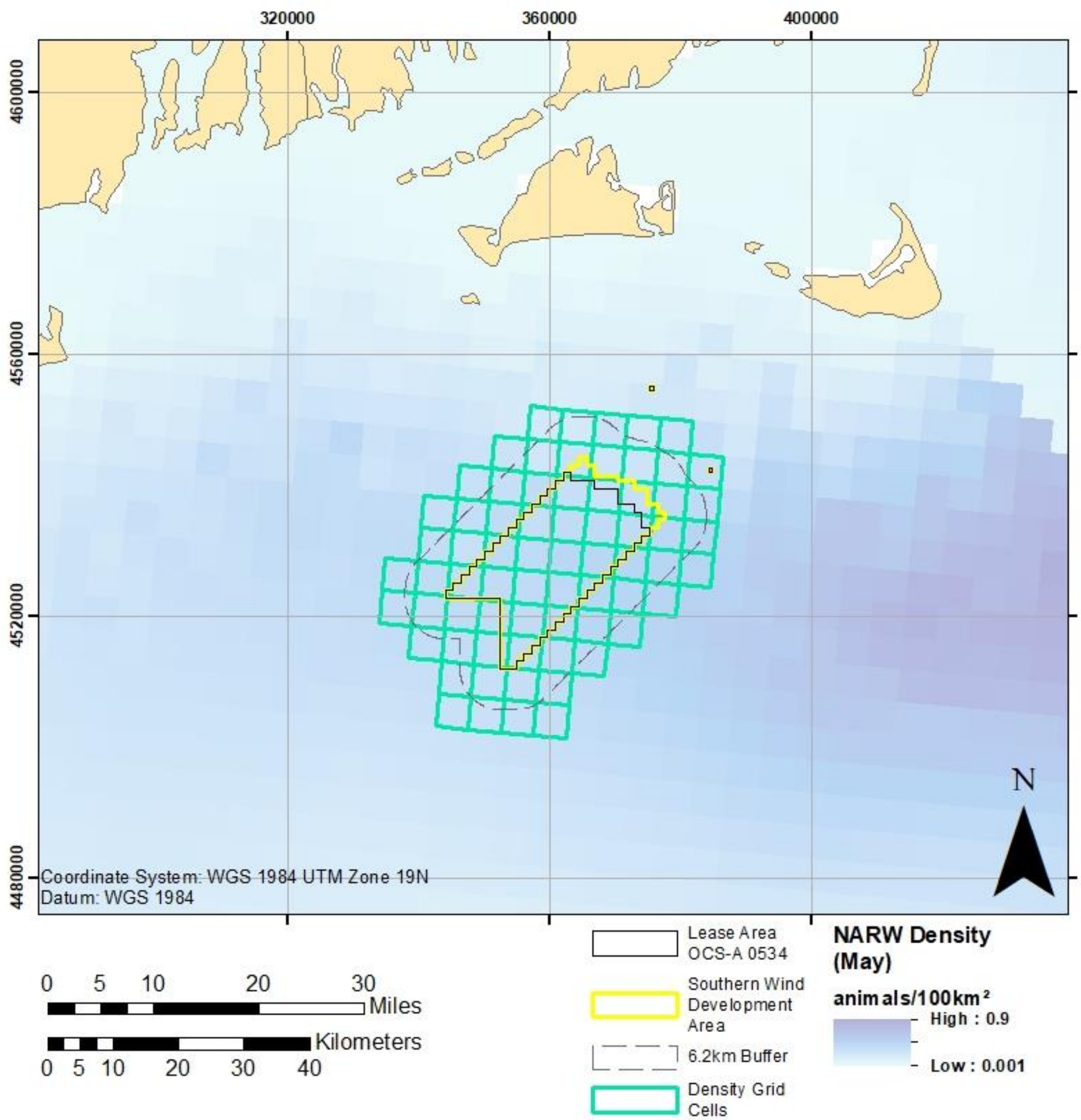

Figure 17. Marine mammal (e.g., NARW) density map (Roberts et al. 2016a, 2021a, 2021b) showing highlighted grid cells used to calculate mean monthly species density estimates within a 6.2-km buffer around New England Wind, based on the longest exposure range to threshold for impact pile driving. Note that the modeled densities are in units of animals/100 km^2, even when grid cells are 5 × 5 km.

Table 10. Mean monthly marine mammal density estimates for all modeled species in a 6.2-km buffer around New England Wind, based on the longest exposure range to threshold for impact pile driving.

Species	Monthly density (animals/100 km^2)												Annual mean	May to Dec mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Fin whale[a]	0.214	0.184	0.178	0.325	0.368	0.369	0.390	0.352	0.280	0.157	0.152	0.159	0.261	0.278
Minke whale	0.065	0.081	0.083	0.181	0.263	0.243	0.087	0.061	0.063	0.074	0.033	0.047	0.107	0.109
Humpback whale	0.030	0.018	0.030	0.221	0.179	0.170	0.123	0.063	0.236	0.196	0.063	0.026	0.113	0.132
North Atlantic right whale[a]	0.660	0.780	0.811	0.904	0.362	0.023	0.004	0.003	0.004	0.010	0.051	0.264	0.323	0.090
Sei whale[a]	0.002	0.002	0.001	0.047	0.047	0.027	0.007	0.004	0.007	0.001	0.002	0.002	0.012	0.012
Atlantic white-sided dolphin	3.881	2.083	2.242	4.317	8.263	7.805	5.504	3.109	2.957	3.698	4.042	5.834	4.478	5.152
Atlantic spotted dolphin	0.002	0.002	0.003	0.013	0.025	0.034	0.070	0.124	0.137	0.124	0.075	0.009	0.052	0.075
Short-beaked common dolphin	16.930	2.935	1.174	3.016	5.785	5.909	6.401	11.882	20.783	23.516	16.500	29.286	12.010	15.008
Bottlenose dolphin, offshore	0.678	0.042	0.013	0.485	0.556	0.650	1.336	1.338	2.671	3.296	1.497	0.768	0.000	0.000
Risso's dolphin	0.016	0.007	0.003	0.003	0.011	0.012	0.029	0.056	0.043	0.015	0.025	0.042	0.022	0.029
Long-finned pilot whale[b]	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Short-finned pilot whale[b]	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461
Sperm whale[a]	0.002	0.003	0.002	0.002	0.003	0.008	0.036	0.038	0.008	0.008	0.008	0.002	0.010	0.014
Harbor porpoise	4.592	8.200	15.828	10.293	4.762	0.932	0.669	0.648	0.538	0.260	0.862	1.980	4.130	1.331
Gray seal[c]	0.653	2.225	2.470	2.818	3.070	0.267	0.047	0.027	0.059	0.091	0.055	0.349	1.011	0.496
Harbor seal[c]	1.466	4.999	5.549	6.331	6.897	0.599	0.106	0.061	0.132	0.205	0.124	0.784	2.271	1.114
Harp seal[c]	0.653	2.225	2.470	2.818	3.070	0.267	0.047	0.027	0.059	0.091	0.055	0.349	1.011	0.496

[a] Listed as Endangered under the ESA.
[b] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[c] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

6.1.1.2. Densities Used for Vibratory Setting of Piles Analysis

Acoustic measurements of vibratory pile driving of large monopiles are unavailable; however, vibratory driving of 72-inch steel pipe piles has an apparent source level of SPL ~167–180 dB re 1 µPa at 10 m (Molnar et al. 2020). Recognizing that the maximum pile size of this Project is larger than 72 inches, it is assumed that these source levels may not be indicative of what would be measured during construction of the Project.

Animals are not expected to experience a behavioral response at distances greater than 50 km (Dunlop et al. 2017a; Dunlop et al. 2017b); therefore, this range is assumed as the cut off for Level B exposures. Furthermore, the source level necessary to produce a received level of 120 dB at 50 km was calculated. Assuming practical spreading loss (15 Log(range)), a source level of 190.5 dB will result in received levels of 120 dB at 50 km. Because vibratory driving of 72-inch steel pipe piles has an apparent source level of SPL ~167–180 dB re 1 µPa (Molnar et al. 2020), it is assumed that the sound source level for a 13 m pile would exceed these measurements and that the behavioral threshold would exceed 50 km. Therefore, all animals within a 50-km radius around a given foundation location would be exposed above the 120 dB SPL threshold for any given day on which vibratory setting was used for pile installation.

Thus, the density grid area used in the density calculations (cells entirely on land were not included, but cells that overlap only partially with land were included) represents a 50 km zone surrounding the SWDA (Figure 18). Table 11 shows the density estimates resulting from those calculations.

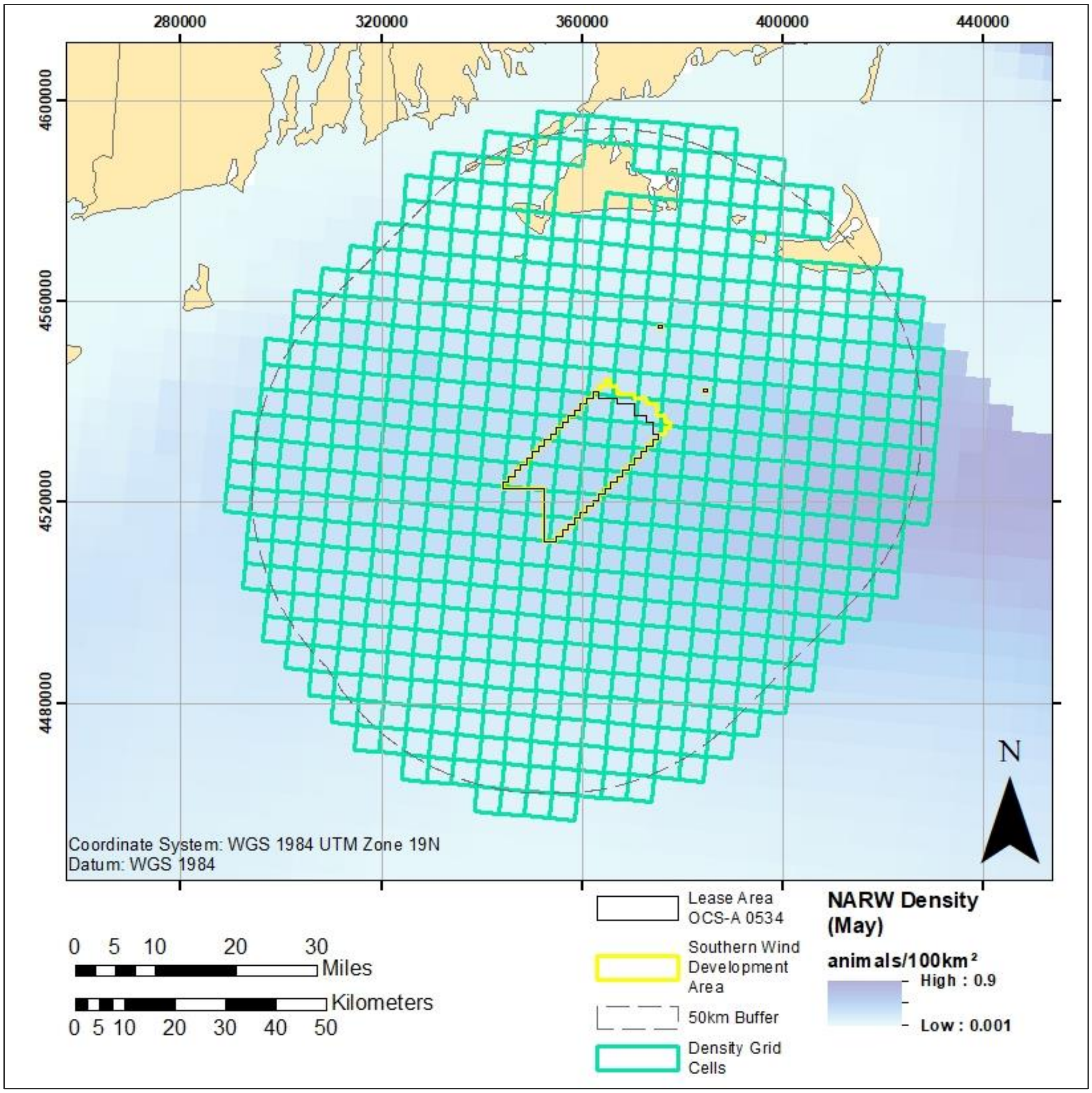

Figure 18. Marine mammal (e.g., NARW) density map (Roberts et al. 2016a, 2021a, 2021b) showing highlighted grid cells used to calculate mean monthly species density estimates within a 50 km buffer around New England Wind, used to estimate exposures to vibratory setting sounds above the 120 dB SPL criterion. Note that the modeled densities are in units of animals/100 km^2, even when grid cells are 5 × 5 km.

Table 11. Mean monthly marine mammal density estimates for all modeled species in a 50-km buffer around New England Wind, used to calculate exposures above the 120 dB behavioral threshold for vibratory setting sounds.

Species	Monthly density (animals/100 km^2)												Annual mean	May to Dec mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Fin whale[a]	0.173	0.169	0.193	0.331	0.327	0.334	0.348	0.316	0.276	0.183	0.148	0.151	0.246	0.260
Minke whale	0.055	0.068	0.070	0.166	0.268	0.240	0.095	0.062	0.064	0.080	0.029	0.040	0.103	0.110
Humpback whale	0.035	0.023	0.045	0.153	0.179	0.183	0.108	0.066	0.190	0.148	0.083	0.055	0.106	0.126
North Atlantic right whale[a]	0.517	0.607	0.640	0.694	0.276	0.020	0.003	0.002	0.003	0.008	0.045	0.247	0.255	0.076
Sei whale[a]	0.002	0.002	0.001	0.041	0.035	0.021	0.008	0.004	0.007	0.002	0.002	0.002	0.011	0.010
Atlantic white-sided dolphin	2.985	1.726	1.800	3.748	6.753	6.195	3.828	2.010	2.356	3.322	3.657	4.271	3.554	4.049
Atlantic spotted dolphin	0.002	0.001	0.003	0.013	0.027	0.050	0.092	0.127	0.127	0.179	0.066	0.008	0.058	0.084
Short-beaked common dolphin	15.796	4.541	2.212	4.236	6.703	8.475	7.293	10.472	14.493	17.788	13.446	20.900	10.530	12.446
Bottlenose dolphin, offshore	0.641	0.175	0.073	1.215	1.417	3.748	7.478	6.064	6.925	5.759	2.911	1.395	3.150	4.462
Risso's dolphin	0.044	0.025	0.013	0.016	0.036	0.052	0.116	0.213	0.136	0.052	0.051	0.086	0.070	0.093
Long-finned pilot whale[b]	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434
Short-finned pilot whale[b]	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320
Sperm whale[a]	0.005	0.006	0.005	0.008	0.012	0.014	0.032	0.030	0.012	0.011	0.009	0.004	0.012	0.015
Harbor porpoise	3.609	5.809	9.848	7.146	3.811	1.136	0.836	0.853	0.625	0.544	1.913	2.099	3.186	1.477
Gray seal[c]	3.446	2.735	2.749	5.640	5.551	1.733	0.386	0.199	0.228	0.474	1.138	3.669	2.329	1.672
Harbor seal[c]	7.743	6.145	6.176	12.672	12.471	3.893	0.866	0.447	0.513	1.065	2.556	8.244	5.233	3.757
Harp seal[c]	3.446	2.735	2.749	5.640	5.551	1.733	0.386	0.199	0.228	0.474	1.138	3.669	2.329	1.672

[a] Listed as Endangered under the ESA.
[b] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[c] Gray and harbor seal densities are the seals guild density scaled by the their relative abundances; gray seals are used as a surrogate for harp seals.

6.1.1.3. Densities Used for Drilling Analysis

An SPL of 140 dB re µPa at 1000 m (as measured by Austin et al. 2018) along with practical spreading loss was used to obtain an estimate of 21.5 km for the range to the 120 dB re µPa behavioral threshold for drilling sounds. The monthly density of each species was calculated as the average of all MGEL/Duke density cells overlapping partially or completely with a 21.5-km buffer of the SWDA.

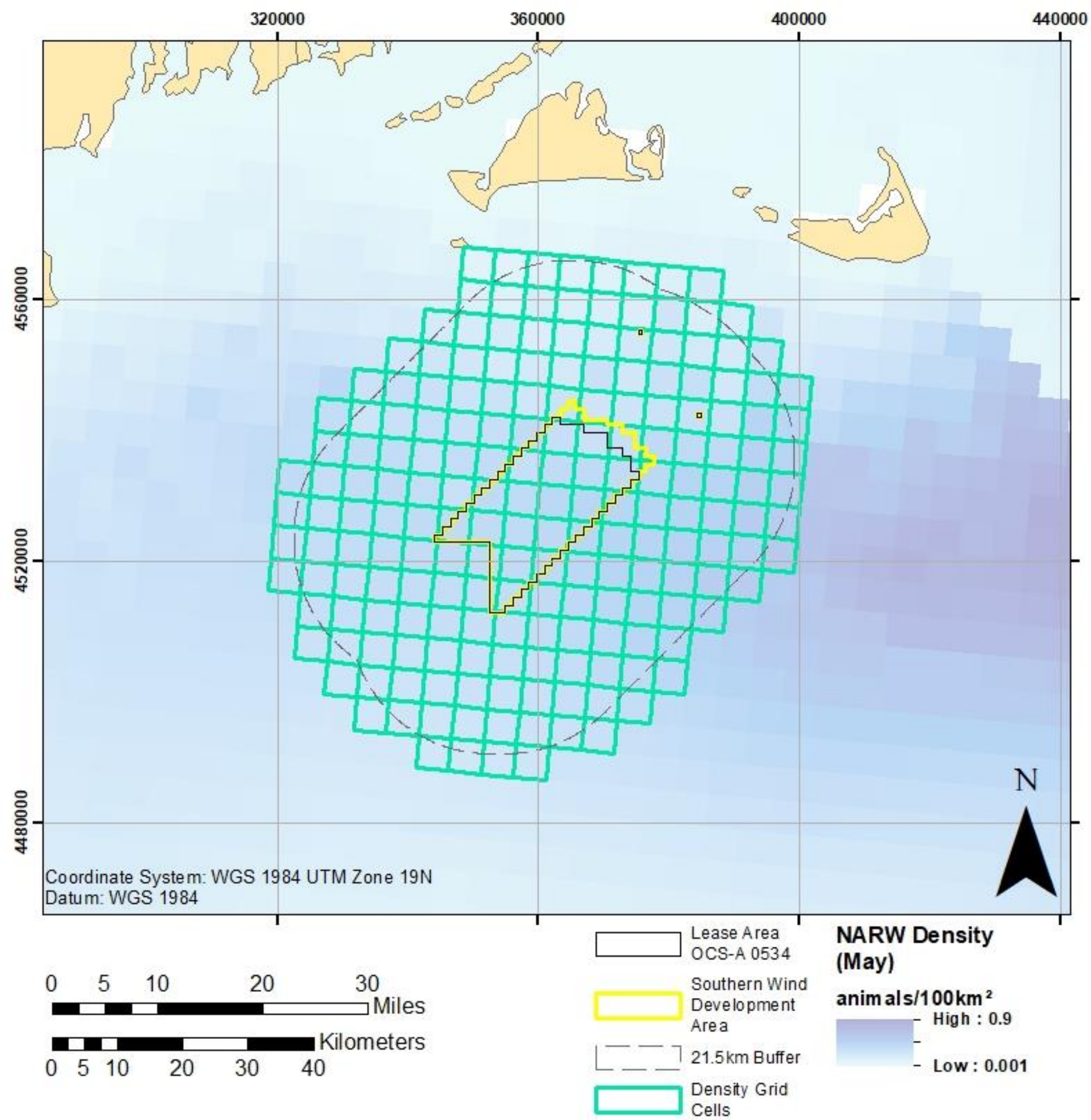

Figure 19. Marine mammal (e.g., NARW) density map (Roberts et al. 2016a, 2021a, 2021b) showing highlighted grid cells used to calculate mean monthly species density estimates within a 21.5 km buffer around New England Wind, used to estimate exposures to drilling sounds above the 120 dB SPL criterion. Note that the modeled densities are in units of animals/100 km^2, even when grid cells are 5 × 5 km.

Table 12. Mean monthly marine mammal density estimates for all modeled species in a 21.5-km buffer around New England Wind, used to calculate exposures above the 120 dB SPL behavioral threshold for drilling sounds.

Species	Monthly density (animals/100 km^2)												Annual mean	May to Dec mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Fin whale[a]	0.187	0.169	0.169	0.310	0.325	0.322	0.351	0.325	0.263	0.157	0.140	0.145	0.239	0.254
Minke whale	0.063	0.079	0.081	0.172	0.258	0.236	0.085	0.059	0.061	0.073	0.033	0.046	0.104	0.106
Humpback whale	0.030	0.018	0.031	0.177	0.157	0.153	0.132	0.076	0.255	0.174	0.062	0.032	0.108	0.130
North Atlantic right whale[a]	0.618	0.725	0.755	0.827	0.329	0.021	0.004	0.003	0.003	0.009	0.048	0.262	0.300	0.085
Sei whale[a]	0.002	0.002	0.001	0.043	0.040	0.021	0.006	0.003	0.007	0.001	0.002	0.002	0.011	0.010
Atlantic white-sided dolphin	3.422	1.941	2.083	4.272	7.876	7.453	4.888	2.677	2.895	3.786	4.011	5.182	4.207	4.846
Atlantic spotted dolphin	0.002	0.002	0.003	0.013	0.024	0.045	0.081	0.140	0.136	0.131	0.068	0.009	0.054	0.079
Short-beaked common dolphin	13.980	2.789	1.142	2.777	5.146	5.524	5.748	10.010	16.618	18.872	13.322	23.055	9.915	12.287
Bottlenose dolphin, offshore	0.576	0.058	0.019	0.551	0.598	0.869	1.812	1.605	2.860	3.145	1.485	0.812	1.199	1.648
Risso's dolphin	0.019	0.009	0.004	0.004	0.013	0.015	0.039	0.076	0.056	0.020	0.025	0.044	0.027	0.036
Long-finned pilot whale[b]	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502
Short-finned pilot whale[b]	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370
Sperm whale[a]	0.002	0.003	0.002	0.003	0.004	0.009	0.034	0.034	0.011	0.010	0.008	0.002	0.010	0.014
Harbor porpoise	4.624	7.291	13.845	9.142	4.362	1.022	0.725	0.670	0.550	0.523	1.304	2.214	3.856	1.421
Gray seal[c]	1.180	2.327	2.411	2.834	3.529	0.452	0.095	0.055	0.088	0.130	0.091	0.511	1.142	0.619
Harbor seal[c]	2.650	5.228	5.417	6.368	7.928	1.015	0.214	0.124	0.198	0.293	0.204	1.149	2.566	1.391
Harp seal[c]	1.180	2.327	2.411	2.834	3.529	0.452	0.095	0.055	0.088	0.130	0.091	0.511	1.142	0.619

[a] Listed as Endangered under the ESA.
[b] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[c] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

6.1.1.4. Densities Used for UXO Analysis

The UXO desktop study (Mills 2021) identified three areas as moderate UXO risk within the project area (Figure 9):

1. The shallow water segment of the OECC (OECC Part 1);
2. The deepwater segment of the OECC (OECC Part 2); and
3. The SWDA.

To calculate marine mammal densities for the 10 potential UXO detonations, whereby 2 UXOs would be assumed at the 12 m depth location, 3 UXOs at 20 m, 3 UXOs at 30 m, and 2 UXOs at 40 m, monthly density was calculated for each species at the shallow portion of the OECC (representing the 12 m depth location) and the combined deepwater segment of the OECC and SWDA (20 m – 62 m depths). As a conservative measure, the month with the highest density among the areas of interest for each species was carried forward to the exposure calculations.

Densities for long- and short-finned pilot whales and for gray and harbor seals were scaled by their relative abundances using Equation 1. As a conservative approach, the gray seal density (i.e., lesser of gray and harbor seal density) was used as a surrogate for harp seal density.

The monthly densities for each species used to estimate exposures above the Level A and Level B acoustic thresholds during potential UXO detonations for New England Wind are shown in Table 13.

Table 13. Maximum monthly density (animals/100 km^2) at the moderate UXO risk areas used to estimate exposures above the Level A and Level B acoustic thresholds during potential UXO detonations for New England Wind.

Species	Maximum monthly density (animals/100 km^2)	
	Shallow OECC Segment	Deep OECC Segment and SWDA
Fin whale[a]	0.000305	0.003792
Minke whale	0.000478	0.002696
Humpback whale	0.001510	0.004146
North Atlantic right whale[a,b]	0.000288	0.009282
Sei whale[a]	0.000011	0.000497
Atlantic white-sided dolphin	0.001318	0.066818
Atlantic spotted dolphin	0.000005	0.001325
Short-beaked common dolphin	0.000846	0.308527
Bottlenose dolphin, offshore	0.370979	0.099623
Risso’s dolphin	0.000001	0.000487
Long-finned pilot whale	0.000009	0.006294
Short-finned pilot whale	0.000007	0.004642
Sperm whale[a]	0.000003	0.000332
Harbor porpoise	0.027993	0.165059
Gray seal[b]	0.321642	0.072733
Harbor seal[b]	0.722646	0.163411
Harp seal[b]	0.321642	0.072733

[a] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[b] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

6.1.1.5. Densities Used for HRG Survey Analysis

To calculate marine mammal densities for the potential HRG survey impact area, it was assumed that the surveys would occur in four areas of interest (see Figure 2):

1. Phase 2 South Coast Variant Offshore Routing Envelope
2. New England Wind Offshore Export Cable Corridor
3. Phase 2 OECC Western Muskeget Variant
4. Maximum Size of the Southern Wind Development Area

Because ranges to thresholds are small for HRG surveys (Appendix D, Table 5), the calculation was limited to these impact areas without any additional buffer. Monthly density was calculated for each area of interest and for each species as the average of the densities from all Duke/MGEL model grid cells that overlap partially or completely with each area of interest. As a conservative measure, the month with the highest density among the four areas of interest for each species was carried forward to the exposure calculations, assuming all HRG survey days could occur during that month.

Table 14. Maximum monthly density (animals/100 km^2) used to estimate exposures above acoustic thresholds during HRG surveys for New England Wind.

Species	Maximum monthly density (animals/100 km^2)
Fin whale	0.37
Minke whale	0.26
Humpback whale	0.29
North Atlantic right whale	0.90
Sei whale	0.05
Atlantic white-sided dolphin	7.87
Atlantic spotted dolphin	0.13
Short-beaked common dolphin	27.63
Bottlenose dolphin, offshore	35.81
Risso's dolphin	0.05
Long-finned pilot whale[a]	0.59
Short-finned pilot whale[a]	0.44
Sperm whale	0.04
Harbor porpoise	15.68
Gray seal[b]	36.59
Harbor seal[b]	82.20
Harp seal[b]	36.59

[a] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[b] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

6.1.2. Marine Mammal Mean Group Size

The mean group sizes used to correct Level B take estimates, as shown in Table 15, for modeled cetacean species were derived from AMAPPS data from 2010–2019 NE shipboard distance sampling surveys (Palka et al. 2021) and informed by data from 2018–2021 HRG surveys conducted by the Proponent (Vineyard Wind 2018, 2020a, 2020c, 2021a). Mean group size was calculated as the number of individuals divided by the number of groups from Table 6-5 of Palka et al. (2021), which summarizes the 2010–2019 AMAPPS NE shipboard distance surveys. Summer sightings (June 1 to August 31) were chosen for these calculations because many species were not observed during fall surveys, and surveys were not conducted during spring or winter. Mean group sizes were also calculated using protected species observer (PSO) data from 2018–2021 HRG surveys conducted by the Proponent (Vineyard Wind 2018, 2020a, 2020c, 2021a) as the average size of all groups observed during the four years for each species. When the PSO data showed a larger mean group size than was shown by the AMAPPS data, the PSO group size was used instead. This was the case for two of the delphinid species – common bottlenose dolphin and Atlantic white-sided dolphin – and for the minke whale (highlighted in Table 15). Though pinnipeds congregate in large numbers on land, at sea they are generally foraging alone or in small groups. Palka et al. (2017) examined the at-sea distribution of seals during 2010–2013 AMAPPS NE aerial surveys (Table 19.1 of that report). Most seals (~95%) could not be identified to species from the air, so the average group size shown in Table 15 was calculated using sightings of all seals (gray, harbor, and unidentified). Palka et al. (2017) acknowledge that these could be either harbor or gray seals, or even harp or hooded seals, so this value was used for all seal species.

In calculating Level B takes from the acoustic modeling exposure results for impact pile driving, if the predicted mean Level B exposure exceeded the mean group size for a given species, the take was not corrected for group size; the requested takes for those species are equal to the predicted Level B exposures rounded up to the nearest integer. In cases where the exposure estimate was less than the mean group size, it was assumed that if one group member was exposed, then all animals in the same group would receive a similar level of sound exposure. Therefore, for species for which the annual number of predicted exposures above threshold was less than the mean group size, the annual number of expected takes was increased to the mean group size rounded up to the nearest integer. The modeling for New England Wind included both species considered "common" and those considered "uncommon" in the SWDA as listed in Table 9. Predicted exposure numbers can be less than the mean group size for uncommon species or for species that are common in the area but generally occur at low densities. Correcting for group size for these species is used as a conservative measure to ensure all animals in a group are accounted for in the take request. For New England Wind, the only species for which this was applied are the sei whale, Atlantic spotted dolphin, Risso's dolphin, and sperm whale. Because pile driving for New England Wind will occur over either 2 or 3 years, the mean group size rule was carried over from each of the annual take estimates to the total take estimates for the entire construction schedule to account for the possibility that a single exposure could occur in every year of a given construction schedule. For example, the estimated annual mean number of sei whales exposed above the Level B threshold from impact pile driving is less than one in any year of either schedule (see Tables 29, 30 and 32–34). These annual estimates were rounded up to 2 because the average sei whale group size from AMAPPS sighting data is 1.4. For construction Schedule A, even though modeling of the whole schedule combined predicted fewer than two Level B exposures, the take request includes two takes each year for a total of four sei whales. Similarly, for schedule B, modeling of the whole schedule predicted fewer than two Level B exposures, but the request is for two takes each year for a total of six sei whales.

Table 15. Mean group size of modeled marine mammal species that could be present in the SWDA, used to correct Level B take estimates for group size.

Species	Number of groups (AMAPPS data)[a]	Number of animals (AMAPPS data)[a]	Mean group size (AMAPPS data)[a]	Mean group size (PSO data)[b]	Group size used in Level B take correction[c]
Fin whale[d]	345	533	1.5	1.6	2
Minke whale	32	32	1.0	1.1	2
Humpback whale	157	370	2.4	1.5	3
North Atlantic right whale[d]	2	4	2.0	1.5	2
Sei whale[d]	20	28	1.4	1.0	2
Atlantic white-sided dolphin	3	61	20.3	27.5	28
Atlantic spotted dolphin	60	1,760	29.3	Not observed	30
Short-beaked common dolphin	444	19,802	44.6	14.0	45
Bottlenose dolphin, offshore	345	3,865	11.2	17.9	18
Risso's dolphin	486	3,131	6.4	Not observed	7
Long-finned pilot whale	41	666	16.2	5.6	17
Short-finned pilot whale	230	2,050	8.9	Not observed	9
Sperm whale[d]	298	491	1.6	1.3	2
Harbor porpoise	4	6	1.5	1.3	2
Gray seal	145	202	1.4	1.2	2
Harbor seal	145	202	1.4	2.0	2
Harp seal	145	202	1.4	Not observed	2

[a] Mean group size for cetaceans from 2010–2019 AMAPPS NE shipboard distance sampling surveys (Table 6-5 of Palka et al. (2021)), and for seals from 2010–2013 AMAPPS NE aerial surveys for all seals because most were not identified to species (Table 19.1 of Palka et al. (2017)).
[b] Mean group size from 2018–2021 PSO sightings data from 2018–2021 HRG surveys conducted by the Proponent (Vineyard Wind 2018, 2020a, 2020c, 2021a). Highlighted blue cells show values that were higher for PSO data than for AMAPPS data.
[c] Group size used for Level B take correction is higher of AMAPPS data and PSO data rounded up to an integer.
[b] Listed as Endangered under the ESA.

Species considered to be rare in the area were not included in the exposure modeling. Because of the low densities predicted for these species in the WEA, exposure modeling would produce zero exposures above threshold for these species. As a conservative measure, the Proponent is requesting take for these rare species based on their group sizes. There are few to zero sightings of these species in the sources used above to calculate group size for the modeled species, so an alternative method had to be developed. Group size calculations for rare species used sighting data from the Ocean Biodiversity Information System database (OBIS 2021). All records for each of the rare species were extracted from the OBIS database and then filtered to include only the area from approximately Cape Hatteras to the Gulf of Maine (35°N to 43°N) and from the coast (76°W) out to the continental shelf edge (66°W) to provide a more precise estimate of potential group size in the SWDA than would be expected using all OBIS records. It was necessary to use this larger area because there are limited to no records of these rare species within the SWDA. The OBIS data were further filtered to remove stranding data, because the group size of stranded animals does not necessarily reflect the group size of free-ranging animals. The one exception to this was the hooded seal – all records of this species in this area from the OBIS database were of single, stranded individuals, and thus a group size of one was used. This number is likely reflective of any free-swimming hooded seal that would occur in the area because this is an Arctic species and only single vagrant animals would be expected. Finally, data from digital aerial surveys were filtered out of this larger dataset because, although useful in determining presence/absence, these data provide no information on group size. The "individualCount" variable in the OBIS data was used to calculate minimum, maximum, and average group sizes for these rare species (Table 16).

For many of these species, in particular the delphinids, maximum group sizes can be in the hundreds or even up to thousands of animals. However, because these animals are rare in the WEA as it is not their preferred habitat, it was assumed that they would be unlikely to form such large aggregations in this area. Thus, the average group size (rounded up to a whole number) was used in the take calculations for these species. Group sizes relevant to the SWDA can be informed by PSO sightings during site characterization surveys. For example, white-beaked dolphins were recorded in both 2019 and 2020 during HRG surveys in this area (Vineyard Wind 2019, 2020) with the sighting of white-beaked dolphins in 2019 consisting of 30 animals. Other rare species encountered in the survey area during previous HRG surveys include false killer whales in 2019 (5 individuals) and 2021 (1 individual) ((Vineyard Wind 2020c, 2020b)) and killer whales in 2022 (2 individuals; data not yet submitted). For these species the take estimates use the observed group size from PSO sightings.

Table 16. Mean group size of rare marine mammal species that could be present in the SWDA.

Species	Minimum group size (OBIS)	Maximum group size (OBIS)	Mean group size (OBIS)	Observed group size (PSO reports)	Group size used in take estimates
Blue whale[a]	1	2	1.0	NA	1
Dwarf sperm whale	1	5	1.7	NA	2
Pygmy sperm whale	1	3	1.3	NA	2
Clymene dolphin	2	1,000	166.8	NA	167
False killer whale[b]	1	30	6.3	5	5
Fraser's dolphin	75	250	191.7	NA	192
Killer whale[b]	1	40	7.3	2	2
Melon-headed whale	20	210	108.8	NA	109
Pan-tropical spotted dolphin	3	300	59.3	NA	60
Pygmy killer whale	2	10	4.5	NA	5
Rough-toothed dolphin	3	45	13.1	NA	14
Spinner dolphin	1	170	50.4	NA	51
Striped dolphin	1	500	63.8	NA	64
White-beaked dolphin[b]	1	200	13.5	30	30
Beluga whale	1	3	1.6	NA	2
Cuvier's beaked whale	1	10	2.8	NA	3
Blainville's beaked whale	3	4	3.3	NA	4
Gervais' beaked whale	1	12	3.5	NA	4
Sowerby's beaked whale	1	10	3.5	NA	4
True's beaked whale	2	5	2.9	NA	3
Northern bottlenose whale	2	7	3.7	NA	4
Hooded seal[c]	1	1	1.0	NA	1

[a] Listed as Endangered under the ESA.
[b] Mean group size for these species from 2018–2021 PSO sightings data from 2018–2021 HRG surveys conducted by the Proponent (Vineyard Wind 2018, 2020a, 2020c, 2021a).
[c] All records of hooded seals in the OBIS database for this region were strandings of single animals.

6.2. Exposure Estimation – Impact Pile Driving

To estimate potential effects on marine mammals (i.e., Level A and Level B harassment) from sound generated during New England Wind impact pile driving activities, JASCO Applied Sciences (JASCO) performed underwater acoustic modeling of these activities on behalf of the Proponent. The basic modeling approach is to characterize the sounds produced by the source, determine how the sounds propagate within the surrounding environment, then estimate species-specific exposure probabilities by combining the computed sound fields with animal movement in simulated representative scenarios. The resulting species-specific exposure probabilities are then converted into predicted numbers of individuals of each species that could be exposed to sounds above Level A and Level B acoustic thresholds to generate take estimates. The modeling methodology is described in the following sections and provided in greater detail in Appendix A. For species with densities too low in the region to provide meaningful modeled exposure estimates (i.e., rare species), the take request is based on average group size.

Take calculations for impact pile driving are provided in detail in the following subsections. Briefly, the methods and assumptions are as follows:

- Predicted sound fields were combined with animal movement modeling to provide probabilistic exposure estimates for each of the modeled piling scenarios (mean number of simulated animals [animats] likely to exceed a given acoustic threshold over a 24-hour period for a pre-determined model animat density, Sections 6.2.1 through 6.2.5).
- 24-hour animat exposures resulting from the modeling were scaled, for each species, by the ratio of their monthly density (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b) to the modeled animat density for each month (see Section 6.2.3 for details on how this calculation is made).
- The number of piling days per month was used in conjunction with the monthly 24-hour animat exposures to estimate project-level exposures (see Section 6.2.3 for details on how this calculation is made).
- Level A exposure estimates are provided for both the cumulative sound exposure level (SEL) and peak pressure level (PK) thresholds (Section 6.2.2.3) – the greater of the SEL and PK exposure estimates for each species was selected to compute Level A takes (see Section 6.2.5 for exposure results and a description of how frequency weighting affects whether the SE_L or PK exposure is greater based on the species' functional hearing group).
- Level A take for NARW was presumed to be zero because of mitigation.
- Level B exposure estimates are provided as sound pressure level (SPL) for both the NOAA (2005) 160 dB re 1 µPa SPL and Wood et al. (2012) weighted behavioral response criteria (Section 6.2.2.4). For the purpose of the LOA request, the NOAA (2005) criterion is used to calculate Level B takes. For comparison Level B takes calculated using the Wood et al. (2012) criteria can be found in Appendix B
- Exposure estimates are provided for various levels of sound attenuation (Section 6.2.5) – take calculations assumed 10 dB sound attenuation.
- All exposure estimates and average group sizes were rounded up to a whole number, before any addition, to compute takes.
- When the model-predicted Level B exposure was less than one average group size (as provided in Section 6.1.2, Table 15) for a given species, the estimated take is one average group size for the species rounded up to a whole number.

- When the model-predicted Level B exposure was greater than or equal to one average group size, the estimated take is the predicted exposure rounded up to a whole number.
- Annual takes assume worst case scenario exposures for each species for each year from either construction schedule A or B (Section 6.8.1).
- The total take request for impact pile driving for all project years summed uses the total exposure estimates from the model results for Schedule B as a conservative measure, except for NARW and gray and harp seals, for which Schedule A predicts greater exposures (Section 6.7.1).
- The rare species Level B take request assumes one average group size, rounded up to a whole number, of each of these species would be exposed in each of three pile driving years (Section 6.7.1.2).
- The rare species Level A take request uses the sei whale (a comparable LF cetacean) as a surrogate for the blue whale, assumes no MF cetaceans or phocids would be exposed above threshold, and assumes one average group size of HF cetaceans would be exposed above threshold (Section 6.7.1.2).

6.2.1. Modeling Methods Overview

6.2.1.1. Source Modeling

JASCO's physical model of pile vibration and near-field sound radiation (MacGillivray 2014) was used in conjunction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010) to predict source levels associated with impact pile driving activities. The sound radiating from the pile itself was simulated as a vertical array of discrete point sources. This modeling approach takes into account parameters that describe the operation—pile type, material, size, and length—the pile driving equipment, and approximate pile penetration depth. Two modeling sites (in the north and south of the Lease Area) were selected to model monopile foundation installation and one modeling site (near the middle of the Lease Area) was selected to model jacket foundations. Because of changes to the planned construction area which shifted the boundary of the SWDA farther south following completion of the modeling, one of the acoustic modeling locations and four of the animal movement modeling locations (see Section 6.2.1.3) were located slightly north of the revised SWDA boundary. These modeling sites were not relocated since they remain representative of the average acoustic characteristics within the SWDA. See Appendix A for a more detailed description of the source modeling.

Forcing functions were computed for 4 m diameter jacket foundation piles and 12 m and 13 m diameter monopile foundations using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010). The model assumed direct contact between the representative hammers, helmets, and piles (i.e., no cushion material). The forcing functions serve as the inputs to JASCO's pile driving source model (PDSM) used to estimate equivalent acoustic source characteristics. Decidecade spectral source levels for each pile type, hammer energy, and modeled location, using an average summer sound speed profile, are provided in Appendix F of Appendix A.

6.2.1.2. Sound Propagation Modeling

JASCO's Marine Operations Noise Model (MONM) and Full Wave Range Dependent Acoustic Model (FWRAM) were used to estimate sound propagation at representative locations in the lease site. MONM and FWRAM combine the outputs of the source model with the spatial and temporal environmental factors (i.e., location, oceanographic conditions, and seabed type) to calculate sound fields produced during pile driving. The lower frequency bands were modeled using MONM and FWRAM, which are based on the parabolic equation method of acoustic propagation modeling. In higher frequency bands, a ray model with losses resulting from absorption was used in the overall propagation loss model. See Appendix F of Appendix A for a more detailed description.

6.2.1.3. Animal Exposure Modeling

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) is an animal movement model that integrates estimated sound fields with species-typical behavior (e.g., dive patterns) in animats. Estimated received sound levels relative to regulatory thresholds for species' hearing groups are calculated for each animat that may occur in the SWDA. By simulating animal movement, the sound fields are sampled in a realistic manner for each species of concern near the sound source, providing species-specific estimates of potential acoustic exposure. Additional details are provided below in Section 6.2.3 and in Appendix A.

6.2.1.4. Sound Attenuation

Several hypothetical broadband sound attenuation levels (0, 6, 10, and 12 dB) were included in the JASCO modeling study for comparison purposes. In estimating takes for this LOA request, impacts to marine mammals were conservatively assessed based on 10 dB of noise attenuation. However, the Proponent expects to implement noise attenuation technology to reduce sound levels by no less than 10 dB with a target of 12 dB or greater, and therefore results using 12 dB attenuation are also provided in the sections below. See additional information on noise attenuation systems in Section 11.2. The full modeling results, showing all levels of attenuation, can be found in the acoustic impact assessment report accompanying this LOA request.

6.2.1.5. Acoustic and Exposure Modeling Scope and Assumptions

Under the maximum design scenario, New England Wind is proposing to install up to 132 foundations in the SWDA. This includes a total of 130 WTG/ESP grid positions with two positions potentially having co-located ESPs (i.e., two foundations installed at one grid position). Due to the range of buildout scenarios for Phases 1 and 2 where certain parts of the SWDA could be included in either phase, the total buildout of New England Wind was considered in the modeling effort (i.e., 132 foundations).

As described in Section 1, two types of foundations were considered in the impact pile driving acoustic modeling study:

- Monopile foundations with either 12 m (39.4 ft) or 13 m (42.7 ft) diameter piles, and
- Jacket-style foundations with four 4 m (13.1 ft) diameter (pin) piles.

To accommodate a range of potential installation scenarios, different combinations of pile size and hammer energy were assessed using a source model including a 12 m monopile using either a 5,000 kJ or 6,000 kJ hammer, a 13 m monopile using a 5,000 kJ or 6,000 kJ hammer, and 4 m pin piles using a 3,500 kJ hammer. Initial source modeling showed minimal difference between the 12 m and 13 m monopile using a 6,000 kJ hammer (1.2 dB difference). Given these similarities, propagation and animal movement modeling to estimate potential exposures was conducted for the most likely to be installed pile diameters and hammer energies. Where the 13 m monopile using a maximum 6,000 kJ hammer is considered, mathematical scaling was used rather than a full model in order to estimate mitigation zones that accommodate this design possibility while ensuring the protection of marine mammals (see Section 11.3.1). Detailed acoustic modeling results, including source levels, spectra, and distances to isopleths, etc., can be found in Appendix A. To produce exposure estimates for the different construction schedules, animal movement modeling assumed installation of one or two monopiles per piling day or installation of four pin piles per piling day. It was also assumed that no concurrent pile driving would be performed.

To produce exposure estimates for the different construction schedules, animal movement modeling assumed installation of one or two monopiles per piling day using a combination of pile diameters and hammer energies, or installation of four pin piles per piling day. It was also assumed that no concurrent pile driving would be performed.

The animal exposure modeling assumed two potential construction schedules as detailed in Tables 7 and 8 in Section 2.2. Exposure estimates were calculated for all years of the construction schedule combined, for each construction schedule, as well as for each individual year within each construction schedule. The scenario that predicted the highest number of NARW Level A and Level B exposures in a 24-hour period was the jacket foundation with four pin piles installation with 3,500 kJ hammer energy, when compared with all the exposure-modeled monopile scenarios, including one and two pile per day installations. Therefore, the jacket foundations with four pin piles installed per day were assumed to provide adequate project design envelope to cover all potential scenarios in Year 2 and Year 3 (for construction schedule B), including the maximum contemplated 13 m diameter monopile with a 6,000 kJ hammer energy.

6.2.2. Acoustic Criteria – Level A and Level B Harassment

To assess the potential impacts of New England Wind-associated sound sources, it is necessary to first establish the acoustic exposure criteria used by US regulators to estimate marine mammal takes. 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 updated in 2018 (NMFS 2016, 2018). The Technical Guidance document also recognizes two main types of sound sources: impulsive and non-impulsive. Non-impulsive sources are further broken down into continuous and intermittent categories.

The Guidance recommends the use of dual criteria for assessing Level A exposures, including a peak (unweighted/flat) sound level metric (PK) and a cumulative SEL metric with frequency weighting. Both the acoustic criteria and weighting function application are divided into functional hearing groups (e.g., low-, mid-, and high-frequency for cetaceans) that species are assigned to, based on their respective hearing ranges. The acoustic analysis used for this LOA request applies the most recent sound exposure criteria used by NMFS to estimate Level A acoustic harassment (NMFS 2018).

Sound levels thought to elicit disruptive behavioral response are described using the sound pressure level (SPL) metric (NMFS and NOAA 2005). NMFS currently uses behavioral response thresholds of 160 dB re

1 µPa for intermittent sounds and 120 dB re 1 µPa for continuous sounds for all marine mammal species (NMFS 2018), based on observations of mysticetes (Malme et al. 1983, 1984, Richardson et al. 1986, 1990b). Alternative thresholds used in acoustic assessments include a graded probability of response approach that take into account the frequency-dependence of animal hearing sensitivity (Wood et al. 2012). Exposure estimates predicted by the modeling study used both the NOAA Fisheries 160 dB re 1 µPa threshold for impulsive sounds and the Wood et al. (2012) criteria for comparison. Details can be found in the acoustic impact assessment report accompanying this LOA request. For the purpose of the LOA request, the NOAA (2005) criterion is used to calculate Level B takes. For comparison Level B takes calculated using the Wood et al. (2012) criteria can be found in Appendix B.

The publication of ISO 18405 Underwater Acoustics – Terminology (ISO 2017) provided a dictionary of underwater bioacoustics (the previous standard was ANSI and ASA S1.1-2013). The JASCO modeling follows the definitions and conventions of ISO (2017) except where stated otherwise (Table 17).

Table 17. Summary of relevant acoustic terminology used by US regulators and in the JASCO modeling report.

Acoustic metric	NMFS (2018)	ISO (2017)	
		Main text	Tables
Sound pressure level	n/a	SPL	L_p
Level of peak sound pressure	PK	PK	L_{pk}
Cumulative sound exposure level	SEL_{cum}	SEL	L_E

The SEL_{cum} metric used by the NMFS describes the sound energy received by a receptor over a period of 24 h. Accordingly, following the ISO standard, this will be denoted as SEL in this LOA request, except for in tables where L_E is used.

6.2.2.1. 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 (Richardson et al. 1995, Wartzok and Ketten 1999, Southall et al. 2007, Au and Hastings 2008). While hearing measurements are available for a small number of species based on captive animal studies, there are no direct measurements of many odontocetes or any mysticetes. 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 (Houser et al. 2001, Parks et al. 2007, Tubelli et al. 2012, Cranford and Krysl 2015); vocalizations (see reviews in Richardson et al. 1995, Wartzok and Ketten 1999, Au and Hastings 2008); taxonomy; and behavioral responses to sound (Dahlheim and Ljungblad 1990, see review in Reichmuth et al. 2007). In 2007, Southall et al. 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 18).

Southall et al. (2019b) published an updated set of Level A sound exposure criteria (i.e., for onset of TTS and PTS in marine mammals). While the authors propose a new nomenclature and classification for the marine mammal functional hearing groups, the proposed thresholds and weighting functions do not differ in effect from those proposed by NMFS (2018). The new hearing groups proposed by Southall et al. (2019) have not yet been adopted by NOAA Fisheries. The NMFS (2018) hearing groups presented in Table 18 are used in this analysis.

Table 18. Marine mammal hearing groups (Sills et al. 2014, NMFS 2018).

Hearing group	Representative species or species' groups	Generalized hearing range[a]
Low-frequency (LF) cetaceans	Mysticetes	7 Hz to 35 kHz
Mid-frequency (MF) cetaceans	most odontocetes, e.g., delphinids, sperm whales, beaked whales	150 Hz to 160 kHz
High-frequency (HF) cetaceans	other odontocetes, e.g., porpoises, *Kogia* spp.	275 Hz to 160 kHz
Phocid pinnipeds in water (PW)		50 Hz to 86 kHz
Phocid pinnipeds in air (PPA)[b]		50 Hz to 36 kHz

[a] The generalized hearing range is for all species within a group. Individual hearing will vary.
[b] Sound from piling will not reach NMFS thresholds for behavioral disturbance of seals in air (90 dB [rms] re 20 µPa for harbor seals and 100 dB [rms] re 20 µPa for all other seal species) at the closest land-based sites where seals may spend time out of the water. Thus in-air hearing is not considered further.

6.2.2.2. Marine Mammal Auditory Weighting Functions

The potential for anthropogenic sound 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 and Turnpenny 1998, Nedwell et al. 2007b). Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS thresholds (Southall et al. 2007, Erbe et al. 2016a, Finneran 2016). Marine mammal auditory weighting functions for all hearing groups (Table 18) published by Finneran (2016) are included in the NMFS (2018) Technical Guidance for use in conjunction with corresponding PTS (Level A) onset acoustic criteria (Table 19). Wood et al. (2012) behavioral response criteria use the M-weighting functions proposed by Southall et al. (2007). The NOAA (2005) 160 dB behavioral threshold is unweighted.

The application of marine mammal auditory weighting functions emphasizes the importance of taking measurements and characterizing sound sources in terms of their overlap with biologically important frequencies (e.g., frequencies used for environmental awareness, communication, and the detection of predators or prey), and not only the frequencies that are relevant to achieving the objectives of the sound producing activity (i.e., context of sound source; NMFS 2018).

6.2.2.3. 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 hearing independent of duration, so an additional metric of peak pressure (PK) is also used to assess acoustic exposure injury risk. A PTS in hearing may be 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, therefore PTS onset may be extrapolated from TTS onset level using an assumed growth function (Southall et al. 2007). The NOAA Fisheries (2018) 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 potential marine mammal Level A exposures resulting from pile driving (Table 19).

Table 19. Summary of relevant PTS onset acoustic thresholds for marine mammal hearing groups (NMFS 2018).

Faunal group	Impulsive signals[a]	
	Unweighted L_{pk} (dB re 1 µPa)	Frequency weighted $L_{E,24h}$ (dB re 1 µPa^{2}s)
Low-frequency (LF) cetaceans	219	183
Mid-frequency (MF) cetaceans	230	185
High-frequency (HF) cetaceans	202	155
Phocid seals in water (PW)	218	185

[a] Dual metric acoustic thresholds for impulsive sounds: The largest isopleth result of the two criteria is used for calculating PTS onset.

6.2.2.4. 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. It is recognized that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison et al. 2012). Due to the complexity and variability of marine mammal behavioral responses to acoustic exposure, NOAA Fisheries has not yet released technical guidance on behavioral thresholds for calculating animal exposures (NMFS 2018). NOAA Fisheries currently uses an SPL of 160 dB re 1 µPa to assess behavioral impact resulting from exposure to impulsive sounds (NOAA 2005), which assumes that all animals exposed to sound at or above 160 dB re 1 µPa are taken by Level B harassment. This metric was derived from the HESS (1999) report that showed a 50% probability of inducing behavioral responses at this SPL, which was based on the responses of migrating mysticete whales to air gun sounds (Malme et al. 1983, 1984). The HESS team recognized that behavioral responses to sound may occur at lower levels, but substantial 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 Appendix B). Southall et al. (2007) found varying responses for most marine mammals between SPLs 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. These criteria were reviewed again recently by an extended version of this panel of experts, who suggested incorporating new methodological developments into data collection for behavioral response assessment (Southall et al. 2021). The panel did not recommend new behavioral exposure criteria, but they do advocate for analysis and reporting of a broader range of noise exposure conditions, rather than a single received level metric, and for the use of noise exposure metrics that are context and subject specific. Tyack and Thomas (2019) explored using a dose-response function to evaluate behavioral responses, whereby the probability of an animal responding is a function of the received sound level at a given distance from the source. They provide a simple example showing how using a single sound metric grossly underestimates the number of animals affected in comparison with the dose-response function. In 2012, Wood et al. (2012) proposed a graded probability of behavioral response to seismic pulses (an impulsive sound) using a frequency-weighted SPL metric. They also designated behavioral response categories for sensitive species (including harbor porpoises and beaked whales) and for migrating mysticetes. The JASCO modeling included both the NOAA (2005) criterion and the Wood et al. (2012) step function (Table 20). In this modeling effort, sei whales and minke whales used the Wood et al. (2012) migrating step function, harbor porpoise used the sensitive step function, and all other species used general. Migrating and sensitive species are indicated in the species column of all results tables showing Level B Wood et al. (2012) exposure ranges and exposure estimates. The 50% response level thresholds of 120 dB for sensitive species, 140 dB for migrating mysticetes, and 160 dB for all other species were used to calculate acoustic ranges. For exposure estimates, the response probabilities shown in Table 20 were used for the different marine mammal groups. For example, for migrating mysticetes the model counts 10% of animats exposed to SPL 120 dB, 50% of animats exposed to SPL 140 dB, and 90% of animats exposed to SPL 160 dB as receiving Level B harassment. A comparison of the exposure estimates derived from these two behavioral acoustic criteria (see Table 20) are shown in Tables 28–34. Detailed results of this modeling can be found in Appendix A. For the purpose of the LOA request, the NOAA (2005) criterion is used to calculate Level B takes. For comparison Level B takes calculated using the Wood et al. (2012) criteria can be found in Appendix B.

Table 20. Acoustic thresholds used in the acoustic modeling to evaluate potential behavioral impacts to marine mammals. Units are sound pressure level. Probabilities are not additive.

Marine mammal group	Species	Frequency weighted probabilistic response[a] (L_p, dB re 1 µPa)				Unweighted threshold[b] (L_p, dB re 1 µPa)
		120	140	160	180	160
Sensitive odontocetes	Harbor porpoise	50%	90%	–	–	100%
Migrating mysticete whales	Minke whale	10%	50%	90%	–	100%
	Sei whale					
All other species		–	10%	50%	90%	100%

[a] Wood et al. (2012).
[b] NMFS recommended threshold (NOAA 2005).

6.2.3. Animal Movement Modeling and Exposure Estimation

JASMINE was used to estimate the probability of exposure of animals to threshold levels of sound arising from impact pile driving operations during construction of New England Wind. Sound exposure models such as JASMINE use simulated animals (animats) to sample the predicted 3-D sound fields with movement rules derived from animal observations (Figure 20). The parameters used for forecasting realistic behaviors (e.g., diving, foraging, aversion, and surface times) were determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. The predicted sound fields were sampled by the model receivers in a way that real animals are expected to by programming animats to behave like marine species that may be present in or near the SWDA. The output of the simulation is the exposure history for each animat within the simulation. An individual animat's sound exposure level is evaluated over a specified duration (i.e., 24 h) to determine its total received acoustic energy (SEL) and maximum received PK and SPL. These received levels are then compared to the threshold criteria described in Section 6.2.2 within each analysis period. The number of animats predicted to receive sound levels exceeding the thresholds indicates the probability of such exposures, which is then scaled by the real-world density estimates for each species to obtain the mean number of real-world animals estimated to potentially receive above-threshold sound levels.

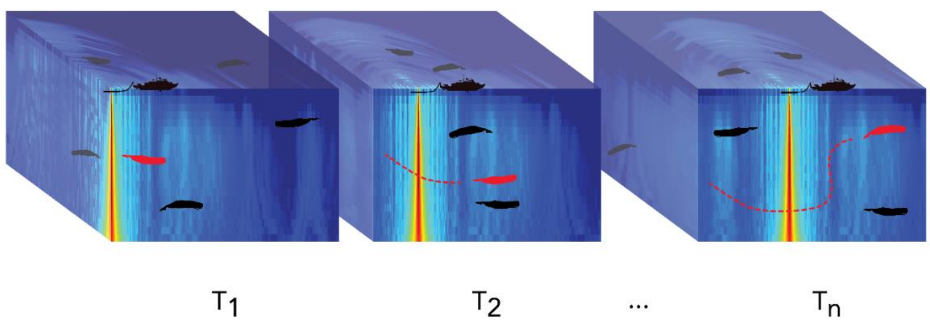

Figure 20. Depiction of animats in an environment with a moving sound field. Example animat (red) shown moving with each time step. The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

Figure 21 shows an example histogram of summary SEL exposures for each animat in a JASMINE simulation. The count above threshold is used to determine the predicted number of exposures above threshold for a given 24-hour scenario.

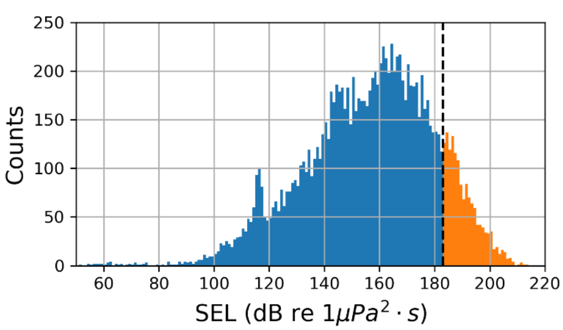

Figure 21. An example animat exposure histogram, showing the number of animats with SEL exposures at different levels for a single simulation. A vertical dashed line indicates an example sound level threshold, and the histogram bars above that threshold level are colored in orange.

Equation 2 describes how 24-h exposures x are calculated using the animat counts, the real-world density, and the sampling (seeding) density.

$$x = d_r \frac{x_{24h}}{d_s}, \tag{2}$$

where x_{24h} is the mean # of animats above threshold within a 24-hour period, d_r is the real-world animal density (e.g., from Roberts et al. (2016a) density models), and d_s is the sampling density. As an example, consider the predicted 24-hour exposures x_A for NARW from an unattenuated 4 m jacket foundation assuming 2 piles are installed per day. The number of animats above threshold x_{24h} is 290.7, the real-world density d_r is 0.00276 animats/km², and the sampling density d_s is 0.597 animals/km²:

$$x = 0.00276 \frac{290.7}{0.597} = 1.343. \tag{3}$$

In this case, the model predicts 1.343 animats will be exposed above threshold based on the installation of two unattenuated 4 m jacket foundations within a 24-hour period. To predict project-level exposures, this calculation is repeated for each foundation type and for each month, assuming density estimates are available monthly. The total number of exposures x_{all} for the project is calculated as a function of the 24-hour exposures for each month and foundation type (e.g, $x_{may,A}$), and the number of days of piling for each foundation type for each month (e.g., $n_{may,A}$). Note that that foundation type here refers to both the specific pile characteristics as well as the number of piles installed sequentially per 24-hour period. Construction schedules for the current project are described in Tables 7 and 8. Equation 4 shows an example calculation where two foundation types, A and B, are installed over the period from May to August.

$$\begin{aligned} x_{all} = {} & (n_{may,A} \cdot x_{may,A}) + (n_{jun,A} \cdot x_{jun,A}) + (n_{jul,A} \cdot x_{jul,A}) + (n_{aug,A} \cdot x_{aug,A}) + (n_{may,B} \cdot x_{may,B}) \\ & + (n_{jun,B} \cdot x_{jun,B}) + (n_{jul,B} \cdot x_{jul,B}) + (n_{aug,B} \cdot x_{aug,B}) \end{aligned} \tag{4}$$

Due to shifts in animal density and seasonal sound propagation effects, the number of animals predicted to be impacted by the pile driving operations is sensitive to the number of foundations installed during each month. Additional details can be found in Appendix A.

6.2.4. Exposure-based Ranges to Thresholds – Impact Pile Driving

Monitoring zones used for mitigation purposes have traditionally been estimated by determining the distance to Level A and Level B thresholds based only on acoustic information. This traditional method tacitly assumes that all receivers (animals) in the area remain stationary for the duration of the sound event. The received level of an animal is a function of its location relative to the sound source and the pathway it takes through the sound field. Therefore, treating animals as stationary may not produce realistic estimates for monitoring zones.

Animal movement modeling can be used to account for the movement of receivers when estimating distances for monitoring zones. The closest point of approach (CPA) for each of the species-specific animats (simulated animals) in a simulation is recorded and then the CPA distance that accounts for 95% of the animats that exceed an acoustic impact threshold (the 95% exposure range [$ER_{95\%}$]) is determined (Figure 22). If used as an exclusion zone, keeping animals farther away from the source than the $ER_{95\%}$ will reduce exposure estimates by 95%.

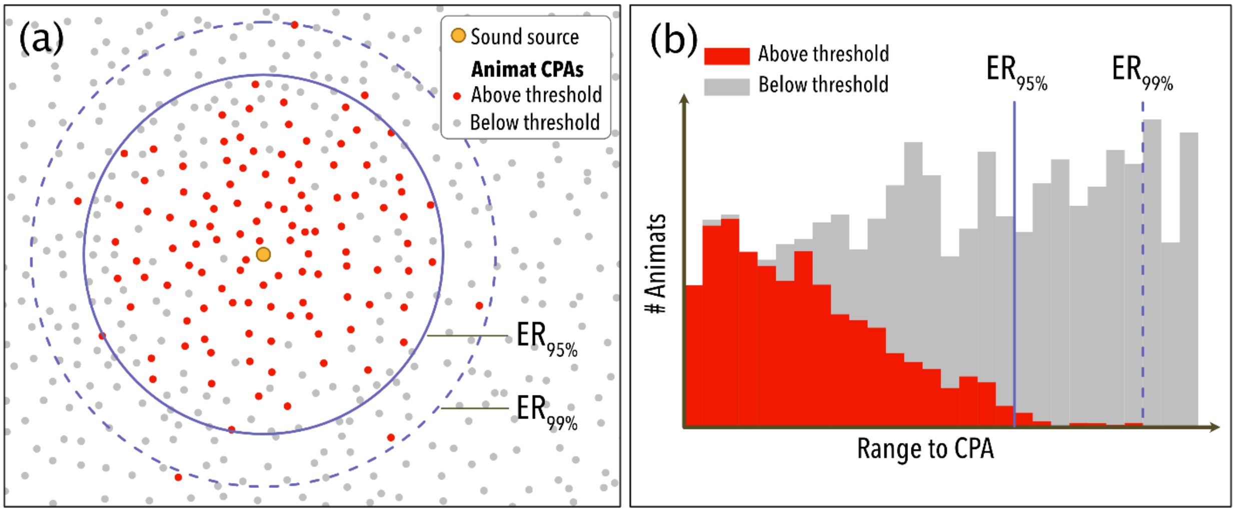

Figure 22. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows a stacked bar plot of the distribution of ranges to animat CPAs. The 95% and 99% Exposure Ranges ($ER_{95\%}$ and $ER_{99\%}$) are indicated in both panels.

Exposure ranges are computed using the simulated movements of individual animats within each species group considered in the animal movement and exposure modeling, so $ER_{95\%}$ results are reported by species rather than hearing group. Below are tables showing $ER_{95\%}$ distances to acoustic thresholds for marine mammal Level A and Level B thresholds for jacket and the most likely to be installed monopile foundations, assuming 0, 10, and 12 dB broadband attenuation. Only the subset of foundation types and installation schedules included in Construction Schedules A and B (see Tables 7 and 8) that provide a project design envelope for multiple scenarios are presented. Results for additional configurations are provided in Appendix H.2.4.

Exposure ranges for two monopiles per day versus one monopiles per day are not greatly different from each other (or consistently larger or smaller) because the driving of each pile are effectively independent events. What differences can be seen are largely due to different instances of JASMINE being run since it is a Monte Carlo simulation. An animat might accumulate more energy over two piles per day in a 24-hour period, but that accumulation of energy is not directly correlated to their exposure range. As described above, the exposure range is the range at which 95% of the animats within that range were exposed, and this may not change greatly between a one per day scenario and two per day scenario as the two piles are essentially treated as separate events. See Appendix A for more details of the modeling process.

Table 21. 12 m monopile, 5,000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

	Species	Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	7.99	2.37	1.91	0.04	0.01	0.01	10.45	4.00	3.71	10.46	3.99	3.72
LF	Minke whale (migrating)	6.38	1.50	0.97	0.04	0.02	0.02	10.04	3.89	3.50	36.32	20.29	17.93
LF	Humpback whale	9.08	2.76	2.12	0	0	0	10.45	3.99	3.74	10.47	3.99	3.74
LF	North Atlantic right whale[c]	7.81	1.84	1.52	0	0	0	10.01	3.94	3.62	10.12	3.97	3.60
LF	Sei whale[c] (migrating)	7.20	1.95	1.26	<0.01	<0.01	<0.01	10.21	3.88	3.67	38.10	21.02	18.41
MF	Atlantic white sided dolphin	0	0	0	0.01	0.01	0.01	9.76	3.78	3.48	5.52	2.75	2.35
MF	Atlantic spotted dolphin	0	0	0	0	0	0	10.11	4.15	2.98	5.69	2.57	1.93
MF	Short-beaked common dolphin	0	0	0	0.01	0.01	0.01	9.79	3.79	3.51	5.61	2.86	2.42
MF	Bottlenose dolphin, offshore	0	0	0	0.01	0.01	0.01	9.35	3.40	2.97	5.03	2.34	1.74
MF	Risso's dolphin	0.02	0	0	0.02	<0.01	<0.01	10.20	3.85	3.62	6.07	2.94	2.65
MF	Long-finned pilot whale	0	0	0	0.02	0.02	0.02	9.90	3.85	3.53	5.55	2.93	2.39
MF	Short-finned pilot whale	<0.01	<0.01	0	<0.01	<0.01	<0.01	9.91	3.83	3.56	5.56	2.86	2.39
MF	Sperm whale[c]	0	0	0	0.02	0.02	0.02	10.18	3.90	3.72	5.71	2.96	2.32
HF	Harbor porpoise (sensitive)	5.17	1.55	1.07	0.56	0.13	0.11	9.97	3.94	3.66	97.57	53.67	46.82
PPW	Gray seal	2.23	0.51	0.42	0	0	0	10.73	4.13	3.95	8.67	3.56	3.28
PPW	Harbor seal	2.03	0.21	0.02	0.02	0.02	0.02	10.28	3.75	3.56	8.33	3.33	3.09
PPW	Harp seal	1.80	0.15	0.06	0.05	0	0	10.43	4.00	3.54	8.50	3.48	3.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 22. 12 m monopile, 5,000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	9.66	2.79	2.19	0.02	0	0	10.31	3.98	3.80	10.37	4.00	3.82
LF	Minke whale (migrating)	7.29	1.67	1.29	0.07	0.02	0.02	9.67	3.80	3.55	36.30	20.44	17.74
LF	Humpback whale	10.91	3.44	2.46	0.03	0.01	0.01	10.44	3.98	3.66	10.50	3.98	3.66
LF	North Atlantic right whale[c]	8.81	2.34	1.69	0.04	<0.01	<0.01	9.99	3.75	3.52	10.10	3.76	3.53
LF	Sei whale[c] (migrating)	8.50	2.04	1.50	0.03	0.02	0.02	10.17	3.85	3.54	38.42	20.94	18.42
MF	Atlantic white sided dolphin	0	0	0	0.02	0.02	0.02	9.47	3.74	3.35	5.48	2.77	2.32
MF	Atlantic spotted dolphin	0	0	0	0	0	0	9.60	3.66	3.32	5.17	2.78	2.33
MF	Short-beaked common dolphin	0	0	0	0.02	0.02	0.02	9.62	3.81	3.46	5.51	2.87	2.36
MF	Bottlenose dolphin, offshore	<0.01	0	0	0.01	0.01	0.01	8.99	3.25	2.96	5.04	2.21	1.92
MF	Risso's dolphin	0.02	<0.01	<0.01	0.02	0.02	0.01	10.01	3.80	3.55	5.82	2.85	2.49
MF	Long-finned pilot whale	0	0	0	0.01	0.01	0.01	9.70	3.74	3.46	5.56	2.89	2.34
MF	Short-finned pilot whale	0	0	0	0.02	0.02	0.02	9.71	3.78	3.48	5.58	2.85	2.31
MF	Sperm whale[c]	0.29	0	0	<0.01	<0.01	<0.01	9.75	3.79	3.55	5.54	2.82	2.39
HF	Harbor porpoise (sensitive)	5.50	1.60	1.28	0.56	0.15	0.09	9.91	3.86	3.63	97.41	53.14	46.68
PPW	Gray seal	2.51	0.56	0.38	0.01	0.01	0.01	10.49	4.17	3.94	8.58	3.68	3.28
PPW	Harbor seal	2.43	0.21	0.16	<0.01	<0.01	<0.01	10.20	3.81	3.63	8.32	3.45	3.14
PPW	Harp seal	2.20	0.31	0.09	0.06	0	0	10.40	4.01	3.60	8.36	3.54	3.12

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 23. 12 m monopile, 6,000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	10.14	3.31	2.45	0.04	0.01	0.01	15.62	6.19	4.63	15.63	6.21	4.66
LF	Minke whale (migrating)	8.15	2.40	1.68	0.02	0.02	0.02	14.49	5.66	4.27	60.34	28.63	25.77
LF	Humpback whale	11.12	3.81	2.89	0.08	0	0	15.58	5.95	4.87	15.57	5.88	4.87
LF	North Atlantic right whale[c]	9.84	2.93	2.03	0	0	0	14.50	5.46	4.51	14.58	5.48	4.52
LF	Sei whale[c] (migrating)	9.31	2.47	2.16	<0.01	<0.01	<0.01	15.08	5.79	4.69	73.70	31.08	26.82
MF	Atlantic white sided dolphin	0	0	0	0.01	0.01	0.01	14.21	5.35	4.34	8.81	3.31	2.93
MF	Atlantic spotted dolphin	0	0	0	0	0	0	15.29	5.87	4.57	8.91	3.13	3.04
MF	Short-beaked common dolphin	0	0	0	0.01	0.01	0.01	14.53	5.68	4.39	9.04	3.36	2.97
MF	Bottlenose dolphin, offshore	0.11	0	0	0.01	0.01	0.01	14.04	4.77	3.94	8.13	3.02	2.72
MF	Risso's dolphin	0.02	0.02	0	0.02	<0.01	<0.01	15.28	5.55	4.52	9.23	3.46	3.04
MF	Long-finned pilot whale	0	0	0	0.02	0.02	0.02	14.61	5.55	4.44	8.81	3.37	3.00
MF	Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	14.46	5.57	4.55	8.97	3.30	3.03
MF	Sperm whale[c]	0.01	0	0	0.02	0.02	0.02	15.19	5.73	4.59	8.98	3.47	3.00
HF	Harbor porpoise (sensitive)	6.53	2.26	1.69	0.60	0.21	0.18	14.64	5.76	4.45	105.70	84.55	80.55
PPW	Gray seal	2.96	0.84	0.52	0	0	0	15.61	6.06	5.03	13.09	4.38	3.88
PPW	Harbor seal	2.86	0.43	0.22	0.02	0.02	0.02	15.39	6.01	4.48	12.58	4.09	3.70
PPW	Harp seal	2.39	0.25	0.09	0.05	0	0	15.38	5.93	4.89	12.83	4.22	3.89

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 24. 12 m monopile, 6,000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	12.55	3.90	2.86	0.02	0	0	15.82	6.01	4.91	15.86	5.97	4.90
LF	Minke whale (migrating)	9.23	2.59	1.82	0.02	0.02	0.02	14.65	5.33	4.39	66.79	29.19	25.67
LF	Humpback whale	13.59	4.62	3.60	0.03	0.01	0.01	15.78	5.92	4.72	15.81	5.93	4.72
LF	North Atlantic right whale[c]	11.16	3.16	2.49	0.04	<0.01	<0.01	14.51	5.60	4.45	14.61	5.65	4.45
LF	Sei whale[c] (migrating)	11.07	3.08	2.25	0.02	0.02	0.02	15.40	5.79	4.79	76.41	32.38	27.74
MF	Atlantic white sided dolphin	0	0	0	0.02	0.02	0.02	14.09	5.40	4.29	8.54	3.22	2.83
MF	Atlantic spotted dolphin	0	0	0	0	0	0	15.03	5.47	3.95	8.53	2.89	2.72
MF	Short-beaked common dolphin	0.02	0	0	0.02	0.02	0.02	14.35	5.54	4.34	8.88	3.33	3.08
MF	Bottlenose dolphin, offshore	0.19	0	0	0.01	0.01	0.01	14.12	4.93	3.77	8.39	2.92	2.57
MF	Risso's dolphin	0.03	<0.01	<0.01	0.02	0.02	0.02	15.39	5.89	4.54	9.27	3.33	3.09
MF	Long-finned pilot whale	0	0	0	0.01	0.01	0.01	14.65	5.50	4.43	8.80	3.26	2.95
MF	Short-finned pilot whale	0.02	0	0	0.02	0.02	0.02	14.60	5.62	4.43	8.85	3.27	2.99
MF	Sperm whale[c]	0.29	0	0	<0.01	<0.01	<0.01	14.98	5.84	4.58	8.81	3.42	2.96
HF	Harbor porpoise (sensitive)	7.01	2.30	1.69	0.66	0.17	0.15	14.63	5.48	4.53	107.40	86.45	82.28
PPW	Gray seal	3.29	1.01	0.56	0.01	0.01	0.01	15.83	6.05	4.92	13.02	4.31	4.07
PPW	Harbor seal	3.31	0.63	0.19	0.07	<0.01	<0.01	15.37	6.03	4.78	12.97	4.15	3.63
PPW	Harp seal	3.07	0.41	0.20	0	0	0	15.69	5.97	4.86	12.86	4.23	3.83

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 25. 13 m monopile, 5,000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	8.78	2.56	1.90	0.02	0	0	12.46	4.29	3.88	12.46	4.24	3.88
	Minke whale (migrating)	6.30	1.50	1.17	0	0	0	11.63	3.98	3.63	48.40	24.76	21.91
	Humpback whale	9.40	2.87	2.27	0.03	<0.01	<0.01	12.35	4.26	3.74	12.37	4.25	3.74
	North Atlantic right whale[c]	8.05	2.26	1.54	0.03	<0.01	<0.01	12.11	4.11	3.70	12.21	4.17	3.70
	Sei whale[c] (migrating)	7.73	1.66	1.25	0.03	<0.01	<0.01	11.98	4.21	3.69	61.51	25.73	22.45
MF	Atlantic white sided dolphin	0	0	0	0	0	0	11.47	3.95	3.58	5.68	2.55	2.27
	Atlantic spotted dolphin	0	0	0	0	0	0	11.50	4.01	3.76	5.34	2.64	2.59
	Short-beaked common dolphin	0	0	0	<0.01	0	0	11.57	3.99	3.48	6.15	2.64	2.31
	Bottlenose dolphin, offshore	0	0	0	0	0	0	10.98	3.53	3.01	5.73	2.30	1.97
	Risso's dolphin	0.01	<0.01	0	<0.01	0	0	12.15	4.26	3.77	6.28	2.62	2.39
	Long-finned pilot whale	0	0	0	0	0	0	11.69	4.08	3.52	5.96	2.68	2.22
	Short-finned pilot whale	0	0	0	<0.01	<0.01	<0.01	11.82	4.10	3.53	6.04	2.68	2.40
	Sperm whale[c]	0	0	0	0	0	0	11.88	4.15	3.64	6.17	2.61	2.36
HF	Harbor porpoise (sensitive)	5.13	1.51	1.07	0.59	0.23	0.19	11.79	4.00	3.63	106.34	85.66	79.37
PPW	Gray seal	2.16	0.59	0.12	0	0	0	12.56	4.53	4.08	9.67	3.73	3.30
	Harbor seal	1.94	0.16	0	0	0	0	12.21	4.25	3.73	9.48	3.31	3.17
	Harp seal	1.85	0.09	0	0	0	0	12.31	4.30	3.75	9.48	3.40	3.07

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 26. 13 m monopile, 5,000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	10.98	3.14	2.24	0.02	0	0	12.35	4.20	3.84	12.35	4.20	3.84
LF	Minke whale (migrating)	7.37	1.65	1.20	0	0	0	11.51	3.82	3.55	49.23	24.59	21.59
LF	Humpback whale	11.59	3.66	2.79	0.05	<0.01	<0.01	12.28	4.26	3.83	12.30	4.26	3.84
LF	North Atlantic right whale[c]	9.52	2.53	1.79	0.02	<0.01	<0.01	11.65	4.03	3.51	11.76	4.07	3.55
LF	Sei whale[c] (migrating)	9.48	2.31	1.62	0.03	<0.01	<0.01	11.87	3.96	3.62	62.48	25.94	22.40
MF	Atlantic white sided dolphin	0	0	0	0	0	0	11.12	3.84	3.31	5.76	2.43	2.20
MF	Atlantic spotted dolphin	0	0	0	0	0	0	11.23	3.85	3.28	5.28	2.55	2.14
MF	Short-beaked common dolphin	0	0	0	<0.01	0	0	11.28	3.95	3.43	5.96	2.65	2.31
MF	Bottlenose dolphin, offshore	0	0	0	<0.01	<0.01	<0.01	10.63	3.37	2.91	5.37	2.22	2.10
MF	Risso's dolphin	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	11.90	4.03	3.64	6.24	2.64	2.42
MF	Long-finned pilot whale	0	0	0	0	0	0	11.51	3.90	3.51	5.80	2.63	2.23
MF	Short-finned pilot whale	0	0	0	<0.01	<0.01	<0.01	11.58	3.95	3.50	5.95	2.64	2.31
MF	Sperm whale[c]	0.30	0	0	<0.01	0	0	11.77	4.08	3.60	6.18	2.58	2.29
HF	Harbor porpoise (sensitive)	5.48	1.50	1.20	0.61	0.21	0.19	11.46	3.95	3.58	107.93	85.98	79.39
PPW	Gray seal	2.55	0.57	0.32	0	0	0	12.49	4.52	4.12	9.67	3.67	3.29
PPW	Harbor seal	2.69	0.19	0.08	0	0	0	12.02	4.25	3.70	9.31	3.34	3.20
PPW	Harp seal	2.22	0.32	0.05	0.06	0	0	12.11	4.29	3.73	9.40	3.49	3.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 27. 4 m pin pile, 3,500 kJ hammer, four pin piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	13.29	4.07	3.14	0.02	<0.01	0	8.47	3.56	3.29	8.49	3.58	3.30
	Minke whale (migrating)	7.87	1.83	1.26	0.01	0	0	8.00	3.34	3.20	37.71	19.07	16.46
	Humpback whale	13.83	4.49	3.25	0.02	0	0	8.44	3.56	3.28	8.44	3.57	3.28
	North Atlantic right whale[c]	10.37	2.54	1.74	0.02	0	0	8.15	3.34	3.16	8.23	3.38	3.19
	Sei whale[c] (migrating)	10.90	2.84	1.89	<0.01	0	0	8.22	3.39	3.23	40.08	19.61	16.97
MF	Atlantic white sided dolphin	0.01	0.01	0.01	0	0	0	8.02	3.27	3.12	4.43	2.33	1.97
	Atlantic spotted dolphin	0	0	0	0	0	0	8.40	3.26	3.17	4.39	2.27	2.01
	Short-beaked common dolphin	<0.01	<0.01	0	0	0	0	7.98	3.34	3.15	4.49	2.41	2.07
	Bottlenose dolphin, offshore	0.08	0.01	0	0	0	0	6.44	2.87	2.59	3.79	1.90	1.50
	Risso's dolphin	0.01	0.01	0.01	<0.01	0	0	8.27	3.38	3.16	4.59	2.42	2.06
	Long-finned pilot whale	<0.01	<0.01	0	0	0	0	7.96	3.30	3.10	4.49	2.32	1.91
	Short-finned pilot whale	0.01	0	0	0	0	0	7.95	3.37	3.16	4.40	2.38	1.96
	Sperm whale[c]	<0.01	<0.01	0	0	0	0	8.17	3.36	3.11	4.61	2.35	1.89
HF	Harbor porpoise (sensitive)	5.90	1.77	1.29	0.53	0.10	0.10	8.15	3.38	3.21	96.13	65.51	54.74
PPW	Gray seal	4.35	1.31	0.96	0	0	0	8.52	3.49	3.38	6.83	3.30	2.91
	Harbor seal	3.33	0.32	0.12	0.06	0	0	8.33	3.44	3.12	6.68	3.08	2.70
	Harp seal	2.85	0.28	0.15	0.07	0	0	8.44	3.49	3.24	6.77	3.21	2.81

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

6.2.5. Exposure Estimates – Impact Pile Driving

The mean number of marine mammals predicted to experience sound levels exceeding Level A and Level B harassment thresholds are provided in Tables 28–34, assuming 0, 10, and 12 dB broadband attenuation, for all years combined for each construction schedule as well as for the individual years of each construction schedule. These exposure estimates are calculated using the pile driving schedules described in Section 2.2. Exposure estimates used species densities derived from the habitat-based models of Roberts et al. (2016a, 2016b, 2017, 2018, 2021a, 2021b), which are the best available data for this application. Level A exposures are shown for both the peak and cumulative thresholds for PTS from Table 19 and Level B exposures are shown for both the NOAA (2005) and Wood et al. (2012) thresholds from Table 20. Minke and sei whales were considered as migrating in the area and the harbor porpoise was considered to be a sensitive species when applying the Wood et al. (2012) criteria. Table 20 shows percent probabilities of response for these criteria. The 50% response level thresholds of 120 dB for sensitive species, 140 dB for migrating mysticetes, and 160 dB for all other species were used to calculate acoustic ranges. For exposure estimates, the response probabilities shown in Table 20 were used for the different marine mammal groups. For example, for migrating mysticetes the model counts 10% of animats exposed to SPL 120 dB, 50% of animats exposed to SPL 140 dB, and 90% of animats exposed to SPL 160 dB as receiving Level B harassment.

In most cases, the exposure estimates are greater for SEL than for PK. For MF cetaceans; however, this is not always the case. Most of the acoustic energy from impact pile driving is at lower frequencies, where these species' hearing is less acute, so the frequency-weighting used in the SEL calculations substantially reduces the effect from that portion of the spectrum. HF cetaceans also have reduced sensitivity at lower frequencies; however their lower sensitivity is counteracted by the much lower threshold for PTS injury for this hearing group (155 dB re 1 $\mu Pa^2 s$). Phocid pinnipeds (PW) have some reduction in hearing sensitivity at low frequencies relative to LF cetaceans; however their auditory weighting function still passes enough low frequency energy that the SEL exposures are generally higher than PK exposures.

Table 28. Construction Schedule A, All Years Summed: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation during all years of Construction Schedule A (Table 7). Construction schedule assumptions are summarized in Section 2.2.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	146.36	21.51	13.94	0.14	0.04	0.02	147.36	33.58	28.56	205.54	66.20	53.73
	Minke whale (migrating)[b]	49.59	9.71	6.32	0.06	0.03	0.03	74.94	26.79	23.90	422.12	207.05	175.39
	Humpback whale	81.08	13.69	9.09	0.13	0.05	0.05	68.89	16.46	14.11	97.99	31.83	25.69
	North Atlantic right whale[c]	18.08	3.09	2.16	0.02	<0.01	<0.01	26.02	7.01	5.98	36.32	11.99	9.72
	Sei whale[c] (migrating)[b]	3.60	0.53	0.36	0.01	<0.01	<0.01	5.44	1.29	1.09	42.29	20.13	16.86
MF	Atlantic white sided dolphin	0.62	0.21	0.21	1.56	1.56	1.56	3,610.99	1,334.89	1,189.53	2,722.32	1,021.70	814.92
	Atlantic spotted dolphin	0	0	0	0	0	0	14.74	3.92	3.38	17.04	4.18	3.03
	Short-beaked common dolphin	4.05	1.28	0	6.96	5.09	5.09	16,247.71	6,999.42	6,371.06	11,666.25	4,697.60	3,805.18
	Bottlenose dolphin, offshore	1.13	0.15	0	0.62	0.62	0.62	825.16	387.83	331.24	690.84	246.92	194.13
	Risso's dolphin	0.04	0.02	<0.01	0.04	0.03	0.03	19.27	6.23	5.59	16.53	5.65	4.45
	Long-finned pilot whale	0.06	0.06	0	0.15	0.15	0.15	447.66	165.24	147.76	324.89	126.66	100.70
	Short-finned pilot whale	0.05	<0.01	<0.01	0.24	0.24	0.24	337.97	121.26	108.08	251.74	94.85	74.60
	Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	8.93	2.64	2.34	7.71	2.52	1.92
HF	Harbor porpoise (sensitive)[b]	359.73	97.62	67.84	34.26	5.91	3.87	758.01	258.58	227.94	11,092.63	5,509.56	4,618.70
PPW	Gray seal	10.12	1.07	0.54	<0.01	<0.01	<0.01	170.45	32.11	24.86	199.28	60.51	47.44
	Harbor seal	29.00	1.95	0.91	0.28	0.18	0.18	321.18	75.85	61.00	402.88	123.09	96.25
	Harp seal	12.51	0.94	0.36	0.10	0	0	187.66	37.64	30.42	225.05	67.95	53.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 29. Construction Schedule A, Year 1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation during year 1 of Construction Schedule A (Table 7). Construction schedule assumptions are summarized in Section 2.2.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	71.33	10.27	6.37	0.06	0.01	0.01	84.00	18.93	16.66	115.42	37.56	30.76
	Minke whale (migrating)[b]	24.01	4.39	2.87	0.03	0.02	0.02	37.99	13.53	12.26	225.15	107.81	91.13
	Humpback whale	39.42	6.41	4.24	0.08	0.04	0.04	39.08	8.99	7.76	55.78	18.05	14.62
	North Atlantic right whale[c]	8.49	1.35	0.96	0.01	<0.01	<0.01	12.83	3.52	3.04	18.90	6.12	4.94
	Sei whale[c] (migrating)[b]	1.77	0.24	0.17	<0.01	<0.01	<0.01	2.60	0.65	0.59	21.63	10.04	8.27
MF	Atlantic white sided dolphin	0.04	0.01	0.01	1.08	1.08	1.08	1,883.99	670.96	605.30	1,414.29	520.33	407.55
	Atlantic spotted dolphin	0	0	0	0	0	0	7.88	2.34	2.04	8.69	2.16	1.59
	Short-beaked common dolphin	0.33	0.11	0	5.98	4.23	4.23	8,037.76	3,142.22	2,861.28	5,868.59	2,238.25	1,783.86
	Bottlenose dolphin, offshore	0.23	0.01	0	0.53	0.53	0.53	415.04	175.42	151.05	353.16	117.19	91.48
	Risso's dolphin	0.02	0.01	<0.01	0.03	0.02	0.02	10.74	3.20	2.86	9.13	3.05	2.37
	Long-finned pilot whale	<0.01	<0.01	0	0.11	0.11	0.11	233.51	80.31	72.04	170.34	64.28	50.21
	Short-finned pilot whale	<0.01	<0.01	0	0.19	0.19	0.19	177.62	57.73	52.07	131.70	48.08	37.18
	Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	4.82	1.36	1.22	4.06	1.32	0.98
HF	Harbor porpoise (sensitive)[b]	167.25	43.98	30.77	17.20	2.82	1.77	371.46	126.74	113.19	5,977.20	2,806.21	2,338.16
PPW	Gray seal	4.43	0.39	0.18	<0.01	<0.01	<0.01	71.26	13.53	12.11	84.23	26.45	20.32
	Harbor seal	12.22	0.67	0.18	0.10	0.10	0.10	131.20	34.04	29.25	170.31	52.58	40.76
	Harp seal	5.10	0.40	0.15	0.05	0	0	77.02	16.61	14.32	92.02	29.07	22.64

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 30. Construction Schedule A, Year 2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation during year 2 of Construction Schedule A (Table 7). Construction schedule assumptions are summarized in Section 2.2.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	75.03	11.24	7.57	0.08	0.02	<0.01	63.36	14.65	11.90	90.12	28.64	22.97
	Minke whale (migrating)[b]	25.58	5.32	3.44	0.02	0.01	0.01	36.96	13.26	11.64	196.97	99.24	84.26
	Humpback whale	41.66	7.28	4.85	0.05	<0.01	<0.01	29.81	7.47	6.35	42.22	13.79	11.07
	North Atlantic right whale[c]	9.60	1.74	1.21	<0.01	<0.01	<0.01	13.19	3.49	2.93	17.42	5.87	4.78
	Sei whale[c] (migrating)[b]	1.83	0.29	0.19	<0.01	<0.01	<0.01	2.85	0.63	0.50	20.66	10.08	8.59
MF	Atlantic white sided dolphin	0.58	0.19	0.19	0.48	0.48	0.48	1,727.00	663.93	584.23	1,308.03	501.36	407.37
	Atlantic spotted dolphin	0	0	0	0	0	0	6.87	1.58	1.34	8.35	2.02	1.45
	Short-beaked common dolphin	3.73	1.17	0	0.98	0.87	0.87	8,209.95	3,857.21	3,509.78	5,797.67	2,459.35	2,021.32
	Bottlenose dolphin, offshore	0.90	0.13	0	0.09	0.09	0.09	410.12	212.42	180.18	337.68	129.74	102.65
	Risso's dolphin	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	8.53	3.03	2.73	7.40	2.60	2.08
	Long-finned pilot whale	0.06	0.06	0	0.04	0.04	0.04	214.15	84.93	75.72	154.55	62.38	50.49
	Short-finned pilot whale	0.04	<0.01	<0.01	0.05	0.05	0.05	160.35	63.54	56.01	120.04	46.77	37.42
	Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	4.11	1.28	1.12	3.65	1.20	0.94
HF	Harbor porpoise (sensitive)[b]	192.48	53.65	37.07	17.06	3.08	2.10	386.54	131.84	114.75	5,115.43	2,703.36	2,280.54
PPW	Gray seal	5.69	0.68	0.36	<0.01	<0.01	<0.01	99.20	18.57	12.75	115.05	34.06	27.12
	Harbor seal	16.78	1.28	0.73	0.18	0.09	0.09	189.97	41.80	31.75	232.57	70.51	55.50
	Harp seal	7.40	0.54	0.21	0.05	0	0	110.64	21.03	16.09	133.03	38.88	30.52

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 31. Construction Schedule B, All Years Summed: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation during all years of Construction Schedule B (Table 8). Construction schedule assumptions are summarized in Section 2.2.

	Species	Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	251.74	37.72	25.35	0.31	0.09	0.02	160.68	41.87	37.77	236.43	78.58	64.38
LF	Minke whale (migrating)[b]	97.69	20.59	13.10	0.10	0.03	0.03	115.38	50.89	46.74	617.91	300.67	253.54
LF	Humpback whale	117.67	20.47	13.67	0.15	0.02	0.02	69.43	19.53	17.64	101.72	34.17	27.70
LF	North Atlantic right whale[c]	19.76	3.92	2.77	0.02	<0.01	<0.01	19.26	6.92	6.23	25.98	9.34	7.75
LF	Sei whale[c] (migrating)[b]	6.78	1.14	0.83	0.02	<0.01	<0.01	6.12	1.88	1.73	54.33	24.66	20.41
MF	Atlantic white sided dolphin	2.60	0.87	0.87	1.17	1.17	1.17	5,332.04	2,385.18	2,160.55	4,060.10	1,638.66	1,327.44
MF	Atlantic spotted dolphin	0	0	0	0	0	0	17.42	4.31	3.75	21.26	5.24	3.76
MF	Short-beaked common dolphin	7.55	2.52	0	5.72	5.16	5.16	19,012.51	9,012.55	8,248.25	13,432.98	5,737.60	4,697.05
MF	Bottlenose dolphin, offshore	2.02	0.31	0	0.41	0.41	0.41	998.97	526.97	447.68	830.86	315.02	248.12
MF	Risso's dolphin	0.05	0.03	<0.01	0.03	0.02	0.01	23.89	8.98	8.23	20.92	7.52	5.97
MF	Long-finned pilot whale	0.18	0.18	0	0.14	0.14	0.14	601.70	260.80	237.32	432.84	181.87	146.36
MF	Short-finned pilot whale	0.08	0.01	0	0.14	0.14	0.14	447.99	194.21	175.55	334.52	135.57	107.62
MF	Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	13.09	4.60	4.19	11.90	4.04	3.13
HF	Harbor porpoise (sensitive)[b]	611.86	173.78	117.38	56.46	8.82	6.32	932.60	400.40	363.83	12,817.69	5,868.55	4,939.12
PPW	Gray seal	13.69	1.55	0.92	<0.01	<0.01	<0.01	103.73	21.91	19.94	131.69	41.14	31.52
PPW	Harbor seal	48.24	3.85	1.64	0.77	0.10	0.10	236.43	77.88	67.72	300.72	99.42	78.24
PPW	Harp seal	20.33	1.42	0.52	0.19	0	0	129.91	36.14	32.17	159.01	52.37	41.11

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 32. Construction Schedule B, Year 1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation during year 1 of Construction Schedule B (Table 8). Construction schedule assumptions are summarized in Section 2.2.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	50.70	7.37	4.60	0.06	0.03	0.02	58.72	13.84	12.25	78.01	26.64	21.86
	Minke whale (migrating)[b]	19.94	3.66	2.38	0.04	0.03	0.03	31.66	11.40	10.32	188.28	87.70	73.94
	Humpback whale	25.35	3.95	2.61	0.04	0.02	0.02	23.68	5.76	5.08	32.30	11.07	8.96
	North Atlantic right whale[c]	5.61	0.90	0.68	<0.01	<0.01	<0.01	8.00	2.35	2.07	11.17	3.84	3.12
	Sei whale[c] (migrating)[b]	1.56	0.21	0.14	<0.01	<0.01	<0.01	2.39	0.61	0.55	20.03	9.14	7.47
MF	Atlantic white sided dolphin	0.07	0.02	0.02	1.17	1.17	1.17	1,380.78	510.25	461.74	1,061.81	400.45	312.54
	Atlantic spotted dolphin	0	0	0	0	0	0	4.18	1.18	1.04	4.65	1.22	0.91
	Short-beaked common dolphin	0.44	0.15	0	5.72	5.16	5.16	4,153.76	1,765.71	1,617.76	3,036.60	1,241.81	998.24
	Bottlenose dolphin, offshore	0.26	0.02	0	0.41	0.41	0.41	227.97	103.85	89.27	201.32	67.85	52.49
	Risso's dolphin	0.01	<0.01	<0.01	0.02	0.02	0.01	6.14	2.02	1.82	5.28	1.86	1.44
	Long-finned pilot whale	<0.01	<0.01	0	0.14	0.14	0.14	150.78	55.12	49.74	111.29	43.69	34.13
	Short-finned pilot whale	0.02	0.01	0	0.14	0.14	0.14	113.55	39.10	35.43	85.78	32.51	25.13
	Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	3.42	1.00	0.90	2.95	0.97	0.72
HF	Harbor porpoise (sensitive)[b]	126.36	33.97	24.01	13.25	2.21	1.41	266.79	94.70	84.39	4,271.24	1,853.85	1,564.77
PPW	Gray seal	3.99	0.39	0.19	<0.01	<0.01	<0.01	63.06	11.85	10.79	73.66	23.56	18.07
	Harbor seal	11.07	0.58	0.17	0.11	0.10	0.10	115.58	30.64	26.45	150.06	46.76	36.35
	Harp seal	4.44	0.40	0.15	0.05	0	0	67.30	14.90	12.82	79.55	25.79	20.11

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 33. Construction Schedule B, Year 2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation during year 2 of Construction Schedule B (Table 8). Construction schedule assumptions are summarized in Section 2.2.

Species		Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	141.85	21.41	14.65	0.18	0.04	0	71.94	19.78	18.01	111.77	36.64	30.01
	Minke whale (migrating)[b]	53.95	11.75	7.44	0.04	0	0	58.09	27.40	25.27	298.11	147.78	124.62
	Humpback whale	63.57	11.38	7.62	0.07	0	0	31.51	9.48	8.65	47.80	15.91	12.90
	North Atlantic right whale[c]	9.33	1.99	1.38	0.01	0	0	7.42	3.01	2.74	9.77	3.63	3.05
	Sei whale[c] (migrating)[b]	3.51	0.63	0.46	<0.01	0	0	2.51	0.86	0.79	23.05	10.43	8.70
MF	Atlantic white sided dolphin	1.78	0.59	0.59	0	0	0	2,786.78	1,322.37	1,198.16	2,114.66	873.30	715.80
	Atlantic spotted dolphin	0	0	0	0	0	0	9.32	2.20	1.91	11.69	2.83	2.01
	Short-beaked common dolphin	5.02	1.67	0	0	0	0	10,498.71	5,120.38	4,684.89	7,345.74	3,176.58	2,613.45
	Bottlenose dolphin, offshore	1.24	0.21	0	0	0	0	542.17	297.54	252.04	442.69	173.81	137.57
	Risso's dolphin	0.03	0.02	<0.01	<0.01	0	0	12.60	4.94	4.55	11.10	4.01	3.21
	Long-finned pilot whale	0.12	0.12	0	0	0	0	318.65	145.35	132.56	227.23	97.65	79.31
	Short-finned pilot whale	0.05	0	0	0	0	0	236.34	109.61	99.02	175.78	72.83	58.29
	Sperm whale[c]	<0.01	<0.01	0	0	0	0	7.02	2.62	2.39	6.50	2.23	1.75
HF	Harbor porpoise (sensitive)[b]	331.45	95.44	63.74	29.50	4.51	3.35	454.54	208.70	190.77	5,834.57	2,740.79	2,303.63
PPW	Gray seal	5.93	0.71	0.45	0	0	0	24.89	6.16	5.60	35.51	10.76	8.23
	Harbor seal	22.75	2.00	0.90	0.40	0	0	73.96	28.91	25.25	92.20	32.22	25.64
	Harp seal	9.72	0.62	0.22	0.09	0	0	38.32	13.00	11.84	48.63	16.27	12.86

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 34. Construction Schedule B, Year 3: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation during year 3 of Construction Schedule B (Table 8). Construction schedule assumptions are summarized in Section 2.2.

	Species	Injury						Behavior					
		L_E			L_{pk}			L_p [a]			L_p [b]		
		Attenuation (dB)						Attenuation (dB)					
		0	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale[c]	59.19	8.94	6.11	0.07	0.02	0	30.02	8.25	7.51	46.64	15.29	12.52
	Minke whale (migrating)[b]	23.80	5.19	3.28	0.02	0	0	25.63	12.09	11.15	131.52	65.19	54.98
	Humpback whale	28.74	5.15	3.44	0.03	0	0	14.25	4.29	3.91	21.62	7.20	5.83
	North Atlantic right whale[c]	4.82	1.03	0.71	<0.01	0	0	3.84	1.56	1.42	5.05	1.88	1.58
	Sei whale[c] (migrating)[b]	1.71	0.31	0.22	<0.01	0	0	1.22	0.42	0.39	11.25	5.09	4.24
MF	Atlantic white sided dolphin	0.75	0.25	0.25	0	0	0	1,164.47	552.56	500.66	883.62	364.91	299.10
	Atlantic spotted dolphin	0	0	0	0	0	0	3.92	0.93	0.80	4.91	1.19	0.84
	Short-beaked common dolphin	2.09	0.70	0	0	0	0	4,360.04	2,126.46	1,945.60	3,050.64	1,319.21	1,085.35
	Bottlenose dolphin, offshore	0.52	0.09	0	0	0	0	228.83	125.58	106.38	186.84	73.36	58.06
	Risso's dolphin	0.01	<0.01	<0.01	<0.01	0	0	5.15	2.02	1.86	4.54	1.64	1.31
	Long-finned pilot whale	0.05	0.05	0	0	0	0	132.27	60.33	55.02	94.32	40.53	32.92
	Short-finned pilot whale	0.02	0	0	0	0	0	98.10	45.50	41.10	72.96	30.23	24.20
	Sperm whale[c]	<0.01	<0.01	0	0	0	0	2.65	0.99	0.90	2.45	0.84	0.66
HF	Harbor porpoise (sensitive)[b]	154.05	44.36	29.63	13.71	2.10	1.56	211.27	97.00	88.67	2711.88	1,273.91	1,070.72
PPW	Gray seal	3.76	0.45	0.28	0	0	0	15.78	3.90	3.55	22.52	6.82	5.22
	Harbor seal	14.42	1.27	0.57	0.25	0	0	46.89	18.33	16.01	58.46	20.43	16.25
	Harp seal	6.17	0.40	0.14	0.06	0	0	24.29	8.24	7.51	30.83	10.31	8.15

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

6.3. Exposure Estimation – Vibratory Setting of Piles

During construction of New England Wind, it may be necessary to start pile installation using a vibratory hammer rather than using an impact hammer to reduce the risk of pile run. The Proponent conducted a seabed drivability analysis to estimate the number of foundation positions that could potentially require vibratory setting of piles. The analysis suggested that up to 50% of foundations (~66 foundations) could require vibratory setting. Adding 20% conservatism to this estimate (20% of 66 is ~13 additional foundations), results in approximately 79 foundations requiring vibratory pile setting. This information was used to estimate the number of days of vibratory setting shown in the pile installation schedules provided in Section 2.2.

6.3.1. Rationale and Assumptions

The following were used to estimate potential Level B exposures for vibratory setting of piles:

- The threshold criterion for Level B harassment for vibratory setting, a continuous sound, is 120 dB re 1μPa root mean square (rms) unweighted sound pressure level (SPL).
- The Proponent is not aware of publicly available acoustic measurements of vibratory pile driving of large (>2 m) monopiles, so a method to estimate expected levels by extrapolation from smaller piles was used. Extrapolation of piling sound levels for larger piles has previously been conducted in Europe for impact pile driving (Bellmann et al. 2020). A similar approach has been used here, which is consistent with extrapolation work undertaken on other Avangrid Renewables projects in non-US jurisdictions.
- Data for the smaller piles are compiled in the GARFO Acoustics Tool (https://s3.amazonaws.com/media.fisheries.noaa.gov/2020-09/GARFO-Sect7-PileDriving-AcousticsTool-09142020.xlsx?.Egxagq5Dh4dplwJQsmN1gV0nggnk5qX). Received SEL levels at 10 m for round steel pile driven with vibratory hammers was plotted as a function of pile diameter and fitted with a power function (method previously accepted by European authorities for impact piling extrapolation for Avangrid Renewables) (Figure 23). As seen in Figure 23, the power function represents the SEL trend as a function of pile diameter with an R^2 value of 0.6465 for piles 12 inches to 72 inches in diameter. Extrapolating to 13 m piles, with a diameter of 512 inches, results in a received level at 10 m of SEL ~198 dB re 1 μPa2·s (~188 dB re 1 μPa2·s assuming NAS and 10 dB of attenuation).
- Pile diameter is not likely to be the best predictor of sound levels produced during vibratory pile driving. While hammer energy may be a better predictor, the hammer and hammer energy in the GARFO data is generally not known. Other factors, including the bottom type and use of noise attenuating systems, also contribute to sound levels. For these reasons, the uncertainty in the predicted SEL for vibratory hammer installation of a 13 m pile is assumed to be high.

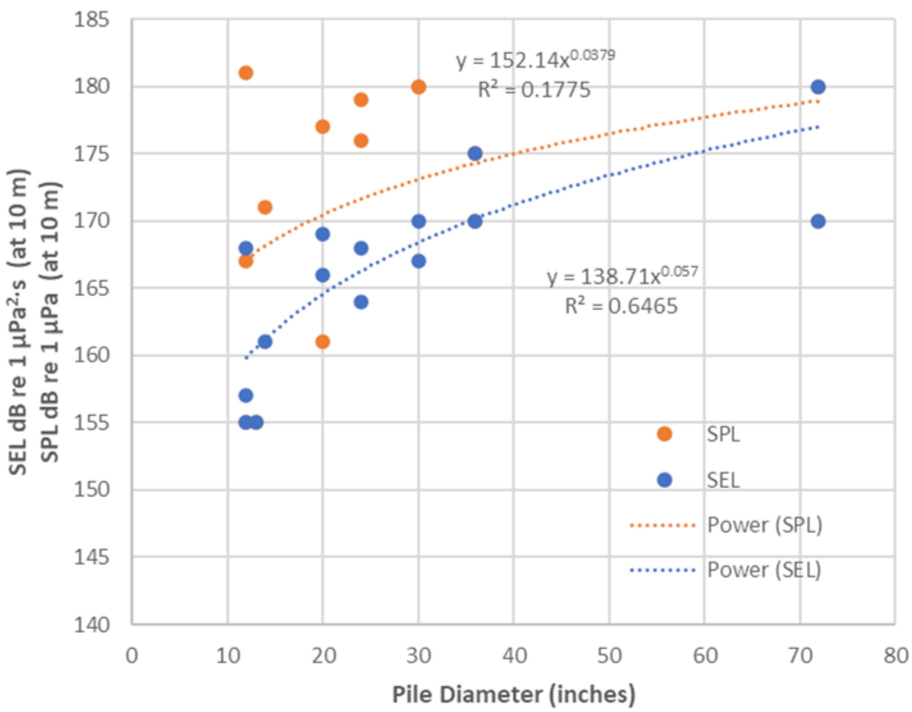

Figure 23. SEL (blue) and SPL (orange) received levels as a function of pile diameter, in inches, from the GARFO Acoustics Tool.

- Assuming (1) a received SEL ~188 dB re 1 µPa2·s at 10 m for 13 m monopiles using NAS, (2) sound propagation by the practical spreading loss model (15 Log(range)), and (3) an average vibratory setting duration of 30 minutes per pile (1 hour per day assuming 2 monopiles), the PTS ranges calculated using the NMFS online User Spreadsheet Tool (NMFS 2020, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fmedia.fisheries.noaa.gov%2F2021-02%2F2020_BLANK_USER_SPREADSHEET_508_DEC.xlsx&wdOrigin=BROWSELINK) are as follows:
    - LF cetaceans = 430.9 m
    - MF cetaceans = 38.2 m
    - HF cetaceans = 637.1 m
    - Phocid pinnipeds = 261.9 m
- Due to the small size of the PTS ranges and the mitigation described in Section 11, the Proponent is not requesting any Level A take of marine mammals for vibratory setting activity.
- The power function fit described above for the received SPL at 10 m is poor, so an alternative approach is needed. Noting that animals are not expected to experience a behavioral response at distances greater than 50 km (Dunlop et al. 2017a; Dunlop et al. 2017b), the source level necessary to produce a received level of 120 dB at 50 km was found. Assuming practical spreading loss (15 Log(range)), a source level of 190.5 dB will result in received levels of 120 dB at 50 km. Vibratory driving of 72-inch steel pipe piles has an apparent source level of SPL ~167–180 dB re 1 µPa at 10 m (Molnar et al. 2020), so it is assumed that the sound levels for a 13 m pile will exceed the behavioral threshold to 50 km. All animals within a 50-km radius around a given foundation location would be

exposed above the 120 dB SPL threshold for any given day on which vibratory setting was used for pile installation.

- Monthly marine mammal densities in the potential impact area used the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the US Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b).
- The average monthly density of each species was calculated as the average of all MGEL/Duke density cells overlapping partially or completely with an area that includes the SWDA plus a 50-km buffer from the edge of the SWDA (cells entirely on land were not included, but cells that overlap only partially with land were included). See Section 6.1.1.2 and Figure 18.
- The larger area used to calculate density is approximately 13,000 km^2.
- The daily impact area was calculated as a circle with radius of 50 km (Area = π x (50 km)^2) centered at a single point source where a given pile is being driven, resulting in an impact area of 7,854 km^2 within the larger area.
- The impact area will be in a different location for each pile driven. Therefore, the average density for the larger area (not including land) was used to get an average density at each pile installation location. For many piles, the impact area will not overlap with land; for others there will be some overlap. Land was not included in the density calculation.
- Each average monthly density value from the larger area was multiplied by the 7,854 km^2 impact area to estimate the daily number of exposures that could occur on a given day during each month in the May through December proposed pile driving period.
- Soil sediment data gathered during geotechnical coring campaigns in the SWDA were analyzed to estimate the number of project foundation positions that might be at risk for pile run. Approximately 50% of positions (~66 foundations) were determined to have the sediment conditions that might indicate a risk of pile run. A 20% contingency on this percentage was added to account for new sediment data analysis or installation contractor-provided information (20% of 66 is ~13 additional foundations). This brought the total number of positions to approximately 79.
- The daily Level B exposure estimates based on 79 foundation positions were multiplied by the number of vibratory hammer piling days each month from the two construction schedules. The monthly exposures were then summed to get yearly exposure estimates as well as species-specific exposure estimates for the complete project buildout.
- Using the same methodology as for impact pile driving, for each species, the higher of the two yearly Level B estimates (Schedule A or Schedule B) was used as a conservative estimate of Level B harassment.

6.3.2. Exposure Estimates – Vibratory Setting

Daily exposure estimates above the 120 dB threshold criterion calculated using the assumptions and methods outlined in Section 6.3.1 are shown in Table 35 for each day of vibratory setting by month.

Table 35. Number of marine mammals of each species that could be exposed to sound above the 120 dB behavioral threshold criterion per day of vibratory pile setting based on their average monthly density within a 50 km buffer of the SWDA and assuming a range to threshold of 50 km.

Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fin whale	25.64	26.24	27.33	24.79	21.68	14.41	11.66	11.83
Minke whale	21.05	18.86	7.42	4.88	5.05	6.26	2.26	3.17
Humpback whale	14.06	14.41	8.47	5.20	14.94	11.60	6.49	4.29
North Atlantic right whale	21.64	1.59	0.26	0.18	0.23	0.60	3.55	19.41
Sei whale	2.72	1.63	0.59	0.30	0.54	0.13	0.17	0.17
Atlantic white-sided dolphin	530.39	486.55	300.64	157.90	185.06	260.91	287.23	335.47
Atlantic spotted dolphin	2.09	3.90	7.21	9.95	10.00	14.03	5.16	0.66
Short-beaked common dolphin	526.47	665.63	572.78	822.43	1,138.26	1,397.04	1,056.03	1,641.49
Bottlenose dolphin, offshore	111.26	294.39	587.33	476.27	543.86	452.33	228.60	109.54
Risso's dolphin	2.81	4.07	9.10	16.73	10.72	4.12	4.03	6.75
Long-finned pilot whale	34.11	34.11	34.11	34.11	34.11	34.11	34.11	34.11
Short-finned pilot whale	25.16	25.16	25.16	25.16	25.16	25.16	25.16	25.16
Sperm whale	0.91	1.10	2.49	2.35	0.96	0.86	0.72	0.31
Harbor porpoise	299.33	89.23	65.69	67.01	49.05	42.75	150.25	164.88
Gray seal	435.96	136.09	30.29	15.64	17.93	37.23	89.34	288.18
Harbor seal	979.49	305.75	68.05	35.14	40.28	83.64	200.72	647.47
Harp seal	435.96	136.09	30.29	15.64	17.93	37.23	89.34	288.18

The resulting Level B exposure estimates from vibratory setting based on Construction Schedules A and B are shown in Tables 36 and 37, respectively. These are used to calculate the vibratory setting takes shown in Section 6.7.2 by rounding up to an integer. No group size correction was applied to Level B takes for vibratory setting because the estimated exposures all exceeded one average group size for all species.

Table 36. Construction Schedule A: Estimated number of Level B exposures from vibratory setting during pile installation by year and for the full 2-year construction schedule.

Species		Year 1	Year 2	All Years Combined
LF	Fin whale[a]	719.90	412.53	1,132.44
	Minke whale	250.97	144.07	395.04
	Humpback whale	315.64	196.61	512.25
	North Atlantic right whale[a]	62.48	36.14	98.62
	Sei whale[a]	22.00	11.85	33.85
MF	Atlantic white-sided dolphin	8,322.95	5,134.42	13,457.37
	Atlantic spotted dolphin	253.69	163.69	417.37
	Short-beaked common dolphin	26,855.21	17,722.03	44,577.24
	Bottlenose dolphin, offshore	13,792.05	8,356.74	22,148.79
	Risso's dolphin	309.34	168.48	477.82
	Long-finned pilot whale	1,057.36	648.06	1,705.43
	Short-finned pilot whale	779.89	477.99	1,257.88
	Sperm whale[a]	49.68	27.82	77.51
HF	Harbor porpoise	2,616.51	1,567.87	4,184.38
PPW	Gray seal	2,087.12	1,223.64	3,310.76
	Harbor seal	4,689.21	2,749.21	7,438.42
	Harp seal	2,087.12	1,223.64	3,310.76

[a] Listed as Endangered under the Endangered Species Act.

Table 37. Construction Schedule B: Estimated number of Level B exposures from vibratory setting during pile installation by year and for the full 3-year construction schedule.

Species		Year 1	Year 2	Year 3	All Years Combined
LF	Fin whale[a]	662.70	754.21	299.36	1,716.27
	Minke whale	244.92	251.31	100.49	596.72
	Humpback whale	282.46	326.89	132.38	741.73
	North Atlantic right whale[a]	58.98	38.47	29.39	126.85
	Sei whale[a]	20.93	20.72	8.95	50.60
MF	Atlantic white-sided dolphin	8,026.92	8,510.24	3,495.86	20,033.03
	Atlantic spotted dolphin	227.09	272.15	106.63	605.86
	Short-beaked common dolphin	23,282.16	27,565.68	11,245.59	62,093.43
	Bottlenose dolphin, offshore	12,606.33	15,190.23	5,908.96	33,705.52
	Risso’s dolphin	262.00	317.18	124.69	703.87
	Long-finned pilot whale	955.04	1,091.47	443.41	2,489.92
	Short-finned pilot whale	704.41	805.04	327.05	1,836.50
	Sperm whale[a]	47.21	54.02	20.97	122.20
HF	Harbor porpoise	2,359.21	2,339.74	1,126.83	5,825.78
PPW	Gray seal	2,010.52	1,674.27	890.19	4574.98
	Harbor seal	4,517.11	3,761.66	2,000.03	10,278.79
	Harp seal	2,010.52	1674.27	890.19	4574.98

[a] Listed as Endangered under the Endangered Species Act.

6.4. Exposure Estimation – Drilling

There may be instances during construction of New England Wind where large sub-surface boulders or hard sediment layers are encountered, requiring drilling to pass through these objects. The Proponent conducted a seabed drivability analysis to estimate the number of foundation positions that could potentially require drilling during pile installation. The analysis suggested that up to 30% of foundations could require drilling. Adding 20% conservatism to this estimate results in approximately 48 foundations requiring drilling. This information was used to estimate the number of days of drilling shown in the pile installation schedules provided in Section 2.2.

6.4.1. Rationale and Assumptions

The Proponent is not aware of acoustic measurements of very large rotational drills specifically for this purpose, but comprehensive measurements of large seabed drills are available from projects in the Alaskan Chukchi and Beaufort Seas. In particular, measurements were made during use of mudline cellar drilling with a 6 m diameter bit (Austin et al. 2018). The mudline cellar is a circular area centered on an oil or gas well on the seabed for the purpose of placing well heads and blow-out preventers below the seafloor elevation. Mudline cellars are important in shallow arctic waters, where deep ice keels can destroy equipment that sits above the seafloor grade. Austin et al. (2018) measured SPL of ~140 dB re µPa at 1000 m and estimated the broadband source level for this device as 191 dB re µPa^{2}m^2 at 1 m. The source level that Austin et al. (2018) estimated did not assume practical spreading loss, so this source level is not used. When assuming practical spreading loss, the source level back-propagated to 1 m is 185 dB re µPa^{2}m^2.

The mudline cellar drilling in the Chukchi Sea was measured at a site with water depth 46 m, which is similar to depths at the deeper sections of the New England Wind project area. Seabed sediment geoacoustic properties differ: the Chukchi Sea drilling site had softer surface sediments with a 14.5 m thick top layer of constant sound speed 1630 m/s and density 1.45 g/cm^3, overlying more consolidated sediments with sound speed 2384 m/s and density 2.32 g/cm^3. In comparison, the New England Wind sediments are believed to consist of a top layer of about 15 m thickness with sound speed gradient 1650–1830 m/s and density 1.87 g/cm^3, overlying more consolidated sands with a sound speed gradient from 1830–2140 m/s through the next 100 m and having density 1.87–2.04 g/cm^3. Overall, the Chukchi Sea surface sediments have a slightly lower sound speed and lower density than the New England Wind site, but the reverse is true for the deeper sediments. Overall, the acoustic reflectivity at lower frequencies is expected to be similar between these sites. The ocean sound speed profiles at both sites are slightly downward refracting in summer, when the activities were measured in the Chukchi and when most pile installations are planned to occur for New England Wind.

A separate modeling study that included mudline cellar drilling was performed to predict noise footprints of that operation in the Chukchi Sea (Quijano et al. 2019). This modeling study found the 120 dB re µPa SPL threshold occurred at a distance of 16 km, which included noise from several vessels near the drillsite on dynamic positioning. We assume that pile installation drilling produces similar sound levels as mudline cellar drilling, and, as a conservative measure, we will use the SPL of 140 dB re µPa at 1000 m (as measured by Austin et al. 2018) along with practical spreading loss to obtain an estimate of 21.5 km to the 120 dB re µPa threshold. If assuming the back-propagated SPL of 185 dB re µPa at 1 m described above, the range to the 120 dB re µPa threshold is the same.

Assuming (1) a sound source level of 185 dB re 1 μPa^2·s at 1 m for drilling (2) sound propagation by the practical spreading loss model (15 Log(range)), and (3) 12 hours of drilling per pile (24 hours per day assuming 2 monopiles), the PTS ranges calculated using the NMFS online User Spreadsheet Tool (NMFS 2020, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fmedia.fisheries.noaa.gov%2F2021-02%2F2020_BLANK_USER_SPREADSHEET_508_DEC.xlsx&wdOrigin=BROWSELINK) are as follows:

- LF cetaceans = 226.2 m
- MF cetaceans = 20.1 m
- HF cetaceans = 334.5 m
- Phocid pinnipeds = 137.5 m

The PTS ranges have been calculated under a conservative assumption that drilling occurs 24 hours a day. Due to the small size of the PTS ranges and the mitigation described in Section 11, the Proponent is not requesting any Level A take of marine mammals for drilling activity.

The following were used to estimate potential Level B take for drilling that may be required during pile installation:

- The threshold criterion for Level B harassment for drilling, a continuous sound, is 120 dB re 1μPa root mean square (rms) unweighted sound pressure level (SPL).
- All animals within a 21.5-km radius around a given drilling location were assumed to be exposed above the 120 dB SPL threshold for any given day on which drilling was used during pile installation.
- The daily impact area was calculated as a circle with radius of 21.5 km (Area = π x (21.5 km)^2), resulting in an impact area of 1,452 km^2.
- Monthly marine mammal densities in the potential impact area used the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the US Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b).
- The monthly density of each species was calculated as the average of all MGEL/Duke density cells overlapping partially or completely with a 21.5-km buffer of the Southern Wind Development Area (SWDA) (cells entirely on land were not included, but cells that overlap only partially with land were included).
- Each monthly density value was multiplied by the 1,452 km^2 impact area to estimate the number of exposures that could occur on a given day during each month in the May through December proposed pile driving period.
- Soil sediment data gathered during geotechnical coring campaigns in the SWDA were analyzed to estimate the number of project foundation positions that might be at risk for encountering boulders or hard sediments causing pile refusal. Approximately 30% of positions (~40 foundations) were determined to have the sediment conditions that might indicate a risk of boulder encounter or pile refusal. A 20% contingency on this percentage was added to account for additional sediment data analysis or installation contractor-provided information (20% of 40, or 8 additional foundations). This brought the total number of positions to approximately 48.
- The daily Level B exposure estimates based on 48 foundation positions were multiplied by the number of piling days each month from the two construction schedules where drilling might be used during installation. The monthly exposures were then summed to get yearly exposure estimates as well as species-specific exposure estimates for the complete project buildout.

- In the total take request for all sound-producing activities, for days when pile installation includes both vibratory setting and drilling, the Level B estimated takes for drilling were not included in the total to avoid double counting.

6.4.2. Exposure Estimates – Drilling

Daily exposure estimates above the 120 dB threshold criterion calculated based on the methods outlined in Section 6.4.1 are shown in Table 38 for each day of drilling by month.

Table 38. Number of marine mammals of each species that could be exposed to sound above the 120 dB behavioral threshold criterion per day of drilling based on their average monthly density within a 21.5 km buffer of the SWDA and assuming a range to threshold of 21.5 km

Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fin whale	4.72	4.67	5.10	4.72	3.81	2.29	2.04	2.11
Minke whale	3.74	3.43	1.23	0.86	0.89	1.06	0.47	0.67
Humpback whale	2.28	2.22	1.92	1.10	3.70	2.53	0.90	0.47
North Atlantic right whale	4.78	0.31	0.05	0.04	0.05	0.13	0.69	3.80
Sei whale	0.58	0.31	0.08	0.05	0.09	0.02	0.03	0.02
Atlantic white-sided dolphin	114.37	108.21	70.97	38.88	42.03	54.97	58.25	75.25
Atlantic spotted dolphin	0.35	0.66	1.17	2.03	1.97	1.90	0.99	0.13
Short-beaked common dolphin	74.72	80.21	83.46	145.35	241.30	274.02	193.43	334.76
Bottlenose dolphin, offshore	8.69	12.61	26.32	23.31	41.53	45.66	21.56	11.79
Risso's dolphin	0.19	0.22	0.57	1.11	0.82	0.28	0.37	0.64
Long-finned pilot whale	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29
Short-finned pilot whale	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Sperm whale	0.06	0.13	0.49	0.49	0.15	0.15	0.12	0.03
Harbor porpoise	63.34	14.85	10.52	9.72	7.99	7.59	18.93	32.15
Gray seal	51.24	6.56	1.38	0.80	1.28	1.89	1.32	7.42
Harbor seal	115.11	14.74	3.11	1.80	2.88	4.25	2.97	16.68
Harp seal	51.24	6.56	1.38	0.80	1.28	1.89	1.32	7.42

The resulting Level B exposure estimates for drilling during pile installation based on Construction Schedules A and B are shown in Tables 39 and 40, respectively. These are used to calculate the drilling takes shown in Section 6.7.3 by rounding up to an integer. No group size correction was applied to Level B takes for drilling because the estimated exposures all exceeded one average group size for all species after rounding up to an integer.

Table 39. Construction Schedule A: Estimated number of Level B exposures from drilling during pile installation by year and for the full 2-year construction schedule.

Species		Year 1	Year 2	All Years Combined
LF	Fin whale[a]	138.31	59.42	197.73
	Minke whale	47.08	21.35	68.43
	Humpback whale	73.61	29.24	102.86
	North Atlantic right whale[a]	13.55	7.38	20.93
	Sei whale[a]	4.15	1.82	5.97
MF	Atlantic white-sided dolphin	2,048.15	938.73	2,986.88
	Atlantic spotted dolphin	49.17	21.84	71.01
	Short-beaked common dolphin	5,211.25	2,400.95	7,612.20
	Bottlenose dolphin, offshore	927.56	397.29	1,324.85
	Risso's dolphin	21.18	9.16	30.33
	Long-finned pilot whale	240.45	109.29	349.74
	Short-finned pilot whale	177.35	80.61	257.96
	Sperm whale[a]	9.39	4.09	13.49
HF	Harbor porpoise	452.36	222.00	674.36
PPW	Gray seal	162.58	79.32	241.90
	Harbor seal	365.27	178.21	543.48
	Harp seal	162.58	79.32	241.90

[a] Listed as Endangered under the Endangered Species Act.

Table 40. Construction Schedule B: Estimated number of Level B exposures from drilling during pile installation by year and for the full 3-year construction schedule.

Species		Year 1	Year 2	Year 3	All Years Combined
LF	Fin whale[a]	84.17	82.27	37.12	203.56
	Minke whale	34.49	30.92	16.35	81.75
	Humpback whale	44.39	41.49	18.79	104.67
	North Atlantic right whale[a]	12.22	7.37	6.40	25.99
	Sei whale[a]	3.26	2.75	1.55	7.56
MF	Atlantic white-sided dolphin	1,366.30	1,267.93	666.85	3,301.08
	Atlantic spotted dolphin	27.63	26.56	10.90	65.08
	Short-beaked common dolphin	3,008.71	2,743.43	1,256.15	7,008.30
	Bottlenose dolphin, offshore	519.02	490.99	218.61	1,228.61
	Risso's dolphin	11.62	11.72	4.35	27.70
	Long-finned pilot whale	145.73	138.44	65.58	349.74
	Short-finned pilot whale	107.48	102.11	48.37	257.96
	Sperm whale[a]	5.09	5.37	2.20	12.66
HF	Harbor porpoise	322.60	262.20	158.32	743.11
PPW	Gray seal	146.30	94.56	72.42	313.27
	Harbor seal	328.70	212.44	162.70	703.84
	Harp seal	146.30	94.56	72.42	313.27

[a] Listed as Endangered under the Endangered Species Act.

6.5. Exposure Estimation – Potential UXO Detonation

Detonation of UXOs may be required if they are encountered during construction activities, such as cable laying, and if avoidance, physical removal, or alternative combustive removal is not feasible. Sounds from detonation of UXOs have the potential to take marine mammals by both Level A and Level B harassment so both Level A and Level B take is being requested for this activity.

6.5.1. Acoustic Modeling Methodology and Assumptions

An acoustic modeling study of peak pressure, acoustic impulse, and sound exposure level from UXO detonation was performed recently for the Revolution Wind project, an Orsted and Eversource Investment joint venture (Hannay and Zykov 2022), which is geographically adjacent to the New England Wind project area. Although this study was targeted for the Revolution Wind project, the results are being applied to Orsted's Ocean Wind 1 and Sunrise Wind projects due to site similarities such as water depth and seabed sediment properties. This modeling study is currently available as Appendix B in the *Revolution Wind Petition for Incidental Take Regulations for the Construction and Operation of the Revolution Wind Offshore Wind Farm* starting at Page 329 of that application (available at https://media.fisheries.noaa.gov/2022-03/RevWind_ITR_App_OPR1.pdf; LGL Ecological Research Associates, Inc. 2022) and Appendix C in the *Ocean Wind Offshore Wind Farm Application for Marine Mammal Protection Act (MMPA) Rulemaking and Letter of Authorization (LOA)* (available at https://media.fisheries.noaa.gov/2022-03/OceanWind1OWF_2022_508APP_OPR1.pdf; HDR 2022).

The modeling study employed an approach adopted from the US Navy of 'binning' items of UXO which may be encountered on the site and may need to be mitigated through detonation. The study included acoustic ranges for potential UXO detonations for four different water depths (12 m, 20 m, 30 m, and 45 m) within the Revolution Wind project area and for five different UXO charge weight bins (E4 [2.3 kg], E6 [9.1 kg], E8 [45.5 kg], E10 [227 kg], and E12 [454 kg]; Table 41) (Hannay and Zykov 2022). The modeling locations were chosen at two sites along the Revolution Wind subsea export cable route in Narragansett Bay in water depths of 12 m and 20 m, and two sites within the Revolution Wind lease area at depths of 30 m and 45 m.

Table 41. Navy "bins" and corresponding maximum UXO charge weights (Maximum equivalent weight trinitrotoluene [TNT]) to be modeled.

Navy bin	Maximum equivalent weight TNT	
	(kg)	(lbs)
E4	2.3	5
E6	9.1	20
E8	45.5	100
E10	227	500
E12	454	1000

Source: Hannay and Zykov 2022

The acoustic modeling considered injurious effects to lung and gastrointestinal tracts of marine mammals using peak pressure and acoustic impulse metrics. Auditory system injury zones were assessed using Sound Exposure Level (SEL) based on Permanent Threshold Shift (PTS) onset. Disturbance to marine mammals was based on Temporary Threshold Shift (TTS) onset. This modeling also considered the use of sound reduction/mitigation technologies that would reduce the produced pressures by 10 dB across all acoustic frequencies. This amount of reduction is expected to be possible using noise abatement systems (NAS) such as modern air curtains.

The peak pressure and acoustic impulse levels and effects threshold exceedance zones depend only on charge weight, water depth, animal mass, and submersion depth. They depend only slightly on local bathymetry that could affect the maximum submersion depth of nearby animals. These results do not depend on seabed composition or acoustic reflectivity. Therefore, the peak pressure and impulse results are expected to be directly relevant for use with New England Wind activities, as long as those activities are performed similarly (i.e., by detonating the same UXO charge sizes, performing only one charge detonation per 24 hours, and using an NAS capable of reducing pressures by at least 10 dB).

The water depths considered in the acoustic modeling study (i.e., 12 m, 20 m, 30 m, 45 m) are relevant to the New England Wind project areas that may require UXO detonation, although the export cable route for New England Wind comes to shore northeast of Cape Cod Island and not into Narragansett Bay, as was considered in the modeling study. The modeled SEL from Revolution Wind are mostly transferable to similar depth sites over New England Wind's project area, with the possible exception of the shallowest site (12 m) that is located in a constrained channel in Narragansett Bay with nearby islands blocking sound propagation in some directions. The area of possible effects threshold exceedances could be larger for other sites with similar water depths when islands or shoals are not nearby to block sound propagation. The SEL results from the other Revolution Wind model sites will be approximately transferable to New England Wind sites of the same depth. Those results, however, depend on the sound propagation loss that is specific to the bathymetric variations along multiple radials leading away from each model site. In general, the bathymetry near the Revolution Wind model sites was gently sloping, but there were some non-uniform bathymetry features included. This could lead to slight differences in the sizes of the effects threshold exceedance zones. Nevertheless, differences of charge sizes within each UXO weight range bin and the unknown fraction of contained explosive that will detonate are likely to produce much more variability in noise level for each bin size than location-dependent effects.

The maximum equivalent weight of the possible UXO types that maybe encountered by the New England Wind project fall within or below bin E12, and possible UXO types expected within the footprint of New England Wind generally fall in bin E10 and below (Mills 2021). The Proponent will employ avoidance through micro-routing/micro-siting of project infrastructure. Due to this avoidance measure, the low likelihood of encounter, and the similarity in bathymetry between the Revolution Wind and New England Wind project areas, the modeling study (Hannay and Zykov 2022) is proposed to be sufficient for New England Wind.

6.5.2. Acoustic Ranges

New England Wind construction operations may encounter UXO along the OECC and within the SWDA. UXO encountered during New England Wind construction activities are expected to be of the same type and sizes considered for the Ocean Wind 1 project (Mills 2021; HDR 2022). For the purposes of the New England Wind LOA application, the same UXO risk assumptions as the Ocean Wind application (HDR 2022) have been made for the New England Wind project, whereby up to 10 E12-bin UXOs were assumed between the various depths expected to be encountered in the project area, estimating 2 UXOs at 12 m, 3 UXOs at 20 m, 3 UXOs at 30 m, and 2 UXOs at 40 m. Based on the results of the UXO desktop study (Mills 2021), the Proponent does not expect that 10 E12-size UXOs will be present, but a combination of up to 10 UXOs may be encountered. As a conservative measure the larger E12 bin will be used to analyze potential effects.

Table 42 presents SEL-based R95% PTS (Level A) and TTS (Level B) isopleths and their equivalent areas, which include both no attenuation results and results with an assumed 10 dB of attenuation due to the use of NAS (Bellmann and Betke 2021). The Proponent will use NAS with an expected 10 dB of attenuation (Bellmann and Betke 2021) for any potential detonations.

Table 42. SEL-based criteria ranges (m) and equivalent areas (km^2) to PTS- and TTS-onset ($R_{95\%}$) for potential UXO detonation for various depths assuming no attenuation and 10 dB attenuation.

Hearing group	Threshold (dB re 1 µPa^{2}s)	No Attenuation				10 dB of Attenuation			
		12 m	20 m	30 m	45 m	12 m	20 m	30 m	45 m
Radii									
Level A (PTS-onset)									
LF	183	7,640	8,800	8,440	8,540	3,220	3,780	3,610	3,610
MF	185	1,540	1,450	1,480	1,410	461	386	412	412
HF	155	11,300	11,000	10,700	10,900	6,200	6,190	6,190	6,160
PW	185	4,340	4,500	4,450	4,520	1,600	1,430	1,480	1,350
Level B (TTS-onset)									
LF	168	18,300	19,200	19,300	19,000	11,000	11,900	11,500	11,800
MF	170	5,860	5,850	5,840	5,810	2,550	2,430	2,480	2,480
HF	140	20,200	20,200	20,200	20,000	14,100	13,800	13,300	13,700
PW	170	13,300	13,200	12,800	13,300	6,750	6,990	6,900	7,020
Area									
Level A (PTS-onset)									
LF	183	183.37	243.28	223.79	229.12	32.57	44.89	40.94	40.94
MF	185	7.45	6.61	6.88	6.25	0.67	0.47	0.53	0.53
HF	155	401.15	380.13	359.68	373.25	120.76	120.37	120.37	119.21
PW	185	59.17	63.62	62.21	64.18	8.04	6.42	6.88	5.73
Level B (TTS-onset)									
LF	168	1,052.09	1,158.12	1,170.21	1,134.11	380.13	444.88	415.48	437.44
MF	170	107.88	107.51	107.15	106.05	20.43	18.55	19.32	19.32
HF	140	1,281.90	1,281.90	1,281.90	1,256.64	624.58	598.28	555.72	589.65
PW	170	555.72	547.39	514.72	555.72	143.14	153.50	149.57	154.82

Source: Hannay and Zykov 2022

LF = low-frequency cetaceans; MF = mid-frequency cetaceans; HF = high-frequency cetaceans; PW = phocid pinnipeds in water

Mortality and non-auditory injury to lung and gastrointestinal organs were considered in the modeling study (Hannay and Zykov 2022). As described, peak pressure and acoustic impulse levels and effects threshold exceedance zones depend only on charge weight, water depth, animal mass, and submersion depth. Maximum distance to gastrointestinal injury (1% of exposed animals) due to peak pressure for detonating an E12-size UXO at all sites assuming 10 dB of attenuation and no attenuation is 125 and 359 m, respectively. Table 43 presents impulse-based isopleths for onset of lung injury and mortality from detonation of an E12-size UXO at various depth sites assuming no attenuation and 10 dB of attenuation.

Table 43. Impulse exceedance distances (meters) for marine mammals for the detonation of an E12 UXO, for Onset of Lung Injury and Mortality at various depths assuming no attenuation and 10 dB mitigation.

Marine mammal group	12 m		20 m		30 m		45 m	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
No Attenuation								
Onset of Lung Injury								
Baleen whales and Sperm whale	291	160	431	219	563	251	648	262
Pilot and Minke whales	361	210	546	300	730	369	843	402
Beaked whales	461	325	707	487	966	644	1,084	746
Dolphins, Kogia, and Pinnipeds	628	446	975	681	1,289	929	1,421	1,052
Porpoises	680	478	1059	733	1,364	1,004	1,518	1,127
Onset of Mortality								
Baleen whales and Sperm whale	189	97	266	116	316	120	334	121
Pilot and Minke whales	238	132	346	173	421	188	453	194
Beaked whales	307	213	458	305	552	367	602	392
Dolphins, Kogia, and Pinnipeds	422	296	644	441	736	536	814	580
Porpoises	458	319	702	477	786	575	868	628
10 dB of Attenuation								
Onset of Lung Injury								
Baleen whales and Sperm whale	151	73	204	80	226	81	237	78
Pilot and Minke whales	192	103	272	126	310	131	330	132
Beaked whales	250	171	366	237	413	267	448	282
Dolphins, Kogia, and Pinnipeds	347	241	508	351	557	400	606	429
Porpoises	377	260	541	381	594	429	648	465
Onset of mortality								
Baleen whales and Sperm whale	90	34	105	34	109	31	108	29
Pilot and Minke whales	120	56	150	58	157	57	162	50
Beaked whales	161	105	206	127	220	132	234	135
Dolphins, Kogia, and Pinnipeds	228	154	285	198	308	211	332	224
Porpoises	248	167	307	215	330	231	353	243

Source: Hannay and Zykov 2022
These distances are based on representative calf/pup and adult mass estimates of animal groups described in this table. As a conservative measure, mass values are based on the smallest expected animals for species' group that might be present within the project area.

Due to the mitigation and monitoring measures described in Sections 11 and 13, such as the use of NAS during all potential detonations, and the small size of the attenuated peak pressure and acoustic impulse zones, the Proponent is not expecting nor requesting take of marine mammals due to mortality and non-auditory injury and this is not discussed further in this application. However, the Proponent is requesting PTS (Level A) and TTS (Level B) take of marine mammals for UXO detonations.

6.5.3. Exposure Calculations

To calculate potential marine mammal exposures, the area distances in Table 42 were multiplied by the highest monthly species density in the deepwater OECC segment and the SWDA for the 20–45 m depths, and by the highest monthly species density in the shallow water OECC segment for the 12 m depth. The result of the areas multiplied by the densities were then multiplied by the number of UXOs estimated at each of the depths to calculate total estimated exposures. The UXO removal processes for New England Wind are expected to be similar as the Ocean Wind 1 project, with the same commitment for a single detonation removal per 24-hour period to reduce accumulated sound exposures and to limit behavioral response.

6.5.4. Exposure Estimates – Potential UXO Detonation

6.5.4.1. Level A Exposures

SEL-based PTS exposures for potential UXO detonations are listed in Table 44 as Level A exposures, below. Level A exposures are unlikely during UXO detonation, but possible. Table 44 presents unmitigated and mitigated Level A exposure estimates for comparison. To reduce potential exposures, the use of NAS (e.g., bubble curtain system or other system) to achieve broadband noise attenuation is planned to be used during all potential UXO detonations. NAS-use is expected to achieve a broadband attenuation level of 10 dB (Bellman et al. 2020; Bellmann and Betke 2021) and will minimize the size of the ensonified zones, thereby reducing the number of potential marine mammal PTS exposures.

Table 44. Estimated potential maximum Level A exposures of marine mammals resulting from the possible detonations of up to 10 UXOs assuming both no attenuation and 10 dB of attenuation.

Species	Estimated Level A Exposures (PTS SEL)	
	No Attenuation	10 dB Attenuation
Fin whale[a]	7.16	1.31
Minke whale	5.19	0.95
Humpback whale	8.26	1.51
North Atlantic right whale[a,b]	17.37	3.17
Sei whale[a]	0.93	0.17
Atlantic white-sided dolphin	3.56	0.27
Atlantic spotted dolphin	0.07	0.01
Short-beaked common dolphin	16.36	1.25
Bottlenose dolphin, offshore	10.80	0.90
Risso's dolphin	0.03	0.00
Long-finned pilot whale	0.33	0.03
Short-finned pilot whale	0.25	0.02
Sperm whale[a]	0.02	0.00
Harbor porpoise[c]	1,120.62	165.32
Gray seal[b]	74.86	8.91
Harbor seal[b]	168.18	20.01
Harp seal[b]	74.86	8.91

[a] Listed as Endangered under the Endangered Species Act.
[b] Level A exposures were estimated for this species, but due to mitigation measures (described in Section 9.1), no Level A takes are expected or requested.
[c] Potential Level A exposures for harbor porpoise with no attenuation were estimated using the distance to PK threshold (PTS = 16,098 m), which is larger than the distance to their PTS SEL threshold.

6.5.4.2. Level B Exposures

SEL-based TTS exposures for potential UXO detonations and are listed in Table 45 as Level B exposures, below. The use of NAS and mitigation measures described in Section 11 will reduce received sound levels and the size of the ensonified zones, thereby reducing the number of potential marine mammal TTS exposures.

Table 45. Estimated potential maximum Level B exposures of marine mammals resulting from the possible detonations of up to 10 UXOs assuming both no attenuation and 10 dB of attenuation.

Species	Estimated Level B Exposures (TTS)	
	No Attenuation	10 dB Attenuation
Fin whale[a]	35.73	13.34
Minke whale	25.95	9.68
Humpback whale	41.54	15.48
North Atlantic right whale[a]	86.49	32.30
Sei whale[a]	4.62	1.73
Atlantic white-sided dolphin	57.49	10.23
Atlantic spotted dolphin	1.14	0.20
Short-beaked common dolphin	264.31	47.01
Bottlenose dolphin, offshore	165.33	30.33
Risso’s dolphin	0.42	0.07
Long-finned pilot whale	5.39	0.96
Short-finned pilot whale	3.98	0.71
Sperm whale[a]	0.28	0.05
Harbor porpoise[b]	4,209.95	801.06
Gray seal	670.08	180.73
Harbor seal	1,505.48	406.05
Harp seal	670.08	180.73

[a] Listed as Endangered under the Endangered Species Act.

[b] Potential Level B exposures for harbor porpoise with no attenuation were estimated using the distance to PK threshold (TTS = 31,202 m), which is larger than the distance to their TTS SEL threshold.

6.6. Exposure Estimation – HRG Surveys

Incidental take is being requested for sound exposure from two deep seismic profilers: the Applied Acoustics AA251 boomer and GeoMarine's Geo Spark 2000 (400 tip) sparker system. JASCO conducted acoustic modeling for several types of geophysical equipment. Details of that modeling effort are included as Appendix D.

The model-predicted horizontal impact distances to Level A and Level B thresholds in meters for the various types of equipment evaluated and the different marine mammal hearing groups are provided in Appendix D. The model results for the two deep seismic profiling sources for which take is being requested are reproduced here in Table 46. No Level A take by serious injury is reasonably expected to occur given the short distances to the Level A thresholds and the mitigation measures to be implemented during the surveys (see Section 11.6), and therefore no Level A take is requested.

Table 46. Horizontal impact distances (in meters) to Level A and Level B threshold criteria.

Source	Level A (PK)				Level A (SEL)				Level B (SPL)
	LF	MF	HF	PW	LF	MF	HF	PW	
	Threshold (dB re 1 µPa)				Threshold (dB re 1 µPa²·s)				(dB re 1 µPa)
	219	230	202	218	183	185	155	185	160
Applied Acoustics AA251 Boomer	—	—	3	—	<1	<1	53	<1	178
GeoMarine Geo Spark 2000 (400 tip)	—	—	4	—	<1	<1	4	<1	141

Both sources were considered impulsive. Threshold criteria are defined in Appendix D.

6.6.1. Assumptions

Exposure calculations assumed that there would be 25 days of HRG surveying per year over each of 5 years (total of 125 days of HRG surveys). For the purpose of the LOA, a start year of 2025 is assumed. A distance of 80 km/day was assumed to be the maximum HRG survey distance possible in a 24-hour period and therefore this was used in the exposure calculations. Additionally, the larger of the exposure values for the two sound sources was carried forward for the take estimate, as a conservative approach.

Because the exact dates of HRG surveys are unknown, as a conservative measure, for each species, it was assumed that the 25 days of surveying each year would occur during the highest density month for that species. Details of the density calculations are provided in Section 6.1.1.5.

6.6.2. Zone of Influence

The zone of influence (ZOI) is a representation of the maximum extent of the ensonified area around a sound source over a 24-hour period. The ZOI for each of the two deep seismic profilers was calculated using the following equation, which defines ZOI for mobile sources:

$$\mathrm{ZOI} = \left(\frac{\text{distance}}{\text{day}} \times 2r\right) + \pi r^2 , \tag{5}$$

where distance/day is the linear distance traveled by the survey vessel per day, in this case, 80 km, and *r* is the horizontal distance to the relevant acoustic threshold. The results of this calculation are provided in Table 47.

Table 47. Zone of influence (km^2) for the two modeled deep seismic profilers.

Source	Level B Zone of influence
Applied Acoustics AA251 Boomer	28.58
GeoMarine Geo Spark 2000 (400 tip)	22.62

6.6.3. Exposure Estimates – HRG Surveys

Exposures above the Level B acoustic thresholds were estimated using the formula:

$$\text{exposures} = \text{ZOI} \times (\text{days}) \times \text{density}, \quad (6)$$

where ZOI is defined in Equation 5, days = 25, and density is from Table 14.

The results of these calculations are shown in Table 48.

Table 48. Number of animals of each species estimated to receive sound levels above the Level B threshold annually during HRG surveys of New England Wind.

Species	Applied Acoustics AA251 boomer	GeoMarine Geo Spark 2000
Fin whale[a]	2.67	2.11
Minke whale	1.82	1.44
Humpback whale	2.09	1.65
North Atlantic right whale[a]	6.44	5.10
Sei whale[a]	0.32	0.26
Atlantic white-sided dolphin	56.24	44.52
Atlantic spotted dolphin	0.93	0.73
Short-beaked common dolphin	197.42	156.27
Bottlenose dolphin, offshore	255.89	202.55
Risso's dolphin	0.38	0.30
Long-finned pilot whale	4.22	3.34
Short-finned pilot whale	3.12	2.47
Sperm whale[a]	0.26	0.21
Harbor porpoise	112.02	88.67
Gray seal	261.41	206.92
Harbor seal	3.29	587.32
Harp seal	1.46	261.41

6.7. Marine Mammal Take Calculations

6.7.1. Take Estimates - Impact Pile Driving

6.7.1.1. Modeled Marine Mammal Species

As noted in Section 6.1, the model-predicted exposure estimates shown in Section 6.2.5 in Tables 28–34 for the two construction schedules for each species by year and for the total schedule form the basis of the take estimates for impact pile driving for modeled marine mammal species, as follows:

- Take calculations used the exposure estimates based on 10 dB sound attenuation.
- All exposure estimates and average group sizes were rounded up to a whole number, before any addition, to compute takes.
- The greater of the SEL and PK exposure estimates for each species was selected to compute Level A takes. This was rounded up to a whole number.
- Level A take for NARW was presumed to be zero because of mitigation.
- When the model-predicted yearly Level B exposure was less than one average group size (as provided in Section 6.1.2) for a given species, the estimated take is one average group size for the species rounded up to a whole number.
- When the model-predicted yearly Level B exposure was greater than or equal to one average group size, the requested take is the predicted exposure rounded up to a whole number.
- For total take estimates, the group size correction was for two average group sizes for Schedule A (a 2-year schedule) and for three average group sizes for Schedule B (a 3-year schedule).
- Jacket foundations with four pin piles installed in one day were determined to predict the highest numbers of Level A and Level B exposures for NARW compared to all other animal movement-modeled scenarios, and are assumed to provide a project design envelope for all possible installation scenarios, including a 13 m diameter monopile installed with up to 6,000 kJ hammer energy. Therefore, jacket foundations were used for all of the installations in Construction Schedule B Year 2 and Year 3, which were used in the final take request.
- Annual take estimates assume worst case scenario exposures for each species for each year from either Construction Schedule A or B (compare Tables 29 and 32 for year 1 and compare Tables 30 and 33 for year 2; Table 34 is used for year 3, i.e., Construction Schedule B). With few exceptions, predicted yearly exposures use Schedule A for year 1 and Schedule B for years 2 and 3.
- The total take estimates for impact pile driving for the full project buildout use the total model-predicted exposure estimates for all years combined from Schedule B as the most conservative, except for Level B exposures for NARW and gray and harp seals, for which Schedule A predicts greater exposures (compare Tables 28 and 31).

For this LOA request, the take estimates for impact pile driving for modeled marine mammal species assume 10 dB sound attenuation as a level that is deemed reasonably achievable. However, the Proponent will employ sound attenuation technology that will reduce pile driving sounds by 10 dB with a target of 12 dB or greater (see Section 11.2). Tables 49 and 50 below compare take estimates calculated using these two attenuation levels for Construction Schedule A and Construction Schedule B, respectively, for the modeled species. The assumptions used for the construction schedules are summarized in Section 2.2. Correction for mean group size was applied to yearly Level B take estimates for sei whales, Atlantic spotted dolphins, and Risso's dolphins for Schedule A for years 1 and year 2. For the Level B total take for schedule A, this correction was applied to these three species as well as to the sperm whale. For Schedule B, a group size correction was applied to sei whales, sperm whales, Atlantic spotted dolphins, and Risso's dolphins for year 1 and year 3; sei whales, Atlantic spotted dolphins, and Risso's dolphins for year 2; and Atlantic spotted dolphins for the total Level B take. In all other cases, the Level B take as calculated from the model-predicted exposure estimates using the 160 dB SPL criterion exceeded the mean group size for the species so no correction was applied.

Table 49. Construction Schedule A: Number of Level A and Level B takes calculated for modeled species for impact pile driving using model results with 10 or 12 dB sound attenuation for comparison. Construction schedule assumptions are summarized in Section 2.2 and modeling methods are described in Section 6.1.

Species		Year 1				Year 2				All years combined			
		Level A		Level B		Level A		Level B		Level A		Level B	
		Attenuation (dB)				Attenuation (dB)				Attenuation (dB)			
		10	12	10	12	10	12	10	12	10	12	10	12
LF	Fin whale[a]	11	7	19	17	12	8	15	12	22	14	34	29
	Minke whale	5	3	14	13	6	4	14	12	10	7	27	24
	Humpback whale	7	5	9	8	8	5	8	7	14	10	17	15
	North Atlantic right whale[a]	0	0	4	4	0	0	4	3	0	0	8	6
	Sei whale[a]	1	1	2[b]	2	1	1	2[b]	2	1	1	4[b]	4
MF	Atlantic white sided dolphin	2	2	671	606	1	1	664	585	2	2	1,335	1,190
	Atlantic spotted dolphin	0	0	30[b]	30	0	0	30[b]	30	0	0	60[b]	60
	Short-beaked common dolphin	5	5	3,143	2,862	2	1	3,858	3,510	6	6	7,000	6,372
	Bottlenose dolphin, offshore	1	1	176	152	1	1	213	181	1	1	388	332
	Risso's dolphin	1	1	7[b]	7	1	1	7[b]	7	1	1	14[b]	14
	Long-finned pilot whale	1	1	81	73	1	1	85	76	1	1	166	148
	Short-finned pilot whale	1	1	58	53	1	1	64	57	1	1	122	109
	Sperm whale[a]	1	1	2	2	1	1	2	2	1	1	4[b]	4
HF	Harbor porpoise	44	31	127	114	54	38	132	115	98	68	259	228
PPW	Gray seal	1	1	14	13	1	1	19	13	2	1	33	25
	Harbor seal	1	1	35	30	2	1	42	32	2	1	76	61
	Harp seal	1	1	17	15	1	1	22	17	1	1	38	31

[a] Listed as Endangered under the ESA. NARW takes presumed to be zero because of mitigation.
[b] Annual Level B take estimate increased to one average group size, total take estimate increased to two average group sizes.

Table 50. Construction Schedule B: Number of Level A and Level B takes calculated for modeled species for impact pile driving using model results with 10 or 12 dB sound attenuation for comparison. Construction schedule assumptions are summarized in Section 2.2 and modeling methods are described in Section 6.1.

	Species	Year 1				Year 2				Year 3				All years combined			
		Level A		Level B		Level A		Level B		Level A		Level B		Level A		Level B	
		Attenuation (dB)				Attenuation (dB)				Attenuation (dB)				Attenuation (dB)			
		10	12	10	12	10	12	10	12	10	12	10	12	10	12	10	12
LF	Fin whale[a]	8	5	14	13	22	15	20	19	9	7	9	8	38	26	42	38
	Minke whale	4	3	12	11	12	8	28	26	6	4	13	12	21	14	51	47
	Humpback whale	4	3	6	6	12	8	10	9	6	4	5	4	21	14	20	18
	North Atlantic right whale[a]	0	0	3	3	0	0	4	3	0	0	2	2	0	0	7	7
	Sei whale[a]	1	1	2[b]	2	1	1	2[b]	2	1	1	2[b]	2	2	1	6	6
MF	Atlantic white sided dolphin	2	2	511	462	1	1	1,323	1,199	1	1	553	501	2	2	2,386	2,161
	Atlantic spotted dolphin	0	0	30[b]	30	0	0	30[b]	30	0	0	30[b]	30	0	0	90[b]	90
	Short-beaked common dolphin	6	6	1,766	1,618	2	0	5,121	4,685	1	0	2,127	1,946	6	6	9,013	8,249
	Bottlenose dolphin, offshore	1	1	104	90	1	0	298	253	1	0	126	107	1	1	527	448
	Risso's dolphin	1	1	7[b]	7	1	1	7[b]	7	1	1	7[b]	7	1	1	21	21
	Long-finned pilot whale	1	1	56	50	1	0	146	133	1	0	61	56	1	1	261	238
	Short-finned pilot whale	1	1	40	36	0	0	110	100	0	0	46	42	1	1	195	176
	Sperm whale[a]	1	1	2[b]	2	1	0	3	3	1	0	2[b]	2	1	1	6	6
HF	Harbor porpoise	34	25	95	85	96	64	209	191	45	30	97	89	174	118	401	364
PPW	Gray seal	1	1	12	11	1	1	7	6	1	1	4	4	2	1	22	20
	Harbor seal	1	1	31	27	2	1	29	26	2	1	19	17	4	2	78	68
	Harp seal	1	1	15	13	1	1	13	12	1	1	9	8	2	1	37	33

[a] Listed as Endangered under the ESA. NARW takes presumed to be zero because of mitigation.
[b] Annual Level B take estimate increased to one average group size, total take estimate increased to three average group sizes.

6.7.1.2. Rare Marine Mammal Species

Take calculations for rare species were based on average group size estimates and calculated as described in Section 6.1.2 using OBIS data, because these species were not modeled due to a lack of density data for the area. As a conservative measure, it was assumed that one average group size of each rare species would be encountered during each year of pile driving and that the pile driving would occur over 3 years (i.e., Schedule B). The calculated Level B take for all years combined is equal to one average group size rounded up to an integer and multiplied by two, assuming rare species would be seen in alternate years (Table 51). For example, white-beaked dolphins were recorded in both 2019 and 2020 during HRG surveys in this area (Vineyard Wind 2019, 2020) with the sighting of white-beaked dolphins in 2019 consisting of 30 animals. Other rare species encountered in the survey area during previous HRG surveys include false killer whales in 2019 (5 individuals) and 2021 (1 individual) ((Vineyard Wind 2020c, 2020b)) and orca (killer whale) in 2022 (2 individuals; data not yet submitted). When species not listed in an LOA are encountered and may be taken, it is necessary to cease survey operations to avoid unauthorized take. To avoid this potential disruption to survey operations, Park City Wind LLC is requesting annual take for these three species based on the largest number of individuals observed within one year: 30 white-beaked dolphins, 5 false killer whales, and 2 orcas. For the full five-year term of the LOA, the request is for 90 white-beaked dolphins, 15 false killer whales, and 6 orcas, assuming they could be encountered every other year (i.e., in three of the five years).

Level A takes for rare species were calculated differently for the different marine mammal hearing groups. For the only LF cetacean, the blue whale, comparison was made with the sei whale because of their similar habitat preferences. Because the blue whale is much rarer than the sei whale in this area, it was assumed that any Level A exposure for blue whales would not exceed those of the sei whale, which was less than one for each of the 3 years in Schedule B. A single take was calculated for each of the 3 construction years as a conservative estimate for this species. For both MF cetaceans and phocid pinnipeds, the Level A take was assumed to be zero because of the short ranges to the Level A thresholds for these hearing groups (see Tables 21–27). For the two HF cetaceans (*Kogia* spp.), the Level A take was calculated as one average group size per year rounded up to an integer and summed for the 3 years.

Table 51. Number of Level A and Level B takes calculated for rare species based on mean group size assuming a 3 year construction schedule and one average group size per year, as described in Section 6.1.2.

Species		Year 1		Year 2		Year 3		All years combined	
		Level A	Level B	Level A	Level B	Level A	Level B	Level A	Level B
LF	Blue whale[a]	1	2	1	2	1	2	3	6
MF	Clymene dolphin	0	167	0	167	0	167	0	501
	False killer whale	0	7	0	7	0	7	0	21
	Fraser's dolphin	0	192	0	192	0	192	0	576
	Killer whale	0	8	0	8	0	8	0	24
	Melon-headed whale	0	109	0	109	0	109	0	327
	Pan-tropical spotted dolphin	0	60	0	60	0	60	0	180
	Pygmy killer whale	0	5	0	5	0	5	0	15
	Rough-toothed dolphin	0	14	0	14	0	14	0	42
	Spinner dolphin	0	51	0	51	0	51	0	153
	Striped dolphin	0	64	0	64	0	64	0	192
	White-beaked dolphin	0	14	0	14	0	14	0	42
	Beluga whale	0	2	0	2	0	2	0	6
	Cuvier's beaked whale	0	3	0	3	0	3	0	9
	Blainville's beaked whale	0	4	0	4	0	4	0	12
	Gervais' beaked whale	0	4	0	4	0	4	0	12
	Sowerby's beaked whale	0	4	0	4	0	4	0	12
	True's beaked whale	0	3	0	3	0	3	0	9
	Northern bottlenose whale	0	4	0	4	0	4	0	12
HF	Dwarf sperm whale	2	2	2	2	2	2	6	6
	Pygmy sperm whale	2	2	2	2	2	2	6	6
PPW	Hooded seal	0	1	0	1	0	1	0	3

[a] Listed as Endangered under the ESA.

6.7.2. Take Estimates –Vibratory Setting

As noted in Section 6.3, the number of days with vibratory setting of piles was based on the Proponent's drivability analysis and is shown for the two construction schedules in Section 2.2. The number of days of vibratory setting of piles per month per year and for the total buildout for each construction schedule was multiplied by the estimated Level B exposure for each species for one day of vibratory setting to provide exposure estimates for the two construction schedules as shown in Section 6.3.2. Takes were calculated from these exposure estimates by rounding up to an integer. No group size correction was applied to Level B takes for vibratory setting because the estimated exposures all exceeded one average group size for all species.

Yearly and total Level B take estimates are shown for Construction Schedules A and B in Tables 52 and 53, respectively. As with impact pile driving, the higher of the take estimates for each species between the two construction schedules was carried forward to the yearly take request as well as the total take request (Table 54). For year 1, Schedule A take estimates were used, except for minke whales, white-sided dolphins, and the three seal species, for which higher take estimates were predicted using Schedule B. For years 2 and 3, and for the full Project buildout, the Schedule B take estimates were used because they were all higher.

Table 52. Construction Schedule A: Estimated number of Level B takes from vibratory setting during pile installation by year and for the full 2-year construction schedule.

	Species	Year 1	Year 2	All years combined
LF	Fin whale[a]	720	413	1,133
	Minke whale	251	145	396
	Humpback whale	316	197	513
	North Atlantic right whale[a]	63	37	99
	Sei whale[a]	22	12	34
MF	Atlantic white-sided dolphin	8,323	5135	13,458
	Atlantic spotted dolphin	254	164	418
	Short-beaked common dolphin	26,856	17,723	44,578
	Bottlenose dolphin, offshore	13793	8,357	22,149
	Risso's dolphin	310	169	478
	Long-finned pilot whale	1,058	649	1,706
	Short-finned pilot whale	780	478	1,258
	Sperm whale[a]	50	28	78
HF	Harbor porpoise	2,617	1,568	4,185
PPW	Gray seal	2,088	1,224	3,311
	Harbor seal	4,690	2,750	7,439
	Harp seal	2,088	1,224	3,311

[a] Listed as Endangered under the Endangered Species Act.

Table 53. Construction Schedule B: Estimated number of Level B takes from vibratory setting of piles by year and for the full 3-year construction schedule.

	Species	Year 1	Year 2	Year 3	All years combined
LF	Fin whale[a]	663	755	300	1,717
	Minke whale	245	252	101	597
	Humpback whale	283	327	133	742
	North Atlantic right whale[a]	59	39	30	127
	Sei whale[a]	21	21	9	51
MF	Atlantic white-sided dolphin	8,027	8,511	3,496	20,034
	Atlantic spotted dolphin	228	273	107	606
	Short-beaked common dolphin	23,283	27,566	11,246	62,094
	Bottlenose dolphin, offshore	12,607	15,191	5,909	33,706
	Risso's dolphin	262	318	125	704
	Long-finned pilot whale	956	1,092	444	2,490
	Short-finned pilot whale	705	806	328	1,837
	Sperm whale[a]	48	55	21	123
HF	Harbor porpoise	2,360	2,340	1,127	5,826
PPW	Gray seal	2,011	1,675	891	4,575
	Harbor seal	4,518	3,762	2,001	10,279
	Harp seal	2,011	1,675	891	4575

[a] Listed as Endangered under the Endangered Species Act.

Table 54. Level B take calculated for vibratory setting of piles based on the higher of the take estimates from either Schedule A or Schedule B for each species. Used in the final take request.

Species		Level B take			
		Year 1	Year 2	Year 3	3-Year total
LF	Fin whale[a]	720	755	300	1,717
	Minke whale	251	252	101	597
	Humpback whale	316	327	133	742
	North Atlantic right whale[a]	63	39	30	127
	Sei whale[a]	22	21	9	51
MF	Atlantic white-sided dolphin	8,323	8,511	3,496	20,034
	Atlantic spotted dolphin	254	273	107	606
	Short-beaked common dolphin	26,856	27,566	11,246	62,094
	Bottlenose dolphin, offshore	13,793	15,191	5,909	33,706
	Risso's dolphin	310	318	125	704
	Long-finned pilot whale	1,058	1,092	444	2,490
	Short-finned pilot whale	780	806	328	1,837
	Sperm whale[a]	50	55	21	123
HF	Harbor porpoise	2,617	2,340	1,127	5,826
PPW	Gray seal	2,088	1,675	891	4,575
	Harbor seal	4,690	3,762	2,001	10,279
	Harp seal	2,088	1,675	891	4575

[a] Listed as Endangered under the Endangered Species Act.

6.7.3. Take Estimates – Drilling

As noted in Section 6.4, the number of days with drilling during pile installation was based on the Proponent's drivability analysis and is shown for the two construction schedules in Section 2.2. The number of days of drilling during pile installation per month per year and for the total buildout for each construction schedule was multiplied by the estimated Level B exposure for each species for one day of drilling to provide exposure estimates for the two construction schedules as shown in Section 6.4.2. Takes were calculated from the exposure estimates by rounding up to an integer. No group size correction was applied to Level B takes for drilling because the estimated exposures all exceeded one average group size for all species after rounding up to an integer.

Yearly and total estimates are shown for Construction Schedules A and B in Tables 55 and 56, respectively. As with impact pile driving, the higher of the take estimates for each species between the two construction schedules was carried forward to the yearly take request as well as the total take request. For year 1, the Schedule A take estimates were used. For years 2 and 3, and for the full Project buildout the Schedule B take estimates were used, because they were greater than the estimates calculated using Schedule A for all species.

Table 55. Construction Schedule A: Estimated number of Level B takes from drilling during pile installation by year and for the full 2-year construction schedule assuming drilling is used on 36% of foundation positions.

Species		Year 1	Year 2	All Years Combined
LF	Fin whale[a]	139	60	198
	Minke whale	48	22	69
	Humpback whale	74	30	103
	North Atlantic right whale[a]	14	8	21
	Sei whale[a]	5	2	6
MF	Atlantic white-sided dolphin	2,049	939	2,987
	Atlantic spotted dolphin	50	22	72
	Short-beaked common dolphin	5,212	2,401	7,613
	Bottlenose dolphin, offshore	928	398	1,325
	Risso's dolphin	22	10	31
	Long-finned pilot whale	241	110	350
	Short-finned pilot whale	178	81	258
	Sperm whale[a]	10	5	14
HF	Harbor porpoise	453	223	675
PPW	Gray seal	163	80	242
	Harbor seal	366	179	544
	Harp seal	163	80	242

[a] Listed as Endangered under the Endangered Species Act.

Table 56. Construction Schedule B: Estimated number of Level B takes from drilling during pile installation by year and for the full 3-year construction schedule assuming drilling is used on 36% of foundation positions.

Species		Year 1	Year 2	Year 3	All Years Combined
LF	Fin whale[a]	85	83	38	204
	Minke whale	35	31	17	82
	Humpback whale	45	42	19	105
	North Atlantic right whale[a]	13	8	7	26
	Sei whale[a]	4	3	2	8
MF	Atlantic white-sided dolphin	1,367	1,268	667	3,302
	Atlantic spotted dolphin	28	27	11	66
	Short-beaked common dolphin	3,009	2,744	1,257	7,009
	Bottlenose dolphin, offshore	520	491	219	1,229
	Risso's dolphin	12	12	5	28
	Long-finned pilot whale	146	139	66	350
	Short-finned pilot whale	108	103	49	258
	Sperm whale[a]	6	6	3	13
HF	Harbor porpoise	323	263	159	744
PPW	Gray seal	147	95	73	314
	Harbor seal	329	213	163	704
	Harp seal	147	95	73	314

[a] Listed as Endangered under the ESA.

Table 57. Level B take calculated for drilling during pile installation based on the higher of the take estimates from either Schedule A or Schedule B for each species. Used in the final take request.

Species		Level B take			
		Year 1	Year 2	Year 3	3-Year total
LF	Fin whale[a]	139	83	38	204
	Minke whale	48	31	17	82
	Humpback whale	74	42	19	105
	North Atlantic right whale[a]	14	8	7	26
	Sei whale[a]	5	3	2	8
MF	Atlantic white-sided dolphin	2,049	1,268	667	3,302
	Atlantic spotted dolphin	50	27	11	72
	Short-beaked common dolphin	5,212	2,744	1257	7,613
	Bottlenose dolphin, offshore	928	491	219	1,325
	Risso's dolphin	22	12	5	31
	Long-finned pilot whale	241	139	66	350
	Short-finned pilot whale	178	103	49	258
	Sperm whale[a]	10	6	3	14
HF	Harbor porpoise	453	263	159	744
PPW	Gray seal	163	95	73	314
	Harbor seal	366	213	163	704
	Harp seal	163	95	73	314

[a] Listed as Endangered under the Endangered Species Act.

6.7.4. Take Estimates – Potential UXO Detonation

Exposure estimates from Section 6.5.4 were rounded up to whole numbers in Table 58 to provide estimated Level A and Level B takes for potential UXO detonations. Although the Proponent intends to use an NAS for each UXO detonation and is requesting mitigated takes, unmitigated takes are also estimated for comparison.

Table 58. Estimated Level A and Level B takes resulting from detonation of up to 10 potential UXOs.

Species		No Attenuation		10 dB of Attenuation	
		Level A	Level B	Level A	Level B
LF	Fin whale[a]	8	36	2	14
	Minke whale	6	26	1	10
	Humpback whale	9	42	2	16
	North Atlantic right whale[a,b]	18	87	4	33
	Sei whale[a]	1	5	1	2
MF	Atlantic white-sided dolphin	4	58	1	11
	Atlantic spotted dolphin	1	2	1	1
	Short-beaked common dolphin	17	265	2	48
	Bottlenose dolphin, offshore	11	166	1	31
	Risso's dolphin	1	1	0	1
	Long-finned pilot whale	1	6	1	1
	Short-finned pilot whale	1	4	1	1
	Sperm whale[a]	1	1	0	1
HF	Harbor porpoise	1,121	4,210	166	802
PPW	Gray seal	75	671	9	181
	Harbor seal	169	1,506	21	407
	Harp seal	75	671	9	181

[a] Listed as Endangered under the Endangered Species Act.
[b] In consultation with BOEM and NMFS, New England Wind will identify appropriate NAS to prohibit all Level A take for North Atlantic right whale.

6.7.5. Take Estimates – HRG Surveys

As a conservative measure, the larger of the exposure values for the two HRG sound sources was carried forward for the take estimate. In order to translate estimated exposures into real-world predicted takes, the exposure numbers in Table 48 were rounded up to whole numbers. Additionally, if the predicted Level B take was lower than one mean group size for any cetacean species, the annual take request was increased to one mean group size. Groups sizes used in this Level B adjustment were the same as those used for impact pile driving take estimation for modeled marine mammal species (Section 6.1.2).

For common dolphins, data collected by Protected Species Observers (PSOs) on survey vessels operating during HRG surveys in 2020–2021 ((Vineyard Wind 2020b, 2021b)) showed an average of approximately 16 common dolphins may be observed within 200 m of a vessel (the approximate Level B distance) per survey day. This value was multiplied by the 25 days of survey estimated for each of the five years to provide a maximum yearly take of 400 and a total take of 2,000 for the five years of HRG surveys.

The estimated takes from New England Wind HRG surveys are shown in Table 59 for species for which density-based exposure estimates were available. Species considered to be rare or not expected to occur in the area were not included in the exposure estimates because the densities would be too low to provide meaningful density-based exposures. Nonetheless, species considered to be rare are occasionally encountered. For example, white-beaked dolphins were recorded in both 2019 and 2020 during HRG surveys in this area (Vineyard Wind 2019, 2020) with the sighting of white-beaked dolphins in 2019 consisting of 30 animals. Other rare species encountered in the survey area during previous HRG surveys include false killer whales in 2019 (5 individuals) and 2021 (1 individual) (Vineyard Wind 2020c, 2020b) and orca (killer whale) in 2022 (2 individuals; data not yet submitted). When species not listed in an LOA are encountered and may be taken, it is necessary to cease survey operations to avoid unauthorized take. To avoid this potential disruption to survey operations, Park City Wind LLC is requesting annual take for these three species based on the largest number of individuals observed within one year: 30 white-beaked dolphins, 5 false killer whales, and 2 orcas. For the full five-year term of the LOA, the request is for 90 white-beaked dolphins, 15 false killer whales, and 6 orcas, assuming they could be encountered every other year (i.e., in three of the five years).

Table 59. Estimated Level B takes from HRG surveys for the effective period of the LOA (5-year total).

Species		Requested yearly maximum takes	Requested 5-year total maximum takes
LF	Fin whale[a]	3	15
	Minke whale	2	10
	Humpback whale	3	15
	North Atlantic right whale[a]	7	35
	Sei whale[a]	2	10
MF	Atlantic white-sided dolphin	57	285
	Atlantic spotted dolphin	30	150
	Short-beaked common dolphin	400	2,000
	Bottlenose dolphin, offshore	256	1,280
	Risso's dolphin	7	35
	Long-finned pilot whale	17	85
	Short-finned pilot whale	9	45
	Sperm whale[a]	2	10
HF	Harbor porpoise	113	565
PPW	Gray seal	262	1,310
	Harbor seal	588	2,940
	Harp seal	262	1,310
Rare species			
MF	White-beaked dolphin[b]	30	90
HF	Killer whale[b]	2	6
	False killer whale[b]	5	15

[a] Listed as Endangered under the ESA.

[b] Rare species take estimate based on one group size per year in 3 of 5 years for species and group sizes observed by PSOs during site characterization surveys.

6.8. Number of Takes Requested

6.8.1. Modeled Marine Mammal Species

The number of takes requested for each marine mammal species per year as well as the total take request are provided in Tables 60 and 61. Yearly maximum takes as well as total maximum takes are shown as a percentage of population size (based on NOAA Fisheries SARs). The take request is for all sound-producing activities that could result in marine mammal harassment, including sources associated with pile installation, HRG surveys, and potential UXO detonation. Sources associated with pile installation include impact pile driving, vibratory setting of piles, and drilling. It is not anticipated that vibratory setting will be required for each pile and drilling is expected to be infrequently needed. It was assumed that vibratory setting of piles could be required on up to 79 foundations and that drilling could be required on up to 48 foundations. For days when pile installation includes both vibratory setting and drilling, only the vibratory setting Level B takes are included (because more takes are predicted for this activity) and not the drilling Level B takes to avoid double counting.

To allow for maximum flexibility and uncertainty in pile driving construction schedules, when requesting takes, the maximum yearly take value from the two proposed construction schedules is requested for each species for impact pile driving, potential vibratory setting of piles/drilling. For HRG surveys the requested take is for 25 days of surveys in each of the five years. In order to provide a maximum potential yearly take, all UXO takes were assumed to occur in a single year. Year 2 was chosen because it has the highest estimated pile driving takes. This method provides a reasonable estimate of maximum total takes, as a conservative measure, while accounting for the maximum annual take that could occur in a given calendar year. As noted in Section 2.1, the take request presumes year 1 will be 2025 for both of the proposed construction schedules. It is assumed there will be no takes resulting from foundation installation during the final 2 years of the requested LOA based on the projected start year of 2025; however, this is subject to change because the exact construction start dates and schedules are unknown at this time. HRG surveys will occur during all 5 years so takes are requested for all of 2025–2029.

The take estimates as described are conservative in that, other than assuming 10 dB of sound attenuation, they do not account for the mitigation measures described in Section 11. These mitigation measures will minimize Level A harassment associated with pile driving activities for all species. Specific mitigation measures focused on preventing harassment of NARW are intended to eliminate Level A exposures entirely for this species. Thus, although exposure estimates show the potential for Level A exposure (see Tables 28–34), no Level A takes are requested for NARW.

Table 60. Requested Level A and Level B takes[a] by year for all activities for the effective period of the LOA (5-year total).

	Species	Population Size	2025[b]			2026			2027			2028			2029		
			Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %
LF	Fin whale[c]	6,802	11	826	12.31	24	875	13.22	9	350	5.28	0	3	0.04	0	3	0.04
	Minke whale	21,968	5	303	1.40	13	323	1.53	6	133	0.63	0	2	0.01	0	2	0.01
	Humpback whale	1,396	7	375	27.36	14	398	29.51	6	160	11.89	0	3	0.21	0	3	0.21
	North Atlantic right whale[c]	368	0	88	23.91	0	91	24.73	0	46	12.50	0	7	1.90	0	7	1.90
	Sei whale[c]	6,292	1	30	0.49	2	30	0.51	1	15	0.25	0	2	0.03	0	2	0.03
MF	Atlantic white-sided dolphin	93,233	2	10,492	11.26	2	11,170	11.98	1	4,773	5.12	0	57	0.06	0	57	0.06
	Atlantic spotted dolphin	39,921	0	343	0.86	1	361	0.91	0	178	0.45	0	30	0.08	0	30	0.08
	Short-beaked common dolphin	172,974	6	33,730	19.50	4	35,879	20.74	1	15,030	8.69	0	400	0.23	0	400	0.23
	Bottlenose dolphin, offshore	62,851	1	14,788	23.53	2	16,267	25.89	1	6,510	10.36	0	256	0.41	0	256	0.41
	Risso's dolphin	35,215	1	336	0.96	1	345	0.98	1	144	0.41	0	7	0.02	0	7	0.02
	Long-finned pilot whale	39,215	1	1,310	3.34	2	1,395	3.56	1	588	1.50	0	17	0.04	0	17	0.04
	Short-finned pilot whale	28,924	1	960	3.32	2	1,029	3.56	0	432	1.49	0	9	0.03	0	9	0.03
	Sperm whale[c]	4,349	1	59	1.38	1	67	1.56	1	28	0.67	0	2	0.05	0	2	0.05
HF	Harbor porpoise	95,543	44	3,197	3.39	262	3,727	4.18	45	1,496	1.61	0	113	0.12	0	113	0.12
PPW	Gray seal	27,300	1	2,513	9.21	10	2,232	8.21	1	1,230	4.51	0	262	0.96	0	262	0.96
	Harbor seal	61,336	1	5,648	9.21	23	5,012	8.21	2	2,771	4.52	0	588	0.96	0	588	0.96
	Harp seal	7,600,000	1	2,516	0.03	10	2,235	0.03	1	1,235	0.02	0	262	0.00	0	262	0.00

[a] Take is the yearly request for all sound-producing activities calculated as described in Sections 6.1–6.7. For days when pile installation includes both vibratory setting and drilling, only the vibratory setting Level B takes are included (because more takes are predicted for this activity) and not the drilling Level B takes to avoid double counting.
[b] For the purpose of this LOA request, year 1 is assumed to be 2025. These dates reflect the currently projected construction start year and are subject to change because exact project start dates and construction schedules are not currently available.
[c] Listed as Endangered under the ESA.

Table 61. Summary of requested Level A and Level B takes[a] for all activities for the effective period of the LOA (5-year total).

Species		Population Size	5 Year Total		
			Level A	Level B	Max Percent
LF	Fin whale[b]	6,802	40	1,948	29.23
	Minke whale	21,968	22	740	3.47
	Humpback whale	1,396	23	878	64.54
	North Atlantic right whale[b]	368	0	228	61.96
	Sei whale[b]	6,292	3	76	1.26
MF	Atlantic white-sided dolphin	93,233	3	25,510	27.36
	Atlantic spotted dolphin	39,921	1	898	2.25
	Short-beaked common dolphin	172,974	8	78,887	45.61
	Bottlenose dolphin, offshore	62,851	2	36,505	58.08
	Risso's dolphin	35,215	1	782	2.22
	Long-finned pilot whale	39,215	2	3,114	7.95
	Short-finned pilot whale	28,924	2	2,283	7.90
	Sperm whale[b]	4,349	1	149	3.45
HF	Harbor porpoise	95,543	340	8,244	8.98
PPW	Gray seal	27,300	11	6,390	23.45
	Harbor seal	61,336	25	14,382	23.49
	Harp seal	7,600,000	11	6,405	0.08

[a] Take is the total request for all sound-producing activities calculated as described in Sections 6.1–6.7. For days when pile installation includes both vibratory setting and drilling, only the vibratory setting Level B takes are included (because more takes are predicted for this activity) and not the drilling Level B takes to avoid double counting.

[b] Listed as Endangered under the ESA.

6.8.2. Rare Marine Mammal Species

The number of takes requested for each rare marine mammal species by year as well as the total take request for each of these species is provided in Table 62 and shown as a percent of population size (based on NOAA Fisheries SARs) in Table 63. To allow for maximum flexibility and uncertainty in construction schedules, when requesting takes for rare species a 3-year construction schedule was assumed, and it was assumed that one group of each of these species could be taken in any of the 3 years. To arrive at the total take request, it was assumed that take could occur in alternate years, so the total take request is based on 2 years of take (i.e., group size x 2). This provides a reasonable estimate of total takes, as a conservative measure, while accounting for the potential that a take could occur in any given calendar year.

The requested take of rare marine mammal species as a percentage of abundance used stock abundance available from NOAA Fisheries SARs (NOAA Fisheries 2021aa). However, these species are rarely seen in the WEA and thus the given population sizes may not be reflective of the size of the actual populations to which they belong. Where no abundance estimate is available for rare species from the SARs, the percent of the population affected was not evaluated. However, because the preferred range of these rare species is outside the affected area, the number of takes in comparison to their total populations is likely to be quite small for all these species.

Table 62. Yearly number of Level A and Level B takes[a] requested for rare species for all activities for the effective period of the LOA (5-year total).

	Species	Stock Size	2025[b]			2026			2027			2028			2029		
			Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %
LF	Blue whale[c]	402	1	2	0.75	1	2	0.75	1	2	0.75	0	0	0.00	0	0	0.00
MF	Clymene dolphin	4,237	0	167	3.94	0	167	3.94	0	167	3.94	0	0	0.00	0	0	0.00
	False killer whale[d]	1,791	0	10	0.56	0	10	0.56	0	10	0.56	0	5	0.28	0	5	0.28
	Fraser's dolphin	NA	0	192	NA	0	192	NA	0	192	NA	0	0	NA	0	0	NA
	Killer whale[d]	NA	0	4	NA	0	4	NA	0	4	NA	0	2	NA	0	2	NA
	Melon-headed whale	NA	0	109	NA	0	109	NA	0	109	NA	0	0	NA	0	0	NA
	Pantropical spotted dolphin	6,593	0	60	0.91	0	60	0.91	0	60	0.91	0	0	0.00	0	0	0.00
	Pygmy killer whale	NA	0	5	NA	0	5	NA	0	5	NA	0	0	NA	0	0	NA
	Rough-toothed dolphin	136	0	14	10.29	0	14	10.29	0	14	10.29	0	0	0.00	0	0	0.00
	Spinner dolphin	4,102	0	51	1.24	0	51	1.24	0	51	1.24	0	0	0.00	0	0	0.00
	Striped dolphin	67,036	0	64	0.10	0	64	0.10	0	64	0.10	0	0	0.00	0	0	0.00
	White-beaked dolphin[d]	536,016	0	60	0.01	0	60	0.01	0	60	0.01	0	30	0.01	0	30	0.01
	Beluga whale	131,450	0	2	0.00	0	2	0.00	0	2	0.00	0	0	0.00	0	0	0.00
	Cuvier's beaked whale	5744	0	3	0.05	0	3	0.05	0	3	0.05	0	0	0.00	0	0	0.00
	Blainville's beaked whale	10,107	0	4	0.04	0	4	0.04	0	4	0.04	0	0	0.00	0	0	0.00
	Gervais' beaked whale	10,107	0	4	0.04	0	4	0.04	0	4	0.04	0	0	0.00	0	0	0.00
	Sowerby's beaked whale	10,107	0	4	0.04	0	4	0.04	0	4	0.04	0	0	0.00	0	0	0.00
	True's beaked whale	10,107	0	3	0.03	0	3	0.03	0	3	0.03	0	0	0.00	0	0	0.00
	Northern bottlenose whale	NA	0	4	NA	0	4	NA	0	4	NA	0	0	NA	0	0	NA
HF	Dwarf sperm whale	7,750	2	2	0.05	2	2	0.05	2	2	0.05	0	0	0.00	0	0	0.00
	Pygmy sperm whale	7,750	2	2	0.05	2	2	0.05	2	2	0.05	0	0	0.00	0	0	0.00
PPW	Hooded seal	NA	0	1	NA	0	1	NA	0	1	NA	0	0	NA	0	0	NA

[a] Take is the yearly request for impact pile driving and HRG surveys calculated as described in Section 6.6.2 based on group size.
[b] For the purpose of this LOA request, Year 1 is assumed to be 2025. These dates reflect the currently projected construction start year and are subject to change because exact project start dates and construction schedules are not currently available.
[c] Listed as Endangered under the ESA.
[d] Take for these species is based on PSO sighting group sizes; for all other species group size is from OBIS data.

Table 63. Summary of total Level A and Level B takes[a] requested for rare species for all activities for the effective period of the LOA (5-year total).

Species		Stock Size	5-Year total		
			Level A	Level B	Max %
LF	Blue whale[b]	402	2	4	1.49
MF	Clymene dolphin	4,237	0	334	7.88
	False killer whale[c]	1,791	0	25	1.40
	Fraser's dolphin	NA	0	384	NA
	Killer whale[c]	NA	0	10	NA
	Melon-headed whale	NA	0	218	NA
	Pantropical spotted dolphin	6,593	0	120	1.82
	Pygmy killer whale	NA	0	10	NA
	Rough-toothed dolphin	136	0	28	20.59
	Spinner dolphin	4,102	0	102	2.49
	Striped dolphin	67,036	0	128	0.19
	White-beaked dolphin[c]	536,016	0	150	0.03
	Beluga whale	131,450	0	4	0.00
	Cuvier's beaked whale	5,744	0	6	0.10
	Blainville's beaked whale	10,107	0	8	0.08
	Gervais' beaked whale	10,107	0	8	0.08
	Sowerby's beaked whale	10,107	0	8	0.08
	True's beaked whale	10,107	0	6	0.06
	Northern bottlenose whale	NA	0	8	NA
HF	Dwarf sperm whale	7,750	4	4	0.10
	Pygmy sperm whale	7,750	4	4	0.10
PPW	Hooded seal	NA	0	2	NA

[a] Take is the total request for impact pile driving and HRG surveys calculated as described in Section 6.6.2 based on group size.
[b] Listed as Endangered under the ESA.
[c] Take for these species is based on PSO sighting group sizes; for all other species group size is from OBIS data.

7. Anticipated Impact of the Activity

Marine mammals rely on sound to carry out life-sustaining functions such as foraging, navigating, communicating, and avoiding predators. Through sound they learn about their environment by gathering information from other marine mammals, prey species, phenomena such as wind, waves, and rain, and from anthropogenic source like seismic activity (Richardson et al. 1995). The effects of sounds from pile driving could include one or more of the following: masking of natural sounds, behavioral disturbance, temporary or permanent hearing impairment (TTS or PTS), or non-auditory physical or physiological effects (Richardson et al. 1995, Nowacek et al. 2007, Southall et al. 2007). Research on the non-auditory effects of sound on marine mammals in the wild is lacking and their biological consequences unknown (Southall et al. 2007, Erbe et al. 2018). Non-auditory effects are not further considered but auditory effects are described in the following sections

Detailed data on reactions of marine mammals to anthropogenic sounds are limited to relatively few species and situations (see reviews in Richardson et al. 1995, Gordon et al. 2003, Nowacek et al. 2007, Southall et al. 2007). However, it is clear that behavioral responses to noise likely begin to occur at distances greater than those for hearing impairment or injury (see Section 7.1.3). Marine mammals' behavioral responses to noise range from subtle to conspicuous changes in behavior and movement (Southall et al. 2007). In some cases, behavioral responses to sound may result in displacement from the area, which in turn may act to reduce the overall exposure to that sound (e.g., Finneran et al. 2015, Wensveen et al. 2015). 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 (Richardson et al. 1995, Wartzok et al. 2003, Southall et al. 2007, Ellison et al. 2012). However, if a marine mammal does react 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).

Marine mammals may also experience masking when exposed to anthropogenic noise, which 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 if the frequency of the introduced sound is close to a signal of interest to the marine mammal, and if the introduced sound is present for a significant fraction of the time (Richardson et al. 1995, Clark et al. 2009, Jensen et al. 2009, Gervaise et al. 2012, Hatch et al. 2012, Rice et al. 2014, Erbe et al. 2016b, Tennessen and Parks 2016). Conversely, if little or no overlap occurs between the introduced sound and the frequencies used by the species, masking is not expected to occur. Also, if the introduced sound is present only infrequently, masking is only expected to occur intermittently, 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 et al. 2013, Finneran and Branstetter 2013, Branstetter et al. 2016, Sills et al. 2017). The biological repercussions of a loss of listening area or communication space, to the extent that this occurs, are unknown.

Exposure to sufficiently intense sound may lead to an increased hearing threshold in any living animal capable of perceiving acoustic stimuli (Finneran 2015b). If this shift is reversed and the hearing threshold returns to normal, the effect is called a temporary threshold shift (TTS). The onset of TTS is often defined as threshold shift of 6 dB above the normal hearing threshold (Southall et al. 2019b). If the threshold shift does not return to normal, the residual shift is called a permanent threshold shift (PTS). Aside from natural causes, threshold shifts can result from acoustic trauma from a very intense sound of short duration, as well as from exposure to lower level sounds over longer time periods (Houser et al. 2017).

In marine mammals, the onset level and growth of TTS is frequency specific, depends on the temporal pattern, duty cycle, and the hearing test frequency of the fatiguing stimuli (Finneran 2015b, Finneran et al. 2017). Exposure to intense impulsive noise might be more hazardous to hearing than non-impulsive noise, and there is a positive relationship between exposure duration and the amount of TTS induced. The role of the temporal pattern of sound on TTS in marine mammals has been studied in both high-frequency and very high-frequency cetaceans (Mooney et al. 2009, Finneran et al. 2010, Kastelein et al. 2014, Kastelein et al. 2015b). The results of these studies show that TTS can accumulate across multiple exposures, but the resulting TTS will be less than the TTS from a single, continuous exposure with the same total sound exposure level (Finneran et al. 2010). Though the relationship between the onset levels of TTS and the onset levels of PTS is not fully understood for marine mammal species, PTS onset acoustic thresholds have been extrapolated from marine mammal TTS measurements using growth rates from terrestrial and marine mammal data (Finneran et al. 2017).

While PTS undoubtedly constitutes an injury, TTS is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or “injury” (Southall et al. 2007, Le Prell et al. 2012). 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. In its regulatory guidance, therefore, NOAA Fisheries does not consider TTS to be injurious (NMFS 2018). Some research, however, has shown that sound exposure can cause cochlear neural degeneration even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009, Liberman 2016). Whether TTS should continue to be considered a non-injurious effect is under debate (Weilgart 2014, Tougaard et al. 2015, 2016).

TTS has been demonstrated and studied in captive odontocetes and pinnipeds exposed to loud sounds (reviewed in Southall et al. 2007, Finneran 2015a) but currently there is no documented evidence of TTS (or PTS) in free-ranging marine mammals exposed to anthropogenic sounds under realistic field conditions.

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 reason 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.

7.1. Potential Effects of Impact Pile Driving on Marine Mammals

Impact pile driving during foundation installation for New England Wind could result in incidental take of marine mammals by Levels A and B harassment caused by exposure to threshold levels of underwater sound produced by this activity. The sounds produced by impact pile driving are described in Section 1.2 of this LOA request and additional details can be found in Appendix A.

7.1.1. Behavioral Disturbance

There is no published information available on the behavioral responses of baleen whales to impact pile driving sounds, but a number of studies have considered impacts from seismic air guns. Baleen whales generally exhibit some response to impulsive sounds from operating air guns (Stone and Tasker 2006), but avoidance radii vary greatly among species, locations, whale behavior, oceanographic conditions affecting sound propagation, etc. (see reviews in Richardson et al. 1995, Gordon et al. 2003). Whales are often reported to show no overt reactions to pulses from large arrays of air guns at distances beyond a few kilometers, even though the air gun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong sound pulses from air guns may react by moving away from and/or around the sound source, demonstrating only localized avoidance responses to operating air gun arrays (Stone and Tasker 2006, Weir 2008, Stone 2015). For example, humpback whales exposed to a 20 cubic inch air gun decreased both dive time and course changes, but there was no evidence of a strong behavioral response (Dunlop et al. 2015). Further, some migrating humpbacks showed no avoidance response at even the highest received levels 160–170 dB re 1 µPa SPL. Migrating bowhead whales, however, appear to have a stronger reaction to seismic activity, with most whales avoiding an operating seismic vessel by 20–30 km (65.6–98.4 mi) (Miller et al. 1999, Richardson et al. 1999). At this range, broadband received source levels were estimated to be 120–130 dB re 1 µPa.

Behavioral state appears to have a significant effect on the magnitude of response to air guns. Feeding bowhead whales, in contrast to migrating whales, show even smaller avoidance distances (Miller et al. 2005, Harris et al. 2007), presumably because moving away from a food concentration has greater cost to the whales than does a course deviation during migration. Similarly, resting groups of humpback whales that contained a calf were more sensitive to a 20 cubic inch air gun than those groups that were migrating (McCauley et al. 2000). In migrating bowhead and gray whales, observed changes in behavior in response to seismic activity appeared to be of little or no biological consequence to the animals as they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984, Malme and Miles 1985, Richardson et al. 1995). 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 to those observed for migrating animals, where they simply avoided the area around the activity and continued on their migratory path, resulting in little assumed 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, further limiting the overall impact.

There are considerably more data available on the behavioral responses of odontocetes to pile driving; however, this is limited primarily to harbor porpoises as they are the most commonly detected cetacean in offshore energy development areas in the North Sea (Waggitt et al. 2020). Research in these development areas have indicated that harbor porpoises may be particularly sensitive to the noise produced during pile driving, with some animals displaced more than 20 km from piling activity (Tougaard et al. 2009b, Brandt et al. 2011, Haelters et al. 2015, Dähne et al. 2017, Brandt et al. 2018). However, despite avoidance during periods of construction activity, there is typically continued use of the area after construction is completed (Madsen et al. 2006). Further, there is evidence that harbor porpoises respond less to pile driving activity over the course of a construction period, which could suggest possible habituation to this disturbance (Graham et al. 2019). Other odontocetes that have demonstrated a response to pile driving include Indo-Pacific bottlenose dolphins in Western Australia, which were less likely to be detected during piling activity (Paiva et al. 2015), and Indo-Pacific humpback dolphins, which showed no overt behavioral avoidance, but did increase travel speed during pile driving (Würsig et al. 2000).

Pinnipeds appear to also exhibit primarily short-term reactions to pile driving activity. Harbor seals exposed to piling in Denmark were observed less on land during pile driving than during time where piling was absent (Edrén et al. 2004, Edrén et al. 2010). However, it is unknown whether they were in fact displaced from the area, or whether they simply remained in the water. Seal deterrent devices were in use during pile driving, and it is also not possible to determine if the observed effect was the result of piling, the deterrent, or a combination of the two. Regardless, there was no decrease in general seal abundance during the construction period, indicating only a short-term effect (Edrén et al. 2004, Edrén et al. 2010). Grey seals appear to demonstrate primarily a decrease in descent speed during a dive, which is proposed to indicate a switch from foraging behavior to more directed horizontal movement, as well as movement away from the source (Aarts et al. 2018). Some reactions were observed at distances beyond 36 km, however some seals continued to return to the area despite the presence of piling activity. Overall, odontocete and pinniped reactions to noise from pile driving appear to be minor and temporary, and it is expected that they will result in minimal overall impacts.

7.1.2. Masking

There are few studies on the masking effects of pulsed sounds, like those related to impact pile driving, on marine mammal calls and other natural sounds that are important to marine mammals. Low-frequency cetaceans such as baleen whales are likely to be more susceptible to masking by the low-frequency noise produced by pile driving (Richardson et al. 1995). However, to date, most studies have considered impacts from a different impulsive source: seismic air guns. Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between seismic pulses (Richardson et al. 1986, McDonald et al. 1995, Greene et al. 1999, Dunn and Hernandez 2009, Nieukirk et al. 2012, Thode et al. 2012, Cerchio et al. 2014, Sciacca et al. 2016). 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 indicated that calling fin whales went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that paper if the whales ceased calling because of masking or if this was a behavioral response not directly involving masking. Also, it appeared that migrating bowhead whales (*Balaena mysticetus*) in the Beaufort Sea decreased their calling rates in response to seismic operations as evidenced by a lower call detection rate, although movement out of the area also contributed to the lower call detection rate (Blackwell et al. 2013, 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 of a lower-energy seismic source. The sparker used during that 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, air gun sounds (Castellote et al. 2012).

Among the odontocetes, dolphins and porpoises are commonly heard calling during pile driving (e.g. Dähne et al. 2013, Leunissen et al. 2019) and while air guns are operating (Gordon et al. 2003, Potter et al. 2007). There was one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), but more recent studies found that sperm whales continue to call in the presence of seismic pulses (Madsen et al. 2002a, Tyack et al. 2003, Jochens et al. 2008). In the case of the smaller odontocetes, the masking effects of pile driving are expected to be negligible because the sounds that are important to these species occur predominantly at much higher frequencies than the dominant components of pile driving sounds. For example, the harbor porpoise produces echolocation clicks of 110–150 kHz (Møhl and 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 Richardson et al. 1995).

Some cetaceans are known to increase the source levels of their calls, shift their peak frequencies, or increase the repetition rate or duration of their calls in response to increased noise (reviewed in Erbe et al. 2016b). Altering vocalizations can increase energetic costs for individual marine mammals (Holt et al. 2015, Noren et al. 2017). However, it is not known how often these types of vocal responses might occur upon exposure to pile driving sounds, and thus what the biological importance of any increased costs might be. If cetaceans exposed to pile driving sounds sometimes respond by changing their vocal behavior, this adaptation, along with directional hearing and pre-adaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would reduce the importance of masking by this sound source.

7.1.3. Hearing Impairment

Marine mammal TTS data from impulsive sources are limited. Finneran et al. (2002) reported a behaviorally-measured TTS of 6 and 7 dB in a captive beluga whale exposed to single impulses from a seismic water gun. Additionally, Lucke et al. (2009) reported AEP-measured TTS of 7 to 20 dB in a captive harbor porpoise exposed to single impulses from a seismic air gun. In addition to these seismic data, Kastelein et al. (2015a) reported a behaviorally-measured mean TTS of 4 dB at 8 kHz and 2 dB at 4 kHz after a harbor porpoise was exposed to a series of impulsive sounds produced by broadcasting underwater recordings of impact pile driving strikes through underwater sound projectors. The cumulative SEL was approximately 180 dB re 1 μPa^2·s. The pressure waveforms for the simulated pile strikes exhibited significant “ringing” not present in the original recordings, and most of the energy in the broadcasts was between 500 and 800 Hz. As a result, some questions exist regarding whether the fatiguing signals were representative of underwater pressure signatures from impact pile driving.

Several impulsive noise exposure studies have failed to find behaviorally measurable TTS. Finneran et al. (2000) exposed dolphins and beluga whales to single impulses from an “explosion simulator” and Finneran et al. (2015) exposed three dolphins to sequences of ten impulses from a seismic air gun (maximum cumulative SEL: 193 to 195 dB re 1 μPa^2·s, PK:196 to 210 dB re 1 μPa) without measurable TTS. Finneran et al. (2003) also exposed two sea lions to single impulses from an arc-gap transducer with no measurable TTS (maximum unweighted SEL: 163 dB re 1 μPa^2·s, PK: 183 dB re 1 μPa).

The criteria used in the exposure modeling (Section 6.2.2) (NMFS, 2018) reflect the most recent scientific review and conclusions of NMFS regarding sound levels that could cause PTS. Based on the exposure modeling results (Tables 28–34), the number of marine mammals that may experience hearing impairment is quite small, even when planned mitigation measures are not considered.

7.2. Potential Effects of Vibratory Pile Driving on Marine Mammals

The sounds produced by vibratory pile driving, described in Section 1.2 of this LOA request, may also result in incidental take of marine mammals by Level B harassment. Many studies consider the combined effects of vibratory and impact pile driving (e.g., Paiva et al. (2015)), or vibratory pile driving with acoustic deterrents (e.g., Edrén et al. (2010)). However, some studies on the impacts of vibratory pile driving alone have suggested a possible minor effect on behavior and the potential for masking.

7.2.1. Behavioral Disturbance

The noise resulting from vibratory piling activities has been demonstrated to impact the echolocation abilities of bottlenose dolphins. When dolphins were exposed to playbacks of vibratory piling, they significantly reduced the number of echolocation clicks on a target compared to periods with no exposure to noise. However, they increased the rate of echolocation after the initial trial, indicating that the dolphins were able to acclimate to the piling noise (Branstetter et al. 2018). Vibratory piling activity has also been associated with a decrease in the probability of occurrence in bottlenose dolphins and harbor porpoises, and with a reduction in the time spent in the area of vibratory piling for bottlenose dolphins (Graham et al. 2017). These responses were observed at predicted received single-pulse SEL values of between 98.8 and 131.7 dB re 1 IPa2 s. However, neither species was excluded from the area and both continued to be present during vibratory piling activities.

7.2.2. Masking

Although bottlenose dolphins exposed to playbacks of noise from vibratory piling eventually increased their echolocation rates, their was no evidence that this was due to masking (Branstetter et al. 2018). The communicative whistles of some species, however, may be more susceptible to masking due to their lower peak frequencies. For example, the echolocation clicks of Indo-pacific humpback dolphins have a peak frequency of 43.5 to 142.1 kHz, while their whistles range from 520 Hz to 33 kHz (Wang et al. 2014). As the dominant frequency of the vibratory hammer measured during that study was below 10 kHz, the authors concluded that the echolocation clicks of this species would be largely unaffected, the whistles in this species could be susceptible to masking.

7.2.3. Hearing Impairment

There are no direct studies on the impact of vibratory pile driving on hearing impairment in marine mammals. However, based on the source levels measured near a vibratory hammer, (Wang et al. 2014) concluded that TTS or PTS could be exceeded under certain conditions (e.g. prolonged exposure) for Indo-pacific humpback dolphins. This study was conducted based on the world's largest vibratory hammer, however, and may not be applicable to all vibratory piling activities.

7.3. Potential Effects of Drilling on Marine Mammals

Sounds emitted by offshore drilling activities for wind farm development are non-impulsive and intermittent. While some impacts on marine mammals have been reported, most have been reported in response to oil production drilling, whereas drilling operations associated with wind farm construction activities would be of a much smaller magnitude.

7.3.1. Behavioral Disturbance

Impacts to marine mammals from underwater sound from drilling depend on the species, distance from the source, and type of drilling activity (Awbrey and Stewart 1983, Richardson et al. 1990a, Richardson et al. 1990b, Miller et al. 2005, Blackwell et al. 2017). Observed responses can include changes in migratory pathways, avoidance, changes in calling behavior, altered diving and feeding patterns, and/or displacement from an area (Richardson et al. 1990b, Miller et al. 2005, Blackwell et al. 2017). However, these responses are expected only when underwater sounds associated with drilling activities are above marine mammal behavioral thresholds (NOAA 2005).

Research suggests that not all marine mammals respond negatively to drilling operations and any reactions to this source are short-term (Blackwell et al. 2004b, Todd et al. 2009). Received sound levels of drilling from construction operations were found to be within the hearing range of phocid seals (<100 Hz); however, no aversion to sound was observed for ringed seals (Blackwell et al. 2004b).

While underwater drilling sounds can have a negative effect on some species (bowhead and beluga whales), others (ringed seals and harbor porpoises) have been documented to be far more tolerant to drilling activities (Moulton et al. 2003, Todd et al. 2009). Further, there are individual differences in the reactions to drilling even within species. Awbrey and Stewart (1983) demonstrated that some beluga whales responded to playbacks of drilling noise up to 3.5 km from the source while others approached to within 15m. In the North Sea, high frequency odontocete species, such as harbor porpoises, have been found feeding around offshore drilling rigs and platforms during routine drilling and production operations at relatively low sound pressure levels (120 dB re 1 µPa) (Todd et al. 2009)

7.3.2. Masking

There are no data available on the masking effects of drilling sounds. However, Blackwell et al. (2004a) measured broadband (10 Hz to 10 kHz) SPL near a drilling platform and found an increase in ambient noise levels from 91 dB re 1 µPa when no drilling was taking place, to a maximum of 124 dB re 1 µPa during drilling activities at one kilometer from the source. Drilling noise was estimated to be audible to seals only to a distance of 1.5 km from the drilling platform, and was not above ambient noise levels beyond 9.4 km. Ambient sound levels In the WEA are expected to be higher than drilling noise. Kraus et al. (2016) suggest that ambient sounds levels at 70.8–224 Hz frequency were 96–103 dB re 1 µPa 50% of the time, with the loudest recorded ambient sound levels at ~115 dB re 1 µPa. Therefore, prolonged drilling activities may cause acoustic masking for marine mammals that are relatively close to the platform but are unlikely to be louder than the ambient sound level near the New England Wind project area.

7.3.3. Hearing Impairment

There are no direct studies on the impact of drilling on hearing impairment in marine mammals. Measurements near mudline cellar drilling found source levels of 191 dB re µPa^{2}m^2 (Austin et al. 2018). This level is below the PTS onset threshold for non-impulsive noise for all marine mammal hearing groups in water with the exception of very-high-frequency cetaceans, however it is above the onset threshold for TTS onset for all marine mammal hearing groups in water with the exception of otariids (Southall et al. 2019b). This indicates a potential risk for TTS for marine mammals, however the drilling activity is expected to be intermittent and short duration.

7.4. Potential Effects of HRG Surveys on Marine Mammals

HRG surveys include multibeam, sidescan, single beam, and sub-bottom profile sonar, and are considered an impulsive sound source. Many HRG sources operate at frequencies (>200 kHz) above the hearing range of marine mammals so are not expected to result in impacts. Research suggests that sound levels produced by HRG sources operating within the hearing range of marine mammals are unlikely to cause injury but could result in temporary behavioral responses.

7.4.1. Behavioral Disturbance

While Varghese et al. (2020) found no consistent changes in Cuvier's beaked whale foraging behavior during multibeam echosounder surveys, analogous studies assessing mid-frequency active sonar on beaked whale foraging found that individuals would stop echolocating and leave the area. Other studies have focused on the responses of marine mammals exposed to sonar. For example, minke whales demonstrated strong avoidance to mid-frequency sonar at 146 dB re 1 µPa (Sivle et al. 2015, Kvadsheim et al. 2017) and Wensveen et al. (2019) showed northern bottlenose whales had a greater response to (military) sonar signals. Surface-feeding blue whales showed no changes in behavior to mid-frequency sonar, but blue whales feeding at deeper depths and non-feeding whales displayed temporary reactions to the source; including cessation of feeding, reduced initiation of deep foraging dives, generalized avoidance responses, and changes to dive behavior (DeRuiter et al. 2013, Goldbogen et al. 2013, Sivle et al. 2015). Several behavioral reactions were seen in beaked whale species in response to mid-frequency sonar sounds (12–400 kHz and 230 dB re 1 µPa) including cessation of clicking, termination of foraging dives, changes in direction to avoid the sound source, slower ascent rates to the surface, longer deep and shallow dive durations, and other atypical dive behavior (Tyack et al. 2011, DeRuiter et al. 2013, Stimpert et al. 2014, Miller et al. 2015, Cholewiak et al. 2017). Sperm whales, killer whales, and long-finned pilot whales have also all demonstrated moderate behavioral responses to mid-frequency sonar, with avoidance of the sound source observed most frequently (Miller et al. 2012).

Exposure to mid-frequency sonar at various sound levels (125–185 dB re 1 µPa) caused behavioral responses in California sea lions (*Zalophus californianus*), including a refusal to participate in trials, hauling out, an increase in respiration rate, and an increase in the time spent submerged (Houser et al. 2016). Hooded seals showed initial avoidance behavior to 1–7 kHz sonar signals at levels between 160 and 170 dB re 1 µPa, but these animals did adapt to the sound and stopped avoiding the source (Kvadsheim et al. 2010a).

7.4.2. Masking

There are limited data on the masking effects of pulsed sounds on marine mammal calls, and there are no direct studies on the impact of HRG surveys on masking in marine mammals. Data from seismic surveys, another impulsive sound source, shows that the detection rates of some cetacean calls are reduced in the presence of seismic pulses (Clark and Gagnon 2006, Nieukirk et al. 2012). However, it is often unclear if this is the result of masking or a cessation of calling activity. For the smaller odontocetes, the masking effects of low frequency, impulsive noise are expected to be insignificant because the calls of these species occur predominantly at much higher frequencies.

7.4.3. Hearing Impairment

There are no direct studies on the impact of HRG surveys on hearing impairment in marine mammals. Although impulsive sounds have been shown to cause TTS in both beluga whales (Finneran et al. 2002) and harbor porpoises (Lucke et al. 2009), other studies have failed to elicit TTS in response to impulsive sounds (Finneran et al. 2000, Finneran et al. 2003, Finneran et al. 2015).

7.5. Potential Effects of UXO Detonation on Marine Mammals

Unexploded ordnances may need to be detonated in situ. An acoustic modeling study of peak pressure, acoustic impulse, and sound exposure level from UXO detonation was performed recently for the Revolution Wind project, an Ørsted and Eversource Investment joint venture (Hannay and Zykov 2022), which is geographically adjacent to the New England Wind project area.

7.5.1. Behavioral Disturbance

There are no direct studies on the impact of UXO detonation on behavioral disturbance in marine mammals. However, a recent acoustic modeling study considered disturbance to marine mammals based on TTS onset (Hannay and Zykov 2022). Results showed that behavioral disturbance could be expected for high-frequency cetaceans, the most sensitive species, between 5.4 km for a 2.3 kg UXO and 31.2 km for a 454 kg UXO.

7.5.2. Masking

There are limited data on the masking effects of pulsed sounds on marine mammal calls, and there are no direct studies on the impact of UXO detonation on masking in marine mammals. Data from seismic surveys, another impulsive sound source, shows that the detection rates of some cetacean calls are reduced in the presence of seismic pulses (Clark and Gagnon 2006, Nieukirk et al. 2012). However, it is often unclear if this is the result of masking or a cessation of calling activity. For the smaller odontocetes, the masking effects of low frequency, impulsive noise are expected to be insignificant because the calls of these species occur predominantly at much higher frequencies.

7.5.3. Hearing Impairment

There are no direct studies on the impact of UXO detonation on hearing impairment in marine mammals. However, a recent acoustic modeling study assessed auditory system injury zones using SEL based on PTS onset (Hannay and Zykov 2022). Results showed that PTS could be expected for high-frequency cetaceans, the most sensitive species, between 2.8 km for a 2.3 kg UXO and 16.1 km for a 454 kg UXO.

7.6. Summary

As reviewed in detail in Sections 7.1 through 7.5 for the different sound-producing activities, there are many uncertainties in predicting the quantity and types of impacts of sound on marine mammals. Behavioral responses in particular can range from subtle to extreme, depend on many factors, and are difficult to predict. Because of this, an approach to calculating marine mammal harassment with several layers of conservatism was applied. This included rounding up to an integer for all predicted exposures (even those much lower than one), rounding up Level B exposures to an average group size when the model predicted fewer than one group size, using worst case scenarios from the two proposed construction schedules, and assuming 10 dB of broadband sound attenuation although the Proponent is targeting 12 dB or greater. Additionally, the mitigation measures detailed in Section 11 were not considered when predicting harassment, except for the NARW, for which special mitigation will be applied to reduce potential Level B harassment and to eliminate Level A harassment entirely. Many of these measures will also reduce harassment of other marine mammal species.

As seen in Tables 28–34 in Section 6.2.5 above, low-frequency cetaceans are more likely to experience Level A harassment than other cetaceans. This occurs because the hearing frequency of this group overlaps with the highest energy frequency bands produced during pile driving. Nonetheless, even when using the conservative measures applied to calculate Level A takes for the full buildout of the project from the estimated exposures, the estimated number of Level A takes (see Table 61) of low-frequency cetaceans are all less than 1.6% of their population sizes, assuming 10 dB of sound attenuation. These are likely to be further reduced by the mitigation measures described in Section 11. Special mitigation for the NARW will assure no Level A harassment of this species. Mid-frequency cetaceans as well as pinnipeds have less acute hearing at lower frequencies, where most of the acoustic energy from impact pile driving occurs. The Level A take estimates as a percent of population are all less than 0.1% for these species. High-frequency cetaceans have reduced sensitivity at lower frequencies but they have a much lower threshold for PTS injury (see Table 19). Nonetheless, the percentage of their population that could experience Level A harassment is estimated at only 0.36%. Additionally, the mitigation measures proposed by New England Wind, including a noise attenuation target of 12 dB or greater, are anticipated to reduce Level A takes to zero for NARW and to near zero for all species.

Although the take calculation methods herein used many conservative assumptions, annual totals of Level B plus Level A harassment from all sound sources combined are predicted to affect less than one third of the population for all marine mammal species (see Table 60). 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 relevant subsistence uses of marine mammals in the SWDA. As such, no relevant subsistence uses of marine mammals would be implicated by this action and no impacts to the availability of species or stocks for subsistence use are expected.

9. Anticipated Impacts on Habitat

Impacts to habitat from New England Wind have been thoroughly analyzed by the Proponent in its site characterization and impact assessment. These are summarized in Volume III of the COP and described here.

9.1. Short-Term Habitat Alterations

Short-term benthic habitat alteration will occur through the installation of cables, as well as the use of any jack-up or anchored vessels. This disturbance is expected to be limited to small areas of the seafloor and the habitat is anticipated to fully recover within a relatively short time period. For example, benthic habitat monitoring following construction of the Block Island Wind Farm off Rhode Island showed that all seafloor disturbance showed at least partial recovery and most had completely recovered within 2–3 years after construction as a result of sediment mobility (HDR 2020b).

The soundscape would be temporarily altered because of pile driving during foundation installation. Studies have shown that the sound produced by pile driving has the potential to elicit behavioral responses, including aversion and avoidance, in both marine mammals (e.g. NMFS 2018) (Wood et al. 2012) and the fish (see Popper and Hawkins 2019 for a review) and invertebrates (e.g. Jones et al. 2020, Jones et al. 2021) that they prey upon. Sections 6.2.1 through 6.2.3 provide an overview of the acoustic analyses conducted to assess potential effects of impact pile driving sounds on marine mammals, including the potential for auditory injury and behavioral response. Details of this analysis can be found in Appendix A. The mitigation measures described in Section 11 are intended to eliminate the potential for marine mammal auditory injury as well as any injury to their prey. Soundscape alteration would be limited to the time when pile driving is actively occurring.

9.2. Longer-Term Habitat Alterations

Longer-term habitat alterations resulting from New England Wind include the creation of hard substrate around WTG and ESP foundations and the loss of habitat from the footprint of the installations as well as the introduction of structures into the water column. These structures are intended to remain in place throughout the approximately 30-year operational life of the project. The proposed foundation layout configuration includes 1.85 km (1 NM) spacing between structures, oriented in fixed east-to-west rows and north-to-south columns, thus providing 1.85 km (1 NM) wide corridors in the east-west and north-south directions as well as 1.3 km (0.7 NM) wide corridors in the northwest-southeast and northeast-southwest directions that allow for transit into and throughout the area making it unlikely that structures would impede marine mammal movement.

9.3. Potential Impacts to Marine Mammal Prey

A thorough review of the impacts to fish and invertebrates during installation and construction of New England Wind is reported in Section 6.6.2.1 of COP Volume III and described here.

Immobile life stages of fish species in or on benthic sediment (i.e. demersal eggs and larvae), demersal fish species, and benthic invertebrates with limited or no motility in the direct path of foundations, scour protection, inter-array and inter-link cables, offshore export cables within the SWDA, cable protection (if any), jack-up vessel legs, or anchors would be the most at risk of direct injury or mortality during construction and installation in the SWDA. Mobile demersal/benthic and pelagic fish and invertebrates would be temporarily displaced by increased suspended sediments and underwater construction but would likely be able to escape harm and avoid construction and installation areas. Construction activities conducted in the winter, if any, may further reduce the avoidance ability of some benthic organisms as low temperatures can influence metabolic rates and locomotion (Brockington and Clarke 2001).

Temporary and permanent habitat loss or alteration is expected for both demersal and pelagic fish. Demersal fish species are expected to be the most affected by bottom habitat loss and alteration because of their strong association with benthic environments. Bottom habitat will be permanently altered to hard substrate from the installation of WTG/ESP foundations and associated scour protection. Bottom habitat may also be permanently altered to hard bottom substrate through the installation of cable protection (as described in Sections 3.2.1.5.4 and 4.2.1.5.4 of COP Volume I) in areas where sufficient cable burial depths cable cannot be achieved. The BOEM DEIS (2018) for Vineyard Wind 1 determined that impacts from the long-term conversion of habitat would be moderate but not affect fishes and invertebrates at a population-level.

Additional bottom habitat alteration is expected from the use of jack-up and/or anchored vessels and from installation of the inter-array, inter-link, and offshore export cables within the SWDA as described in Sections 3.3.1.3 and 4.3.1.3 of COP Volume I. Anchored vessels may be equipped with spud legs that are deployed to secure the cable laying vessels while its anchors are being repositioned. Bottom habitat in the direct path of the inter-array, inter-link, and offshore export cables within the SWDA will be disturbed from the surface to a depth of 1.5–2.5 m. Additionally, to monitor weather and sea state conditions during construction, the Proponent may deploy meteorological oceanographic ("metocean") buoys within the SWDA; if so, anchors for the metocean buoys will also temporarily disturb bottom habitat.

Within the maximum size of the SWDA and encompassing both Phases 1 and 2, the amount of permanent habitat alteration from the installation of WTG/ESP foundations, associated scour protection, and potential cable protection (if required) would be approximately 1.17 km^2. The amount of habitat disturbance from the use of jack-up and/or anchored vessels, cable installation, and metocean buoy anchors would be approximately 4.08 km^2. The total area of alteration within the SWDA due to foundation and scour protection installation, jack-up and/or anchored vessel use, inter-array and inter-link cable installation, potential cable protection (if required), and metocean buoy anchors is 5.19 km^2, which is 1.1% of the maximum size of the SWDA.

As with the SWDA, immobile benthic species or early life stages in the direct path of construction vessels within the OECC would experience direct mortality or injury. Mobile demersal/benthic and pelagic fish and invertebrates may be temporarily displaced by increased suspended sediments and underwater construction but would likely be able to escape harm and avoid construction and installation areas. Some displaced fish and invertebrates may be subjected to indirect injury or mortality through increased predation or competition in areas surrounding the construction site. Overall, the slower avoidance response of juvenile and adult demersal fish and benthic invertebrate species subjects them to increased injury or mortality during dredging and cable installation. As mentioned above, slow avoidance responses can be further exaggerated if construction activities occur during the cold winter months for some species, such as horseshoe crab, that bury into the offshore sediment in the winter (Walls et al. 2002).

Benthic habitat in the direct path of the cable installation vessels, dredging vessels, vessel anchors, and anchor sweep zone will be disturbed while cables are being installed along the OECC. As described in COP Volume II, the OECC will pass through a variety of sediment types, including sand/mud, pebble-cobble, and dispersed boulders. Much of the OECC is considered low complexity, sandy, soft bottom habitat and the majority of video transects taken along the OECC recorded flat sand/mud or sand waves (see COP Volume II). Coarser complex substrates, including pebble-cobble and boulders, were found mainly in Muskeget Channel and are important for habitat for the juveniles of some fish species, like Atlantic cod (*Gadus morhua*) (Lindholm et al. 2001, Grabowski et al. 2018).

Once cable installation is complete, temporary to permanent habitat alteration may occur due to the resettling of disturbed finer-grained sediment over gravel and other coarse substrate. However, because sedimentation thicknesses are typically expected to be less than 5 mm, dynamic processes will likely uncover larger grains with time. For a small portion of the OECC, permanent alteration may also occur where desired burial depth cannot be achieved. In these areas with limited burial depth, cable protection may be placed over the cables. The Proponent’s goal, however, is to minimize the use of cable protection to the greatest extent possible and will do so through a careful route assessment and the selection of the most appropriate cable burial tool for each segment of the cable route.

As detailed in Appendix III-T of COP Volume III, within the OECC for Phases 1 and 2, the amount of permanent habitat alteration from the potential installation of cable protection (if required) would be approximately 0.22 km^2. The amount of habitat disturbance from cable installation, anchoring, the potential dredging of the tops of sand waves in certain locations, the potential for limited vessel grounding in the nearshore, and the limited use of jack-up vessels for cable splicing would be approximately 2.48 km^2. Total seafloor impacts in the OECC would be approximately 2.60 km^2.

If the Western Muskeget Variant is used for one or two Phase 2 export cables, the amount of permanent habitat alteration for both Phases combined from the potential installation of cable protection (if required) would be approximately 0.23–0.24 km^2. The amount of habitat disturbance for both Phases combined from cable installation, anchoring, the potential dredging of the tops of sand waves in certain locations, the potential for limited vessel grounding in the nearshore, and the limited use of jack-up vessels for cable splicing would be approximately 2.47–2.49 km^2. Total seafloor impacts in the OECC for both Phases combined would be approximately 2.61 km^2.

9.3.1. Suspended Sediments

Temporary increases in suspended sediments in the water column during construction activities (i.e., HRG surveys, potential UXO detonation, drilling, vibratory setting, and impact pile driving) are expected and may affect demersal and pelagic fish species and benthic invertebrates. Increased suspended sediment can impair the visual abilities of fish species and impact foraging, navigation, and sheltering behaviors. For mollusks, such as soft shell clams and northern quahog (*Mercenaria mercenaria*), suspended sediments can reduce oxygen consumption and filter feeding abilities and lead to reduced growth (Wilber and Clarke 2001).

Concentration and duration of sediment suspension dictate the severity of the effects to fish and benthic organisms. Reduced growth and oxygen consumption of some mollusk species has been observed when sediment concentrations of 100 mg/L persisted for two days (Wilber and Clarke 2001). Sublethal effects (i.e. fine sediment coating gills and cutting off gas exchange with water thus resulting in asphyxiation) were observed for adult white perch (*Morone americana*) when 650 mg/L of suspended sediments persisted for five days (Sherk et al. 1974). Lethal effects were observed for other adult fish species at concentrations greater than 1,000 mg/L that persisted for at least 24 hours (Sherk et al. 1974, Wilber and Clarke 2001). Fish eggs and larvae are typically more sensitive, with delayed hatching observed for white perch at a sediment concentration of 100 mg/L for one day (Sherk et al. 1974), which will be considered herein as a conservative threshold for potential impacts to finfish and invertebrates. See Section 6.5 of the COP for further details.

Suspended sediment modeling conducted for New England Wind demonstrates that all expected concentrations and durations of exposure are below those causing sublethal or lethal effects to fish or benthic organisms. As described in Appendix III-A of COP Volume III, modeling was conducted for typical installation of offshore export and inter-array cables, dredging, and the use of a vertical injector for cable installation.

Modeling for offshore export cable and inter-array cable installation indicated that under typical or maximum-impact cable installation methods, suspended sediments would be present within the lower portion of the water column for short periods of time. The maximum anticipated suspended sediment concentrations that persist for at least 60 minutes would be greater than 200 mg/L but less than 650 mg/L. These concentrations would drop rapidly to below 50 mg/L within a maximum of between one to two hours. Concentrations of suspended sediments of at least 10 mg/L typically stayed within 200 m (656 ft) of the cable centerline but could extend up to 2.2 km (1.2 nautical miles [NM]) from the inter-array cable centerline. Total suspended solids concentrations greater than 10 mg/L above ambient would substantially dissipate within one to two hours and fully dissipate in less than four hours. Results for export cable installation in the Western Muskeget Variant are similar. Therefore, these concentrations and durations of exposure are below those causing sublethal or lethal effects to fish and invertebrates even with an overly conservative threshold.

Installation along the OECC may require discontinuous (i.e., intermittent) dredging of the tops of sand waves to achieve sufficient burial depths. As described in Appendix III-A of COP Volume III, this will likely be accomplished with a trailing suction hopper dredge (TSHD) or by jetting by controlled flow excavation for smaller sand waves. Sediment dispersion modeling of the TSHD indicated that concentrations of suspended sediments above 10 mg/L extended up to a maximum of 16 km (8.6 NM) from the area of activity; however, concentrations above 10 mg/L persist for less than six hours. For export cable installation, total suspended solid concentrations greater than 10 mg/L typically stayed within 200 m (656 ft) of the alignment but could extend a maximum distance of approximately 2.1 km (1.1 NM). Most of the sediment settles out in less than three to four hours. Finfish and invertebrates may be affected by the mobilization and suspension of sediments during dredging and cable installation activities, but all sediment settles out of suspension within three to six hours, thus concentrations do not exceed the potential impact thresholds.

The Proponent may elect to use a vertical injector cable installation tool with deeper penetration such that dredging of the tops of sand waves is not required to achieve sufficient burial depths. A representative section of deeper installation was modeled, and results indicated that concentrations of suspended sediments above 10 mg/L extended up to a maximum of 1.2 km (0.6 NM) from the cable trench centerline. Most of the sediment settles out in less than three hours; however, suspended sediments at this concentration could persist for between four to six hours in smaller areas. Overall, this method is not anticipated to affect finfish and invertebrates because all sediments settle out of suspension within six hours and thus do not exceed the sublethal and lethal sensitivity thresholds.

9.3.2. Sediment Deposition

The resettlement of disturbed sediments may cause additional mortality or injury to immobile species or life stages through burial and smothering. For demersal eggs of fish and squid, deposition greater than 1 mm can result in the burial and mortality of that life stage (Berry et al. 2011). A sedimentation threshold of 20 mm (0.8 in) was used as the general threshold for shellfish. This threshold is inclusive of most shellfish and life stages, including more sensitive subtidal mussel and oyster beds, and is conservatively based on the work of Colden and Lipcius (2015), Essink (1999), and Hendrick et al. (2016). Considering the thickness and distribution of sedimentation, the BOEM DEIS (2018) for Vineyard Wind 1 determined that impacts from sedimentation on finfishes and invertebrates during construction would be minor and short-term.

Simulations of typical cable installation methods in the SWDA and OECC (see Appendix III-A of COP Volume III) indicated that deposition of 1 mm (0.04 in) or greater (i.e., the threshold of concern for demersal eggs) was constrained to within 100 m (328 ft) from the route centerline. No area of deposition greater than 5 mm (0.2 in) are expected for the typical installation parameters, though there was a small, isolated area associated with the vertical injector model scenario with deposition between 5 mm (0.2 in) to 10 mm (0.4 in) (see Appendix III-A of COP Volume III). At this deposition thickness, there are limited areas with potential temporary negative impacts to demersal eggs and species of similar sensitivity. Further, given that the expected deposition is less than 10 mm (0.4) for all modeled cable installation scenarios, cable installation is not anticipated to affect shellfish or other organisms of similar sensitivity to deposition. Results for export cable installation in the Western Muskeget Variant are similar.

In areas along the OECC where sand wave dredging was simulated to occur, deposition greater than 1 mm (0.04 in) associated with the TSHD was mainly constrained to within 1 km (0.54 NM) but extended up to 2.3 km (1.2 NM) in isolated patches when subject to swift currents through Muskeget Channel. Modeling results also indicated that there will be some small areas of deposition greater than 20 mm (0.8 in) from dredging and dumping extending up to 0.9 km (0.49 NM) from the route centerline. At this deposition thickness, there are limited areas with potential temporary negative impacts to all life stages of shellfish and species of similar sensitivity to deposition.

9.3.3. Water Withdrawals

Direct mortality of planktonic life stages could occur via water withdrawals for vessel functions and potentially from the cable installation and dredging vessels during construction and operation of both Phases of New England Wind. Mortality of organisms entrained in water withdrawal pumps is expected to be 100% because of the physical stresses associated with from being flushed through a pump system and potential temperature changes (USDOE MMS 2009). Species most at risk of mortality from water withdrawals are those with pelagic eggs (see Appendix III-F of COP Volume III). Considering the duration and relative size of the impact area, the BOEM DEIS (2018) for Vineyard Wind 1 determined that impacts from entrainment of fishes and invertebrates during construction would be minor. A similar minor effect is anticipated for New England Wind.

9.3.4. Increased Sound Exposure

Construction of New England Wind would introduce underwater noise and may result in increased sound exposure of finfish and invertebrates. Underwater sounds would include repetitive, high-intensity (impulsive) sounds produced by pile driving, HRG surveys, and UXO detonation, and non-impulsive, lower-frequency sounds produced by vessel propulsion, drilling, and cable installation. Intensity of produced sound would vary with some sounds being louder than ambient noise. Ambient noise within Lease Area OCS-A 0501 was measured as, on average, between 76.4 and 78.3 dB re 1 μPa^2/Hz (Alpine Ocean Seismic Surveying, Inc. 2017). Kraus et al. (2016) suggest that ambient sounds levels at 70.8–224 Hz frequency were 96–115 dB re 1 µPa. These studies were performed prior to the segregation of Lease Area OCS-A 0501 into OCS-A 0501 and OCS-A 0534. Ambient noise can influence how fish detect other sounds as fish have localized noise filters that separate background noise and other sounds simultaneously (Popper and Fay 1993). All fishes have hearing structures that allow them to detect sound particle motion. Some fishes also have swim bladders near or connected to the ear that allow them to detect sound pressure, which increases hearing sensitivity and broadens hearing abilities (Popper et al. 2014, Hawkins and Popper 2017). The most relevant metric associated with sound perception for most fish species is particle motion; however, except for a few species, there is an almost complete lack of relevant data on particle motion sensitivity in fish (Popper and Fay 2011, Popper et al. 2014).

In general, increased sound sensitivity and the presence of a swim bladder makes a fish more susceptible to injury from anthropogenic sounds because loud, usually impulsive, noises can cause swim bladders to vibrate with enough force to inflict damage to tissues and organs around the bladder (Halvorsen et al. 2011, Casper et al. 2012). The least sound-sensitive fish species are those that do not have a swim bladder, including flatfishes such as winter flounder and elasmobranchs. Fishes with swim bladders not connected to or near inner-ear structures, such as Atlantic sturgeon, also primarily detect noise through particle motion and are therefore less sensitive to sound. The most sensitive species are those with swim bladders connected or close to the inner ear, such as Atlantic herring and Atlantic cod. These species can acquire both recoverable and mortal injuries at lower noise levels than other species (Thomsen et al. 2006, Popper et al. 2014).

Exposure to anthropogenic sound sources could have a direct consequence on the functionality and sensitivity of the sensory systems of marine invertebrates. Numerous studies have investigated the effect of sound on marine invertebrates but have been conducted in confined environments that make it difficult to control and assess the acoustic conditions. Moreover, by measuring and reporting only the pressure component of sound, the results are of reduced relevance for assessing any observed effects. Most crustacean species lack swim bladders and are considered less sensitive to sound, though understanding of the impact of sound on invertebrates is limited (Edmonds et al. 2016).

Effects elicited by other non-impulsive sound sources such as vibratory pile driving (if used) and dynamic positioning (DP) are not described in peer-reviewed publications or gray literature reports. It is reasonable to assume that the potential effects of sound from these activities are comparable to those documented for sound from vessel propulsion as described in the non-impulsive sound category below. The BOEM DEIS (2018) for Vineyard Wind 1 determined that impacts on fishes and invertebrates from vessel sounds during construction would be minor and short-term.

9.3.4.1. Potential Effects of Impact Pile Driving on Marine Mammal Prey

Sound generated from pile driving could impact fishes and invertebrates nearby because the high-intensity, impulsive sounds of pile driving can produce noise over 200 dB at the source and have been linked to mortality, ruptured gas bladders, damage to auditory processes, and altered behavior in some fish species (Popper and Hastings 2009, Casper et al. 2012, Riefolo et al. 2016).

Impact pile driving is carried out using an impact hammer, which consists of a falling ram that strikes the top of a pile repeatedly and drives it into the ground. When the ram strikes the pile, the impact creates stress waves traveling down the length of the pile, which couples with the surrounding medium, radiating acoustic energy into the water (see Appendix A). Pile driving also generates vibration waves in the sediment, which can radiate back into the water from the seabed. The sound from impact pile driving is transient, repetitive, and discontinuous (Reinhall and Dahl 2011, McPherson et al. 2017). Pile driving can be conducted both above the surface and subsea and has a typical strike interval of 1.5 to 2 seconds.

Field measurements of pile driving show that source, or near-source, levels are typically in the range of 210 to 250 dB re 1 µPa (McHugh 2005, Tougaard et al. 2009c, Bailey et al. 2010b) and frequency is predominantly <1 kHz (Robinson et al. 2007, Tougaard et al. 2009a), although they can extend to much higher frequencies (MacGillivray 2018), including at least 100 kHz (Tougaard et al. 2009a). Sound thresholds derived from Popper et al. (2014) indicated that pile driving sound above 207 dB peak can lead to mortality of the most sensitive fish species, such as Atlantic herring, while noise above 186 dB can lead to impairment. Longfin squid exhibited a startle response to recorded pile driving sound played at 190–194 dB but habituated quickly and startle responses typically diminished within the first eight strikes, although the response returned when the squid were tested again 24 hours later (Jones et al. 2020). The authors did not report any physical harm from the sound exposure but speculated that it could reduce the ability to detect and avoid predators. No behavioral disturbances were noted in brown trout (*Salmo trutta*) exposed to impact piling (source level 194 dB re 1 µPa) at close ranges (400m), with no difference in activity level or startle response during piling (Nedwell et al. 2003b).

The effects of impulsive sound on fish eggs and larvae have been studied in the context of offshore pile driving. Bolle et al. (2012) investigated the risk of mortality in common sole (*Solea solea*) larvae by exposing them to impulsive stimuli in an acoustically well-controlled study. Even at the highest exposure level tested, at an SEL of 206 dB re 1 µPa^2·s (corresponding to 100 strikes at a distance of 100 m), no statistically significant differences in mortality were found between exposure and control groups.

Popper et al. (2014) published exposure guidelines for fish eggs and larvae, which are based on pile driving data. The guidelines proposed a precautionary threshold for mortality of fish eggs and larvae of greater than 207 dB re 1 µPa PK, which they note is likely conservative.

There are no studies available on the potential effects of pile driving sounds on plankton and no established acoustic thresholds for plankton.

9.3.4.2. Potential Effects of Vibratory Pile Driving on Marine Mammal Prey

There are few studies on the effects of vibratory pile driving on potential marine mammal prey. However, as with impact pile driving, Nedwell et al. (2003a) detected no changes in activity level or startle response in brown trout exposed to vibro-piling at close ranges (<50 m).

9.3.4.3. Potential Effects of Drilling on Marine Mammal Prey

It is unclear whether or not the sound emitted by marine drilling activities impact fish. The available literature suggests that noise effects on fish produced by non-impulsive drilling operations may mask acoustic signals conveying important environmental information (McCauley 1994, Popper et al. 2014). Masking may arise when sounds exceed the hearing thresholds of fish and it is probable that, within close proximity to drilling operations, sounds would reach above the recommend thresholds. McCauley (1998) determined that any noise effects to fish from marine drilling activity would likely be temporary behavioral changes within a few hundred meters of the source. For instance, measured source levels during drilling operations reached 120 dB at 3–5 km, which may have caused fish avoidance (McCauley 1998). Recordings of planktivorous fish choruses were still active during drilling operations off the coast of the Timor Sea; however, it is likely that partial masking of their calls would have occurred (McCauley 1998).

There are no data on the effect of sound from drilling on marine invertebrates. However, evidence from research on the levels of particle motion associated with behavioral responses in blue mussels indicates that the threshold of sensitivity in this species falls within vibration levels measured near blasting, pile driving, and impact drilling (Roberts et al. 2015b). Only a small number of studies have indicated reception of vibration in bivalves and an associated behavioral response, which included closing syphons and, in more active mollusks, moving away from the substrate (Mosher 1972, Ellers 1995, Kastelein 2008).

9.3.4.4. Potential Effects of HRG Surveys on Marine Mammal Prey

Potential impacts of low frequency impulsive HRG sources on fish may include behavioral responses, masking of biologically important sounds, temporary hearing loss, and physiological effects (BOEM 2014b, Popper et al. 2014, Popper and Hawkins 2019). Although air guns are not a proposed action for New England Wind, they provide insight on potential effects from impulsive sound. Parry et al. (2003) studied the abundance of plankton after exposure to impulsive air gun sounds but found no evidence of mortality or changes in catch-rate on a population-level. However, McCauley et al. (2017) found that after exposure to impulsive air gun sounds generated with a single air gun (150 in^3), zooplankton abundance decreased and mortality in adult and larval zooplankton increased two- to three-fold when compared with controls. In this first large-scale field experiment on the impact of seismic activity on zooplankton, a sonar and net tows were used to measure the effects on plankton. They determined there was a horizontal maximum effect-range of 1.2 km. Their findings contradicted the conventional idea of limited and very localized impact of intense sound in general, and seismic air gun signals in particular, on zooplankton. The results indicated that there may be noise-induced effects on these taxa and that these effects may even be negatively affecting ocean ecosystem function and productivity. However, the study was compromised by methodological design issues (small sample sizes, large daily variability in the baseline and experimental data), the statistical robustness of the data, and conclusions (large number of speculative conclusions that appear inconsistent with the data collected over a two-day period). The lead author stressed that even though their conclusions were based on numerous assumptions, the combined likelihood of all measured parameters occurring without being correlated to the air gun survey is extremely low (McCauley, pers. comm.).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Richardson et al. 2017) simulated the large-scale impact of a seismic survey on zooplankton using the mortality rate found by McCauley et al. (2017). The aim of the CSIRO study was to estimate the spatial and temporal impact of seismic activity on zooplankton on the Northwest Shelf of Western Australian. The major findings of the CSIRO study were that seismic activity had substantial impacts on zooplankton populations on a local scale within or close to the survey area; however, on a regional scale, the impacts were minimal and not discernible over the entire Northwest Shelf Bioregion. The study found that the time for the zooplankton biomass to recover to pre-seismic levels inside the survey area, and within 15 km of the area, was only three days following the completion of the survey. This relatively quick recovery was due to the fast growth rates of zooplankton as well as the dispersal and mixing of zooplankton from both inside and outside of the impacted region (Richardson et al. 2017).

Fields et al. (2019) exposed zooplankton (the copepod Calanus finmarchicus) to seismic pulses at various distances up to 25 m from a seismic air gun source. The source levels produced were estimated to be 221 dB re 1 µPa2·s. The study observed an increase in immediate mortality rates of up to 30% of copepods in samples compared to controls at distances of 5 m or less from the air guns. Mortality one week after exposure was significantly higher by 9% relative to controls in the copepods placed 10 m from the air guns. Fields et al. (2019) also reported that no sublethal effects occurred at any distance greater than 5 m from the seismic source. The findings of the study indicated that the potential effects of seismic pulses to zooplankton are limited to within approximately 10 m from the seismic source. Fields et al. (2019) also note that the findings of the McCauley et al. (2017) study are difficult to reconcile with the body of other available research and may, therefore, provide an overly conservative estimate of the potential effects of seismic pulses to zooplankton.

There are indications that New Zealand scallop (*Pecten novaezelandiae*) larvae exposed to extended periods of air gun signals during their ontogeny may be negatively affected as reported by Aguilar de Soto et al. (2013). The authors found an increase in abnormality and mortality rates in scallop larvae after continued exposure to playbacks of intense air gun signals in a laboratory experiment. These results indicated that there may be species-specific differences in sensitivity of early life stages to sound exposure. In addition, research on the response of blue mussels to pile driving indicated that clearance or filtration rate increased with pile driving noise, likely in response to increased metabolic demands triggered by stress (Spiga et al. 2016).

Day et al. (2016) conducted a study on the effects of exposures of southern rock lobster (*Jasus edwardsii*) and scallop to impulsive sounds produced by an air gun. Their study used field and laboratory experimental approaches to investigate potential impacts of marine seismic surveys on these species. The study used a real air gun and had improved control over experimental parameters compared to other reported studies, as it is likely that particle motion and interface waves are the more relevant stimulus. Accordingly, their results are more relevant than those obtained under laboratory conditions with animals exposed to simulated signals. Day et al. (2016) provide a regression of particle acceleration versus range for the single 150 in3 air gun used in the study and showed that acceleration levels at the 10 and 100 m ranges were typically 26 and 5 ms-2, respectively. The study also references an unpublished maximum particle acceleration measurement of 6.2 ms-2 from a 3,130 in3 air gun array at 477 m range in 36 m of water. Consistent with other studies of high-intensity, low-frequency sound exposure of crustaceans and mollusks (Edmonds et al. 2016, Carroll et al. 2017), the study found no evidence of mass mortality directly following air gun exposure. Consequently, the authors rejected the hypothesis that exposure to seismic air guns causes immediate mass mortality. Unlike other studies, this study uncovered a few issues concerning long-term health and ecology. Two reflex behaviors, tail tonicity or extension and righting behavior, were assessed. These reflexes have been used in lobster fishery industries in grading animals for their likelihood of survival. While results for tail tonicity were inconclusive, there was a significant response to exposure in the righting response, which is a more complex reflex requiring neurological control and muscle coordination.

André et al. (2011) and Solé et al. (2013) provide evidence of acoustic trauma in four cephalopod species—common cuttlefish (*Sepia officinalis*), common octopus (*Octopus vulgaris*), European squid (*Loligo vulgaris*), and southern shortfin squid (*Illex condietii*)—which they exposed (underwater) for two hours to low-frequency sweeps between 50–400 Hz (1 second duration) generated by an in-air speaker. The received level at the animals' position was 157 dB re 1 µPa with peak levels (unspecified) up to 175 dB re 1 µPa. Both studies reported permanent and substantial morphological and structural alterations of the sensory hair cells of the statocysts following noise exposure, with no indication of recovery.

In a recent experiment, Solé et al. (2017a) exposed common cuttlefish to tonal sweeps between 100–400 Hz in a controlled exposure experiment in open water. Their results showed a clear statistical relationship between the cellular damage detected in the sensory cells of the individuals exposed to the sound sweeps and their distance from the sound source. The authors measured the particle motion and pressure of the signals received by the animals, but due to the signal type (frequency sweep), they only provided the maximum received levels or an estimate thereof, respectively. The maximal particle motion level was 0.7 ms^{-2} observed at 1 m depth, the pressure reached levels of 139–142 dB re 1 μPa^2. The reported sound pressure levels were only slightly higher than the hearing threshold determined for longfin squid measured by Mooney et al. (2010). The maximum particle motion (reported in terms of particle acceleration) reported by Solé et al. (2017a) is in the same order of magnitude as the behavioral thresholds measured at 100 Hz by Packard et al. (1990) using a standing wave acoustic tube.

The Proponent conducted acoustic modeling (see Volume III of the COP Appendix III-M for details) to estimate the noise propagation of pile driving assuming broadband noise attenuation levels of 10 and 12 dB in relation to thresholds of mortality and recoverable injury for fishes with different hearing structures, based on thresholds in Popper et al. (2014). Although noise attenuation mitigation technology is expected to be implemented to reduce sound levels by a target of approximately 12 dB or greater, impacts to marine species were conservatively assessed based on 10 dB of noise attenuation.

Sound with peak sound pressure (dB re 1 µPa) up to 213 dB and frequency-weighted sound exposure level (dB re 1 $\mu Pa^2 \cdot s$) up to 219 dB was predicted to occur. Applying the thresholds for potential injury for fish with no swim bladder with 10 dB attenuation levels, the radial distance to PK sound levels associated with jacket foundation piles, 12 m monopile foundation piles, and 13 m monopile foundation piles are 108, 157, and 127 m, respectively. These estimates do not account for any aversion that might occur as a result of the use of sound attenuation technologies (e.g. bubble curtains). Popper et al. (2014) does not define quantitative acoustic thresholds for behavioral response in fish. GARFO (2016) uses a 150 dB SPL threshold for all fish. When this criterion is used, distances to potential behavioral disturbance for fish are over 8 km and 14 km from jacket foundation piles and monopiles, respectively.

In summary, with 10 dB attenuation, injury to fish from pile driving could extend out to a few kilometers with behavioral impacts up to 14 km. However, impairment from pile driving noise is less likely to occur during construction because a soft-start technique will be employed, and mobile fishes and invertebrates will be able to leave the area before full strength pile driving occurs.

9.3.4.5. Potential Effects of UXO Detonation on Marine Mammal Prey

Physical effects from pressure waves generated by underwater sounds (e.g., underwater explosions) could potentially affect fish within proximity of a UXO detonation. Fish near an explosion could be injured or killed, as the shock wave from an underwater explosion is lethal to fish at close range (Keevin and Hempen 1997). At greater distance from the detonation, the extent of mortality or injury depends on a number of factors including fish size, body shape, orientation, and species (Wright and Cybulski 1983, Keevin and Hempen 1997). At the same distance from the source, larger fish are generally less susceptible to death or injury, elongated forms that are round in cross-section are less at risk than deep-bodied forms, and fish oriented sideways to the blast suffer the greatest impact (Yelverton and Richmond 1981, O'Keeffe and Young 1984). Species with gas-filled organs have higher mortality than those without them (Goertner 1982, Continental Shelf Associates 2004). Fish near the source that survive the explosion may experience hearing loss, and fish at greater distances may exhibit a behavioral reaction or show no response. Occasional behavioral reactions to intermittent explosions are unlikely to cause long-term consequences for individual fish or populations. Animals that experience hearing loss as a result of exposure to explosions may have a reduced ability to detect relevant sounds such as predators, prey, or social vocalizations. It is uncertain whether some hearing loss over a part of a fish's hearing range would have long-term consequences for that individual.

9.3.4.6. Potential Effects of Vessels on Marine Mammal Prey

Non-impulsive sound associated with construction of New England Wind is primarily vessel related and includes sounds that arise from vessel propulsion and the use of DP thrusters. Sound emission from vessels in general, but especially under DP, depends on vessel operational state and is strongly weather-dependent. Zykov et al. (2013) and McPherson et al. (2019) report a maximum broadband source level of 192 dB re 1 μPa for numerous vessels with varying propulsion power under DP. The characteristics of these sounds are described in more detail in Appendix A.

Vessel noise can present a chronic impact for fish species (Popper 2003), whose communication is mainly based on low-frequency sound signals (Ladich and Myrberg 2006, Myrberg and Lugli 2006). Continuous noise greater than or equal to 158 dB root-mean-square (rms) for 12 hours can lead to behavioral disturbance, while noise above 170 dB rms for 48 hours can lead to injury (Popper et al. 2014, Hawkins and Popper 2017). Vessel noise can also cause avoidance behavior that interferes with feeding and breeding, alter schooling behaviors and migration patterns, and mask important environmental auditory cues (CBD 2012, Barber 2017). Recent studies have shown that vessel noise can induce endocrine stress response (Wysocki et al. 2006); diminish hearing ability; and mask intra-specific relevant signals in exposed fish species (Scholik and Yan 2002, Amoser et al. 2004, Vasconcelos et al. 2007, Codarin et al. 2009). Masking communication is of concern because although fishes are generally not loud (120 dB re 1 μPa at 1 m, with the loudest on the order of 160 dB re 1 μPa), species make unique noises that allow for individual identification (Normandeau Associates 2012). In addition, vessel noise has the capacity to provoke short-term changes in the spatial position and group structure of pelagic fish in the water column (Buerkle 1973, Olsen et al. 1983, Schwarz and Greer 1984, Soria et al. 1996, Vabø et al. 2002, Handegard et al. 2003, Mitson and Knudsen 2003, Ona et al. 2007, Sarà et al. 2007).

Fish can respond to approaching vessels by diving towards the seafloor or by moving horizontally out of a vessel's path, with reactions often initiated well before a vessel reaches the fish (Ona et al. 2007, Berthe and Lecchini 2016). The avoidance of vessels by fish has been linked to the high levels of infrasonic and low-frequency sound (greater than 10 to 1000 Hz) emitted by the ships. Accordingly, it was suggested that silent ships have a higher chance of encountering more fish than noisier ones (De Robertis et al.

2010). This assumption was initially contradicted when two research vessels were compared to determine their effect on schooling herring (Ona et al. 2007). The authors found that the reaction initiated by the silent vessel was stronger and more prolonged than the one initiated by the conventional vessel. In a comment to this publication, Sand et al. (2008) pointed out that fish are highly sensitive to particle acceleration and that the cue, in this case, may have been low-frequency particle acceleration caused by displacement of water by the moving hull in the near field of the vessel. This fact would explain the stronger response to the larger, noise-reduced vessel in the study by Ona et al. (2007), which would have displaced more water as it approached.

Nedelec et al. (2016) investigated the response of reef-associated fish by exposing them in their natural environment to playback of motorboat sounds. They found that juvenile fish increased hiding and ventilation rate after a short-term boat sound playback, but responses diminished after long-term playback, indicating habituation to sound exposure over longer durations. These results were corroborated by Holmes et al. (2017) who also observed short-term behavioral changes in juvenile reef fish after exposure to boat noise as well as desensitization over longer exposure periods.

Previous impact assessment studies for various cable projects have concluded that sound related to subsea cable installation or cable operation is not a significant issue. This was based on the prediction that anticipated sound levels would not exceed existing ambient sound levels in the area, although background sound level measurements were often not presented (Meißner et al. 2006). A detailed modeling and measurement study of construction activities associated with cable installations concluded that underwater sound generated by the cable laying vessels was similar to that of other vessels already operating in the area and no significant acoustic impacts were identified (Austin et al. 2005). Nedwell et al. (2003a) calculated a maximum source level of 178 dB created by trenching, operation of vessels and machinery (based on measurements of large vessels operating in deep water) during construction of an offshore wind farm in UK waters. In the same study, a recorded SPL of 123 dB was measured for cable trenching activities in very shallow water at a range of 160 m from the source. The sound was described as highly variable and dependent on the physical properties of the seabed that was being cut at the time.

There is a moderate risk within tens to hundreds of meters of the source that sounds emitted by trenching, vessel operations, and cables may elicit behavioral reaction in fish without a swim bladder and those with a swim bladder not involved in hearing; at larger distances the risk is low. The risk that fish with a swim bladder involved in hearing display behavioral reactions near the sources is high, at intermediate distances, and, at greater distances, the risk is low.

Although the study of effects of sound on invertebrates (e.g., crustaceans, cephalopods, and bivalves) is in its nascency, it is evident that invertebrates are sensitive to particle motion (as opposed to pressure) (Popper and Hawkins 2018) and that they can detect vibrations in the sea bed (Roberts et al. 2015b, Roberts and Breithaupt 2016, Roberts and Elliott 2017). While there are currently no agreed upon metrics or clearly defined levels (in terms of sound pressure or particle motion) for assessing the effects or impacts of sound on invertebrates (Hawkins and Popper 2017), recent experiments have measured sound pressure levels and particle motion associated with trauma in cuttlefish (*Sepia officinalis*) (Solé et al. 2017b) and longfin squid (*Doryteuthis pealeii*) (Mooney et al. 2016). Some studies have found potential behavioral effects (e.g., flight or retraction) or physiological (e.g., stress) responses in invertebrates. For example, shore crabs (*Carcinus maenas*) in the presence of vessel noise ceased feeding and were slower to retreat to shelter (Wale et al. 2013b). The common prawn (*Palaemon serratus*) had fewer intra-specific interactions and spent more time outside of their shelters where the sound pressure levels were lower (Filiciotto et al. 2016). Lobsters (*Nephrops norvegicus*) reduced locomotor activity and clams (*Ruditapes philippinarum*) exhibited behaviors that ultimately prevented feeding (Solan et al. 2016).

Shore crabs exposed to playbacks of vessel noise demonstrated an increase in oxygen consumption that was presumed to indicate a higher metabolic rate and/or stress (Wale et al. 2013a). A similar response was observed in the blue mussel (*Mytilus edulis*), which not only increased oxygen consumption but also had more fragmentation of cellular DNA (Wale et al. 2016). In Pacific oysters (*Magallana gigas*), chronic exposure to vessel noise was shown to depress activity and food uptake, ultimately limiting growth (Charifi et al. 2018). Evidence from a field experiment with sea hares (*Stylocheilus striatus*) demonstrated a significant increase in the likelihood of developmental failure at the embryonic stage and mortality at the free-swimming stage, when exposed to play-backs of vessel noise (Nedelec et al. 2014).

As stated in the BOEM Environmental Assessment and the Alternative Energy Programmatic Environmental Impact Statement that were prepared for the assessment and designation of wind energy areas by BOEM, regular vessel traffic occurs throughout this area; thus, implying that biological resources in the area are presumably habituated to this noise (BOEM 2007, 2014a). In addition, the BOEM DEIS (2018) for Vineyard Wind 1 determined that short- and long-term impacts from construction noise will have minor impacts on finfish and invertebrate species.

9.3.5. Avoidance, Minimization, and Mitigation Measures

The SWDA is located in the MA WEA, which was identified as suitable for wind energy development after a multi-year, multi-agency public process, partially because of its relatively low number of important fish and invertebrate habitat, therefore reducing potential for impacts. As described in Section 2.1 of COP Volume I, the OECC was also sited taking environmental factors into consideration.

To mitigate the potential impacts of injury to fish from pile driving, New England Wind will apply a soft-start procedure to the pile driving process, which delivers initial pile drives at a lower intensity, allowing fish to move out of the activity area before the full-power pile driving begins. In addition, the Proponent expects to implement noise attenuation mitigation to reduce sound levels by a target of approximately 12 dB or greater and adhere to an anticipated time of year restriction on pile driving between January 1 and April 30 to protect North Atlantic right whales (see Section 6.7.4 of COP Volume III), which may also confer protection to fish that occur within the SWDA during that timeframe. Considering the implementation of mitigation measures for pile driving, the anticipated impact on fish in or near the SWDA is temporary avoidance reactions. Although vessel presence in the SWDA will be intensified, avoidance behaviors are expected to be similar to those already displayed by fish when near fishing or recreational vessels. The WTGs, and ESPs, will also be widely spaced, leaving a large portion of the SWDA undisturbed by WTG, and ESP, installation.

Immobile life stages of fishes and invertebrates in or on benthic sediment (i.e., demersal eggs) and sessile benthic organisms in the direct path of construction may experience direct mortality from physical stresses, sediment suspension, and deposition. Offshore export cable installation will avoid important habitats such as eelgrass beds and hard bottom sediments where feasible. Impacts may be minimized using mid-line buoys that are designed to minimize seabed impacts from cable sweep, if feasible and safe, and installation equipment that further minimizes installation impacts on the seabed. In nearshore areas where sensitive resources are located near the potential landfall sites, horizontal directional drilling may be used to minimize disturbance of coastal habitats by drilling underneath them instead of through them.

The Proponent is committed to fisheries science and research as it relates to offshore wind energy development. Working with the School for Marine Science and Technology (SMAST), the Proponent is already collecting pre-construction fisheries data (via trawl and drop camera surveys) within the SWDA. The results of ongoing fisheries studies are published on the Proponent’s website at the following link: www.parkcitywind.com/fisheries-science. The Proponent plans to develop a framework for during and post-construction fisheries studies within the SWDA. In recognition of the regional nature of fisheries science, the Proponent expects that such studies during and post-construction will involve coordination with other offshore wind energy developers in the MA WEA and RI/MA WEA. The Proponent also expects the development of the fisheries studies will be undertaken in coordination with BOEM, agencies, fisheries stakeholders, academic institutions, and other stakeholders. The Proponent is already engaging in collaboration with other developers, fishing industry representatives, and state and federal agencies through its participation in the Responsible Offshore Science Alliance and a Regional Wildlife Science Collaborative.

10. Anticipated Effects of Habitat Impacts on Marine Mammals

10.1. Short-Term Habitat Alterations

Benthic habitat disturbance will have a relatively small footprint and the habitat is anticipated to recover fully over a short time period. Displacement of mobile marine mammal prey resulting from this disturbance is also anticipated to be limited temporally because they are likely to be attracted to the resulting structure (see Section 10.2). Thus, benthic disturbance is unlikely to result in any adverse impact to marine mammals.

The temporarily altered soundscape resulting from pile driving is likely to have the greatest impact on the marine mammal community. Habitat displacement or avoidance of construction activities by marine mammals is expected during foundation installation based on modeled sound levels and studies of other wind energy projects showing significant avoidance behavior and displacement during pile driving (Richardson et al. 1995, Carstensen et al. 2006, Tougaard et al. 2009b, Brasseur et al. 2010, Brandt et al. 2011, Dähne et al. 2013, Bailey et al. 2014, Bergström et al. 2014). Research suggests that this displacement is limited temporally to the construction phase, and 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 (Bergström et al. 2014).

10.2. Longer-Term Habitat Alterations

As discussed in Section 9, alteration of existing benthic habitat will occur as a result of the creation of hard substrate around WTG and ESP foundations and from the footprint of the installations. Additionally, water column habitat will be altered by the introduction of structures. While various studies of the impact of wind farms in Europe have produced inconsistent results, marine mammals are likely to use the area after the WTGs are installed, as demonstrated by the continued use of areas where other structures have been built in marine environments. For example, Delefosse et al. (2018) evaluated sightings of marine mammals around 25 fixed oil and gas installations in the North Sea. Observations of harbor porpoises, minke whales, killer whales (*Orcinus orca*), white-beaked dolphins (*Lagenorhynchus albirostris*), pilot whales, harbor seals, and gray seals reflected the general expectation for marine mammal abundance and diversity in the area. A study of a wind farm in the Baltic Sea documented 89% fewer harbor porpoises inside the wind farm during construction and 71% fewer 10 years later compared to baseline levels (Teilmann and Carstensen 2012). However, a similar study found a significant increase of 160% in the presence of harbor porpoise within an operating wind farm in the Dutch North Sea (Scheidat et al. 2011). For the SWDA, WTGs/ESPs will be oriented in an east-west, north-south grid pattern with 1 NM (1.85 km) spacing between WTG/ESP positions. Such large distances between WTGs/ESPs will minimize the extent of habitat modification that could potentially impact marine mammals. Barriers to activities, including migration, are not anticipated from modification of the water column habitat. Thus, these longer-term habitat alterations are unlikely to have a negative impact on marine mammals.

There are data to suggest that marine mammals could be attracted to New England Wind infrastructure. Studies of harbor porpoise echolocation clicks around oil and gas installations in the North Sea suggest they were feeding around these structures (Todd et al. 2009, Clausen et al. 2021). Todd et al. (2020) compiled and analyzed video from offshore operators that showed sperm whales, bottlenose dolphins, and gray and harbor seals in the vicinity of offshore structures. 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). In addition to greater food availability near offshore structures, where certain vessels and/or vessel-based activities are excluded from portions of the area for periods of time, New England Wind may provide shelter for marine mammals (e.g., Scheidat et al. 2011).

10.3. Potential Impacts to Marine Mammal Prey

Overall, impacts to finfish and invertebrate species are expected to be short-term and localized during the construction and installation of New England Wind stemming from impacts from direct construction mortality, noise, sediment suspension and deposition, and water withdrawals. The high species richness in the SWDA may enhance recovery following any construction and installation related disturbances (MacArthur 1955). The MA WEA was selected by BOEM to exclude most sensitive fishes and invertebrate habitat and the Offshore Development Area is primarily composed of uniform sandy bottom habitat, which will likely begin recovering quickly after construction is completed relative to other habitat types. Previous research indicated that dynamic, sandy physical habitat begins to recover substantially within a few months of disturbance and can fully recover by measure of abundance within two years and recover by measure of biomass and diversity in two to four years (van Dalfsen and Essink 2001, Dernie et al. 2003). Some alteration from unconsolidated fine habitat to structured habitat in the SWDA may change species assemblages in the SWDA and attract more structure-oriented species.

Mobile species will be able to avoid construction areas and are not expected to be substantially impacted by construction and installation. Impacts to mobile pelagic fishes and invertebrate species include localized and short-term avoidance behavior. These impacts can be minimized or offset through mitigation consisting of a “soft-start” pile driving regime, sound reduction technologies, and efficient construction practices.

Direct mortality may occur to immobile benthic organisms that are in the direct path of construction processes. Mortality of drifting pelagic egg and larval life stages in the Offshore Development Area may occur from water withdrawals by construction vessels. Although eggs and larvae may be entrained and will not survive, loss of many equivalent adults and population-scale impacts are not expected because most of these species produce millions of eggs each year and already have low adult survival rates. In addition, mortality of pelagic eggs due to increased suspended sediments is expected to be limited because sediment plumes are predicted to have low-concentrations and resettlement will occur quickly (less than six hours in the water column).

Burial and mortality of some demersal eggs and sessile organisms are also expected during cable installation in the Offshore Development Area, at locations where sediment deposition is greater than 1 mm (for the most sensitive demersal eggs) or 20 mm (for shellfish). However, lethal deposition levels are only expected in small, localized areas adjacent to the cable routes and sediment discharge areas. Burrowing mollusks in the area, such as quahogs, will likely be able to avoid most lethal burial depths and are only expected to be slightly impacted and exhibit short-term avoidance/feeding behavior. Overall, demersal sessile (i.e., less mobile) benthic organisms will incur the brunt of construction impacts, but since the impacted area is only a small portion of the available habitat in the region, significant population-scale impacts are highly unlikely.

Creation of hard bottom habitat and the introduction of structures into the water column may benefit marine mammals by increasing prey availability. Offshore wind energy structures may benefit fish by acting as artificial reefs, increasing fish aggregation and productivity, and improving prey species abundance and diversity during long-term operation (Petersen and Malm 2006, Wilhelmsson et al. 2006, Inger et al. 2009, Lindeboom et al. 2011, Scheidat et al. 2011, Bailey et al. 2014, Degraer et al. 2019). This artificial reef phenomenon is fairly well documented around oil and gas platforms off California and in the Gulf of Mexico, which are considered to have rich fish assemblages (e.g., Claisse et al. 2014, Ajemian et al. 2015, Love et al. 2015), and in the North Sea, where feeding habits of major fish species were closely associated with an offshore oil platform (Fujii 2016). Benthic monitoring following the construction of the Block Island Wind farm off Rhode Island documented an abundant and diverse epifaunal community surrounding the foundation 3 years after construction as well as the presence of squid and several fish species (HDR 2020a).

11. Mitigation Measures to Protect Marine Mammals and Their Habitat

Working collaboratively with BOEM and NOAA Fisheries, the Proponent will develop mitigation measures that are expected to effectively avoid and minimize the risk of impacts to marine mammals from underwater sound and vessel collision during construction and installation. The Proponent is using acoustic modeling (see Appendix III-M) as a tool to inform approaches to mitigation. Modeling, as part of permitting and regulatory processes, will be used to evaluate potential risks and specific mitigation and best management practice (BMP) options.

Mitigation and BMPs must consider both practicability for a large-scale development and effectiveness at avoiding and minimizing impacts to marine mammals. Practicability includes safety, logistical ability, project integrity, environmental impacts, and the potential to extend the New England Wind construction duration, which may have secondary impacts on marine mammal and other resources. Options will be modeled and weighed against biological value and effectiveness relative to practicability. NOAA and BOEM will be engaged in this iterative and adaptive process that may also incorporate lessons learned from Vineyard Wind 1 and other offshore wind farm development in the MA WEA and RI/MA WEA.

The core menu of potential monitoring and mitigation measures for marine mammals is described below and summarized in Table 70. Examples of planned monitoring and mitigation measures include the establishment of clearance and exclusion zones, pile driving soft-start procedures, vessel strike avoidance measures, noise abatement technology, and the use of Protected Species Observers (PSOs) and passive acoustic monitoring (PAM), among others. Given the duration of the permitting process and timeline for offshore construction (particularly for Phase 2), monitoring and mitigation measures must retain some flexibility so that lessons learned from other offshore wind projects and new technologies and techniques may be incorporated in the future. As noted above, the Proponent expects to further refine these core mitigation and monitoring measures in coordination with agencies and stakeholders.

The core mitigation measures are described in (but not limited to) the following subsections.

11.1. Seasonal Restrictions on Pile Driving Activities

Historical and anticipated NARW presence will be used to inform a time of year restriction on pile driving that will minimize the amount of pile driving that occurs when the migratory NARW is likely to be in the Offshore Development Area and will thus limit sound exposure for this Endangered species. The Proponent expects to establish a restriction on pile driving activities (i.e., impact pile driving, vibratory driving, and drilling) between January 1 and April 30. The seasonal restriction would also have a protective effect for other marine mammal species. There is no seasonal restriction applied to HRG surveys and potential detonation of UXO.

11.2. Noise Abatement Systems

NAS, 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. These systems may be deployed in series, such as a double bubble curtain with two rings of bubbles encircling a pile. Attenuation levels also vary by type of system, frequency band, and location. Small bubble curtains have been measured to reduce sound levels from approximately 10 dB to more than 20 dB but are highly dependent on depth of water and current, and configuration and operation of the curtain (Koschinski and Lüdemann 2013, Bellmann 2014, Austin et al. 2016). Larger bubble curtains tend to perform a bit better and more reliably, particularly when deployed with two rings (Koschinski and Lüdemann 2013, Bellmann 2014, Nehls et al. 2016).

Hydro Sound Dampers (HSDs), such as encapsulated bubble nets, 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 and 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) concluded that attenuation greater than 10 dB is not reliably predicted because sound transmitted through the seabed and re-radiated into the water column becomes the dominant source of sound in the water (Buehler et al. 2015). The measured results and manufacturers' claims seem correct in the context of attenuation measured levels near the bubble curtain where they may indeed reduce the sound levels by greater than 20 dB if there is little re-radiated sound from the seabed. It is useful to keep in mind that a reduction of 10 dB means reducing the sound energy level by 90%, and to achieve 20 dB attenuation means removing 99% of the sound energy. If 10% of the total sound energy is reintroduced via the seabed then it will limit the overall performance of the attenuation system to 10 dB.

Several hypothetical broadband attenuation levels (0, 10, and 12 dB) were included in the modeling of impact pile driving for comparison purposes (see Appendix A). When calculating takes from impact pile driving, impacts to marine mammals were conservatively assessed based on 10 dB of noise attenuation. However, the Proponent expects to implement noise attenuation technology to reduce sound levels by a target of 12 dB or greater, so exposure and range estimates for this activity show both values for comparison. Pile driving sound attenuation technology under consideration for New England Wind includes piling equipment that is optimized for sound reduction (e.g., Integrated Pile Installer), underwater noise abatement systems (e.g., AdBm encapsulated bubble sleeve), and/or bubble curtains. New England Wind will use two noise attenuation systems during pile driving (e.g., two bubble curtains, one bubble curtain and one AdBm encapsulated bubble sleeve, etc.) for monopile installation and up to two noise attenuation systems for jacket installation.

New England Wind will also use NAS for all UXO detonation events and is committed to achieving a minimum of 10 dB of attenuation.

Although the take request only reflects estimates assuming NAS during impact pile driving and potential detonation of UXO, the Proponent also intends to use NAS during all vibratory driving and drilling activity.

11.3. Establishment of Protective Zones during Pile Driving

Clearance and shutdown zones will be established to minimize and avoid potential impacts of underwater sound on marine mammals during pile driving activities. These zones are identified either by an impact range or an area within which monitoring or mitigation occurs. The size of the zones will be activity- and species-specific for marine mammals. These zones are described below.

- Clearance zones are typically zones in which visual or acoustic observations of marine mammals are made for a specified period of time prior to starting an activity that produces sound levels that could result in Level A or Level B exposures. The duration and distance of the clearance zone may vary by activity and species. If a marine mammal is observed entering or within the relevant species-specific clearance zone prior to initiating the sound producing activity, then activity will be delayed and the observed animal will be allowed to leave the clearance zone of their own volition.
- A shutdown zone is an area surrounding a noise source in which the noise producing activity must be powered down, when technically feasible, if the relevant species is observed entering or within the area. If it is determined that a shutdown is not technically feasible during piling driving due to human safety concerns or to maintain installation feasibility, reduced hammer energy will be used if the lead engineer determines it is technically feasible. Pile driving will only be reinitiated after a shutdown once the clearance zones are confirmed to be clear of marine mammals for the minimum species-specific time periods. The size of the shutdown zones are activity- and species-specific. Observations of marine mammal presence beyond the limits of the shutdown zones will not trigger shutdown or other actions but can provide advance warning of this mitigation. This can also inform understanding of any adaptive management for potential behavioral disturbance.

11.3.1. Impact Pile Driving

Clearance and shutdown zones used for mitigation purposes have traditionally been estimated by determining the distance to injury and behavioral thresholds based only on acoustic information, which assumes that all animals in the area remain stationary for the duration of the sound event and may not produce realistic estimates for these zones. To inform the establishment of protective zones for marine mammals due to impact pile driving, the JASCO acoustic modeling study used animal movement modeling to estimate exposure-based ranges to the various Level A and Level B acoustic harassment threshold criteria (see Tables 21–27) for several different pile driving configurations and with different levels of sound attenuation. Summary results from this modeling are shown in Section 6.2.4 and additional details can be found in Appendix A. The simulation result is the $ER_{95\%}$ (95% exposure range), which is the horizontal distance that includes 95% of the closest points of approach of animats that receive sound levels that exceed a given impact threshold. If used as a shutdown zone, keeping animals farther away from the source than the $ER_{95\%}$ will reduce exposure estimates by 95%.

For mitigation purposes, a scaling exercise of the monopile exposure ranges was conducted to protect marine mammals in the event that the 13 m monopile with a 6,000 kJ hammer is used. The exercise was completed by scaling up the largest 10 dB attenuated, modeled SEL exposure ranges (between 1 pile per day or 2 piles per day results) for the 13 m monopile with a 5,000 kJ hammer scenario by the percentage increase between the largest 10 dB attenuated, modeled SEL exposure ranges of the 12 m monopile with a 5,000 kJ hammer scenario versus a 6,000 kJ hammer scenario for each hearing group:

$$Percentage\ increase = (a - b)/a$$
$$Alternative\ mitigation\ zone = (c \times Pecentage\ increase) + c$$

where a is the 12 m monopile with a 5,000 kJ hammer exposure range, b is the 12 m monopile with a 6,000 kJ hammer exposure range, and c is the 13 m monopile with a 5,000 kJ hammer exposure range. As a conservative measure, these resultant, alternative zones are then rounded up for PSO clarity (see Table 64).

Table 64. Scaled exposure ranges.

Hearing group	Species	Largest 12 m monopile with 5,000 kJ SEL exposure range	Largest 12 m monopile with 5,000 kJ SEL exposure range	Largest 13 m monopile with 5,000 kJ SEL exposure range	Scaled Ranges	Rounded for PSO Clarity
LF	Fin whale[a]	2,790	3,900	3,140	4,915	4,920
	Minke whale	1,670	2,590	1,650		
	Humpback whale	3,440	4,620	3,660		
	North Atlantic right whale[a]	2,340	3,160	2,530		
	Sei whale[a]	2,040	3,080	2,310		
MF	Atlantic white sided dolphin	0	0	0	NA[b]	NA[b]
	Atlantic spotted dolphin	0	0	0		
	Short-beaked common dolphin	0	0	0		
	Bottlenose dolphin, offshore	0	0	0		
	Risso's dolphin	<10	20	<10		
	Long-finned pilot whale	0	0	0		
	Short-finned pilot whale	<10	<10	0		
	Sperm whale[a,c]	0	0	0		
HF	Harbor porpoise	1,600	2,300	1,510	NA[b]	NA[b]
PW	Gray seal	560	1,010	590	1,064	1,070
	Harbor seal	210	630	190		
	Harp seal	310	410	320		

[a] Listed as Endangered under the ESA.
[b] Mid-frequency cetaceans' and harbor porpoise' exposure ranges were not able to be scaled because their 12 m monopile with a 5,000 kJ hammer SEL exposure ranges are greater than their 12 m monopile with a 6,000 kJ hammer SEL exposure ranges; therefore, the scaling exercise does not provide a percentage increase.
[c] Highlighted blue cells represent the largest exposure range for each hearing group and for each scenario, for which the scaling exercise is applied.
[d] These exposure ranges can be found in Section 6.2.4.

The Level A and Level B exposure ranges along with the mitigation zones are provided in Tables 65–67. These exposure ranges and mitigation zones are based on the modeled monopile and jacket piling scenario and with noise attenuation technology that assumes 10 dB broadband noise attenuation. For monopile foundations, the clearance and shutdown zones shown in Table 65 are based on the largest range to the Level A SEL threshold for the different hearing groups. The alternative clearance and shutdown zones are based on the estimated exposure range resultant from the scaling exercise described above. These alternative zones would only be monitored in the unlikely event that a 13 m monopile is installed with a 6,000 kJ hammer energy. Mitigation zones implemented during construction activity may be modified, with NMFS approval, based on received sound level measurements during piling operations. The sound field verification details are described in Section 13.1.

Table 65. Monopile Foundation: Proposed species-specific shutdown and clearance zones (m) based on their exposure ranges estimated from impact pile driving with 10 dB broadband sound attenuation.

Hearing group	Species	Level A (m)		Level B (m)	Clearance zone[b]	Shutdown zone[c]	Vessel separation distance (m)	Alternative clearance and shutdown zone for 13 m MP at 6,000 kJ[d,e]
		L_E	L_{pk}	L_p				
LF	Fin whale[a]	3,900	10	6,190	4,620	4,620	100	5,500
	Minke whale	2,590	20	5,660	4,620	4,620	100	5,500
	Humpback whale	4,620	10	5,950	4,620	4,620	100	5,500
	North Atlantic right whale[a]	3,160	<10	5,600	**See Table 67**	**See Table 67**	500	**See Table 67**
	Sei whale[a]	3,080	20	5,790	4,620	4,620	100	5,500
MF	Atlantic white sided dolphin	0	20	5,400	50	50	50	50
	Atlantic spotted dolphin	0	0	5,870	50	50	50	50
	Short-beaked common dolphin	0	20	5,680	50	50	50	50
	Bottlenose dolphin, offshore	0	10	4,930	50	50	50	50
	Risso's dolphin	20	20	5,890	50	50	50	50
	Long-finned pilot whale	0	20	5,550	50	50	50	50
	Short-finned pilot whale	<10	20	5,620	50	50	50	50
	Sperm whale[a]	0	20	5,840	4,620	4,620	100	5,500
HF	Harbor porpoise	2,300	210	5,760	2,300	2,300	50	2,300
PW	Gray seal	1,010	10	6,060	1,010	1,010	50	1,070
	Harbor seal	630	20	6,030	1,010	1,010	50	1,070
	Harp seal	410	0	5,970	1,010	1,010	50	1,070

[a] Listed as Endangered under the ESA.

[b] The clearance zone for large whales (excluding North Atlantic right whale), porpoise, and seals is based upon their respective maximum Level A exposure range. Mid-frequency cetacean clearance zones were set at a conservatively large distance compared to their maximum Level A exposure range. NARW clearance zones are represented in Table 67.

[c] The shutdown zone for large whales (excluding North Atlantic right whale), porpoise, and seals is based upon their respective maximum Level A zone. Mid-frequency cetacean shutdown zones were set at a conservatively large distance compared to their maximum Level A exposure range. NARW shutdown zones are represented in Table 67.

[d] In the unlikely event that a 13 m monopile would need to be installed at 6,000 kJ, the alternative clearance and shutdown zones would be applied. This zone is set equal to the maximum, scaled up Level A zone for large whales.

[e] Although the scaled alternative zone for large whales was calculated and rounded to 4,920 m, 5,500 m is considered as their alternative clearance and shutdown zone for conservancy to further prevent any Level A harassment of ESA listed species.

[f] Mid-frequency cetaceans (except sperm whale) and harbor porpoise do not receive a scaled up, alternative zone because their 12 m monopile with a 5,000 kJ hammer SEL exposure ranges are greater than their 12 m monopile with a 6,000 kJ hammer SEL exposure ranges; therefore, the scaling exercise does not provide a percentage increase.

Table 66. Jacket Foundation: Proposed species-specific shutdown and clearance zones (m) based on their exposure ranges estimated from impact pile driving four, 4 m pin piles per day using a 3,500 kJ hammer with 10 dB broadband sound attenuation.

Hearing Group	Species	Level A (m)		Level B (m)	Clearance Zone[b]	Shutdown Zone[c]	Vessel Separation Distance (m)
		L_E	L_{pk}	L_p			
LF	Fin whale[a]	4,070	<10	3,560	4,490	4,490	100
	Minke whale	1,830	0	3,340	4,490	4,490	100
	Humpback whale	4,490	0	3,560	4,490	4,490	100
	North Atlantic right whale[a]	2,540	0	3,340	**See Table 67**	**See Table 67**	500
	Sei whale[a]	2,840	0	3,390	4,490	4,490	100
MF	Atlantic white sided dolphin	10	0	3,270	50	50	50
	Atlantic spotted dolphin	0	0	3,260	50	50	50
	Short-beaked common dolphin	<10	0	3,340	50	50	50
	Bottlenose dolphin, offshore	10	0	2,870	50	50	50
	Risso's dolphin	10	0	3,380	50	50	50
	Long-finned pilot whale	<10	0	3,300	50	50	50
	Short-finned pilot whale	0	0	3,370	50	50	50
	Sperm whale[a]	<10	0	3,360	4,490	4,490	100
HF	Harbor porpoise	1,770	100	3,380	1,770	1,770	50
PW	Gray seal	1,310	0	3,490	1,310	1,310	50
	Harbor seal	320	0	3,440	1,310	1,310	50
	Harp seal	280	0	3,490	1,310	1,310	50

[a] Listed as Endangered under the ESA.
[b] The clearance zone for large whales (excluding North Atlantic right whale), porpoise, and seals is based upon their respective maximum Level A exposure range. Mid-frequency cetacean clearance zones were set at a conservatively large distance compared to their maximum Level A exposure range. NARW clearance zones are represented in Table 67.
[c] The shutdown zone for large whales (excluding North Atlantic right whale), porpoise, and seals is based upon their respective maximum Level A zone. Mid-frequency cetacean shutdown zones were set at a conservatively large distance compared to their maximum Level A exposure range. NARW shutdown zones are represented in Table 67.

Table 67. North Atlantic right whale mitigation zones.

Installation	Level A (m)		Level B (m)	Visual clearance zone (m)	Visual shutdown zone (m)	PAM clearance zone (m)[a]	PAM shutdown zone (m)[b]	Alternative PAM shutdown zone for 13 m MP at 6,000 kJ[c]
	L_E	L_{pk}	L_p					
Monopile Foundation; from driving two, 12 m monopiles per day using a 6,000 kJ hammer with 10 dB broadband sound attenuation	3,160	<10	5,600	Any distance	Any distance	5,600	4,620	5,500
Jacket Foundation; from driving four, 4 m pin piles per day using a 3,500 kJ hammer with 10 dB broadband sound attenuation	2,540	0	3,340	Any distance	Any distance	4,490	4,490	NA

[a] The PAM clearance zone is set equal to the NARW Level B zone or the maximum Level A zone for large whales during impact pile driving, whichever is larger (see Table 65 and Table 66).
[b] The PAM shutdown zone is set equal to the maximum Level A zone for large whales during impact pile driving (see Table 65 and Table 66).

[c] In the unlikely event that a 13 m monopile would need to be installed at 6,000 kJ, the alternative PAM shutdown zone would be applied. This zone is set equal to the maximum, scaled up Level A zone for large whales during impact pile driving (see Table 65).

11.3.2. Vibratory Setting and Drilling

Protective zones have also been established for vibratory setting and drilling activity during pile installation. Calculations of the noise impact zones for each activity can been found in Section 6. As described in Section 6.3.1, the daily, Level B impact area that was calculated for vibratory setting of piles is a circle with radius of 50 km (7,854 km^2) and the Level A impact area is a maximum of 401.4 m. The daily impact area for drilling is a circle with radius of 21.5 km (1,452 km^2) (Section 6.4.1). Because no Level A exposures were calculated for both drilling and vibratory setting, and the Level A PTS ranges for vibratory are all lower than for impact driving (see Section 6.3.1), the mitigation zones for these activities are assumed to be the same as for impact driving of either monopile or jacket foundations, whichever has larger zones, as a conservative measure. Mitigation zones implemented during construction activity may be modified, with NMFS approval, based on received sound level measurements during piling operations. The sound field verification details are described in Section 13.1.

Table 68. Proposed species-specific shutdown and clearance zones (m) for vibratory setting and drilling activity based on the largest mitigation zones proposed for impact pile driving.

Hearing group	Species	Clearance zone[b]	Shutdown zone[b]	Vessel separation distance (m)
LF	Fin whale[a]	4,620	4,620	100
	Minke whale	4,620	4,620	100
	Humpback whale	4,620	4,620	100
	North Atlantic right whale[a]	**See Table 67**	**See Table 67**	500
	Sei whale[a]	4,620	4,620	100
MF	Atlantic white sided dolphin	50	50	50
	Atlantic spotted dolphin	50	50	50
	Short-beaked common dolphin	50	50	50
	Bottlenose dolphin, offshore	50	50	50
	Risso's dolphin	50	50	50
	Long-finned pilot whale	50	50	50
	Short-finned pilot whale	50	50	50
	Sperm whale[a]	4,620	4,620	100
HF	Harbor porpoise	2,300	2,300	50
PW	Gray seal	1,310	1,310	50
	Harbor seal	1,310	1,310	50
	Harp seal	1,310	1,310	50

[a] Listed as Endangered under the ESA.
[b] Mitigation zones for were assumed to be the same as for impact driving of either monopile or jacket foundations, whichever has larger zones for each species' group.

11.3.3. Potential UXO Detonation

Clearance zones will be established to minimize and avoid potential impacts of underwater sound to marine mammals during UXO detonation. The clearance zones presented Table 69 are based on the longest 10-dB attenuated range to PTS onset thresholds across all depth locations that were calculated by Hannay and Zykov (2021) (see Table 42), with the exception of the dolphin clearance zone of 650 m. The dolphin clearance zone is informed by the longest 10-dB attenuated range to onset of lung injury assuming detonation of an E12 bin (see Table 43), which resulted in a larger zone than their PTS onset zone (Hannay and Zykov 2021). All other ranges to onset of lung injury for marine mammals under the same assumptions are lower than their PTS zones; therefore, Table 69 would protect all marine mammals from onset of lung injury. The onset of gastrointestinal injury for all animals assuming detonation of an E12 bin and 10 dB of attenuation is 125 m, which is lower than all PTS onset ranges for any marine mammal species (Hannay and Zykov 2021); therefore, the mitigation zones proposed in Table 69 would protect all marine mammals from gastrointestinal injury. PAM monitoring zones were established based on the longest 10 dB attenuated range to TTS onset for each of the marine mammal hearing groups as shown in Table 42.

Table 69. Protective zones (m) used during potential UXO detonation.

Hearing group	Range to PTS onset threshold	Visual and PAM Clearance zone	Range to TTS onset threshold	PAM Monitoring Zone
LF	3,780	3,800	11,900	11,900
MF	461	500 (650[a])	2,550	2,550
HF	6,200	6,200	14,100	14,100
PW	1,600	1,600	7,020	7,020

[a] A visual and PAM clearance zone of 650 m is only proposed for dolphins because their maximum onset of lung injury zone, attenuated by 10 dB and regardless of the modeled depth location, is 606 m. This zone has been rounded up to 650 m for PSO clarity. All other mid frequency cetaceans will be cleared to 500 m.

11.3.4. HRG Surveys

Visual and acoustic monitoring of clearance and shutdown zones during pile driving and HRG surveys will be conducted by NMFS-approved PSOs, and the final requirements and data sharing will be determined in collaboration with BOEM and NOAA Fisheries.

Clearance Zone

- Clearance zones will be monitored around the center of the acoustic sources for marine mammals.
- Clearance zones will be monitored for all listed species for 30 minutes to ensure that no marine mammals are present before any CHIRP SBPs, boomer or sparker sources are initiated.
- The following clearance zones will be implemented during operations of boomer or sparker sources:
  - 500 m (656 ft) for all listed species
  - 100 m (328 ft) for other marine mammals
- The clearance zones must be visible to the naked eye or using appropriate visual technology during the entire clearance period before commencing operations of boomers and sparkers.

- If any marine mammal is observed within the clearance zones during the 30-minute clearance period, ramp-up will not begin until the animal(s) is/are observed exiting the clearance zones, or until an additional time period has elapsed with no further sightings (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

Shutdown Zone

- Shutdown zones will be monitored around the center of the sources for marine mammals.
- The following shutdown zones will be implemented during all HRG survey activities:
  - 500 m (656 ft) for North Atlantic right whales;
  - 100 m (328 ft) for all other marine mammal species; and
- No shutdown zones for certain delphinids.

11.4. Ramp-up/Soft-Start Procedures

11.4.1. Pile Driving

A ramp-up (i.e., soft-start) will be used at the commencement of pile driving activity to provide additional protection to marine mammals potentially located near the construction effort. A soft-start allows marine mammals to become aware of noise at low levels and avert from the area prior to the commencement of full energy pile driving activities. A soft-start utilizes an initial set of very low energy strikes from the impact hammer, followed by a waiting period. Additional strike sets gradually increase energy to what is needed to install the pile, which is usually less than hammer capability. The following, additional soft-start procedures will be performed at the start of impact pile driving:

- Soft-start will not begin until the clearance zone has been cleared by the visual PSOs or PAM operators, when appropriate.
- Each soft-start will last for a minimum of 20 minutes.
- A soft-start will also be implemented if piling is halted for 30 minutes or longer during installation.
- If any marine mammal is detected within the applicable shutdown zone during the soft-start, activities will be delayed until the animal is observed leaving the shutdown zone or until 30 minutes have passed without a detection of the animal within the shutdown zone.

11.4.2. HRG Surveys

- Ramp-up will not be initiated during periods of inclement conditions or if the CZ cannot be adequately monitored by PSOs using appropriate visual technology for a 30-minute period.
- A ramp-up begins with the powering up of the smallest acoustic HRG equipment at its lowest power output. When technically feasible the power is then gradually turned up and other acoustic sources added such that the source level increases gradually.
- PSOs will stand-watch for a minimum of 30 minutes to ensure the CZs are clear of marine mammals prior to commencement of ramp-up procedures. If a marine mammal is observed, ramp-up may not

begin until the marine mammal has exited the CZ or until the following additional time periods have elapsed with no further sightings:

- 30 minutes for NARW and other non-delphinid cetaceans; and
- 15 minutes for delphinid cetaceans and pinnipeds.

11.5. Vessel Strike Avoidance Measures

The Proponent will adhere to legally mandated vessel speeds, approach limits, and other vessel strike avoidance measures to reduce the risk of impact to NARWs as a result of New England Wind activities in the SWDA. For example, federal regulations require that vessels maintain a separation distance of 457 m (1500 ft) from an observed NARW (see 50 CFR 224.103 (c)). As safe and practicable, New England Wind's vessels operating in the SWDA will also follow NOAA guidelines for vessel strike avoidance, including vessel speed restrictions and separation distances, that are applicable at the time of construction. During appropriate time periods and within certain areas (described in Section 4.1.5.3), New England Wind-related vessels traveling to/from Salem Harbor will transit at 18.4 km per hour (10 knots) or less within NOAA-designated NARW critical habitat and outside critical habitat.

Regardless of the guidance in effect at the time of construction, vessel operators and crew will maintain a vigilant watch for marine mammals, and will slow down or maneuver their vessels, as appropriate, to avoid a potential interaction with a marine mammal. Vessels will also maintain required separation distances, which will be monitored by trained observers or PSOs. New England Wind personnel will check the NMFS' NARW reporting systems on a daily basis. Additionally, it is expected that vessel captains will monitor USCG VHF Channel 16 throughout the day to receive notifications of any sightings. This information would be used to alert the team to the presence of a NARW in the area and to implement mitigation measures as appropriate. Whenever multiple New England Wind vessels are operating, all sightings of listed species will be communicated between vessels to all PSOs.

11.5.1. Additional Avoidance Measures during HRG Surveys

- All vessel operators and crews will maintain a vigilant watch for marine mammals at all times, and slow down or stop their vessel to avoid striking protected species, except under extraordinary circumstances when complying with this requirement would jeopardize the safety of the vessel or crew.
- Monitoring of a 500 m (1,640 ft) vessel strike avoidance zone may be performed by PSOs or crew members, however, any crew members responsible for monitoring will be trained to broadly identify protected species and marine mammals, such as the North Atlantic right whale or other whale species.
- All vessel operators will reduce vessel speed to 10 knots (5.1 m/s) or less when mother/calf pairs, pods, or larger assemblages of marine mammals are observed near an underway vessel.
- All vessel operators will comply with 10 knots (5.1 m/s) speed restrictions in any DMA.
- New England Wind will monitor NMFS NARW reporting systems from November 1st through July 31th and whenever a DMA is established within any areas vessels operate.
- When marine mammals are sighted while a vessel is underway, the vessel shall take action to avoid violating the relevant separation distance (e.g., attempt to remain parallel to the animal's course, avoid

excessive speed or abrupt changes in direction until the animal has left the area, reduce speed and shift the engine to neutral). This does not apply to any vessel towing gear or any vessel that is navigationally constrained.

North Atlantic right whales and ESA-listed marine mammals:

- New England Wind will ensure all vessels maintain a separation distance of 500 m (1,640 ft) or greater from any sighted NARW and other ESA-listed marine mammals.
- New England Wind will ensure that the following avoidance measures are taken if a vessel comes within 500 m (1,640 ft) of any NARW.
    - If underway, any vessel will steer a course away from any NARW at 10 knots (5.1 m/s) or less until the 500 m (1,640 ft) minimum separation distance has been established, unless:
    - If a NARW is sighted within 100 m (328 ft) to an underway vessel, the vessel operator must immediately reduce speed and promptly shift the engine to neutral. The vessel operator must not engage the engines until the NARW has moved beyond 100 m (328 ft), at which point the vessel will steer a course away from any NARW at 10 knots (5.1 m/s) or less until the 500 m (1,640 ft) minimum separation distance has been established.
    - If a vessel is stationary, the vessel will not engage engines until the NARW has moved beyond 100 m (328 ft), at which point the vessel will steer a course away from any NARW at 10 knots (5.1 m/s) or less until the 500 m (1,640 ft) minimum separation distance has been established.

Non-ESA-listed whales:

- New England Wind will ensure that all vessels maintain a separation distance of 100 m (328 ft) or greater from any sighted non-ESA-listed whales.
- The following avoidance measures are taken if a vessel comes within 100 m (328 ft) of any non-delphinid cetacean:
    - If underway, the vessel must reduce speed and shift the engine to neutral and must not engage the engines until the whale has moved beyond 100 m (328 ft).
    - If stationary, the vessel must not engage engines until the whale has moved beyond 100 m (328 ft).

Delphinid cetaceans and pinnipeds:

- New England Wind will ensure that:
    - All vessel underway will not divert to approach any cetaceans or seals.
    - When feasible, all vessels will maintain a separation distance of 50 m (164 ft) or greater from any sighted delphinid cetacean or pinniped.
    - All vessels underway will remain parallel to a sighted delphinid cetacean's or pinniped's course whenever possible and avoid excessive speed or sudden changes in direction. If a delphinid(s) is visually detected approaching the vessel or towed survey equipment (e.g., to bow ride), the PSOs and crew will use professional judgement in making course and/or speed adjustments
    - All vessels underway reduce vessel speed to 10 knots or less when pods (including mother/calf pairs) or large assemblages of delphinid cetaceans are observed.
    - If a whale is observed that cannot be confirmed to species, the vessel operator must assume that it is an ESA-listed species and take appropriate action.

- The requirements listed in this section do not apply if compliance would create imminent and serious threat to a person or vessel.

11.6. Potential UXO Detonation Protocols

UXO detonation may be required during construction and installation of the Project if other, preferable removal options (see Section 1.2.4) are not feasible. The exact number and type of UXOs that may be encountered in the project area are not yet known, but for the purpose of this LOA request it is assumed that up to 10 E12-bin UXOs may need to be detonated in place.

The following mitigation measures will be implemented in the event that an UXO detonation is necessary.

- Only one detonation may occur in a 24-hour period.
- Detonations will only occur during daylight hours.
- A 60-minute pre-start clearance period will be implemented prior to any in-situ UXO detonation.

The clearance zone (see Table 69) must be fully visible for at least 30 minutes prior to commencing detonation.

- All marine mammals must be confirmed to be out of the clearance zone prior to initiating detonation.
- If a marine mammal is observed entering or within the relevant clearance zones prior to the initiation of detonation, the detonation must be delayed.
- The detonation may commence when either the marine mammal(s) has voluntarily left the respective clearance zone and been visually confirmed beyond that clearance zone, or when 30 minutes have elapsed without redetection for whales, including the NARW, or 15 minutes have elapsed without redetection of dolphins, porpoises, and seals.

11.7. HRG Mitigation Protocols

HRG surveys may be required during construction and installation of the Project. Survey operations may be conducted over 24-hour periods. To provide survey flexibility, the specific locations and amount of survey vessels will be determined at the time of contractor selection.

Mitigation measures implemented during HRG surveys for sources operating at or below 180 kHz can decrease the potential impacts to marine mammals from sound exposure by reducing the distance to disturbance and therefore the likelihood of Level B sound exposures. New England Wind will comply with all applicable monitoring and mitigation regulations and any lease or permit conditions placed on the Project by regulatory agencies. New England Wind is proposing the mitigation measures, provided in Table 70, to reduce the potential for negative impacts to marine mammals during survey acquisition; however, the final mitigation plan will be determined in consultation with NMFS. The selection of appropriate mitigation techniques will consider safety, effectiveness for the Project, and practical application of individual measures, as well as all measures in-concert.

Shutdown Procedures

- An immediate shutdown of HRG survey equipment specified in the IHA permit will be required if a marine mammal is detected at or within its respective shutdown zone.
- The vessel operator must comply immediately with any call for shutdown by the PSO.
- Any disagreement between the PSO and vessel operator should be discussed only after shutdown has occurred.
- HRG survey equipment may be allowed to continue operating if dolphins voluntarily approach the vessel (e.g., to bow ride) when the sound sources are at full operating power.
- If a species approaches or enters the Level B harassment zone, shutdowns will occur if a marine mammal authorization has not been granted, or, an authorized species' takes have already been met.
- If HRG survey equipment is shutdown longer than 30 minutes while PSOs have been monitoring, clearance followed by ramp-up activities will commence.
- If another marine mammal enters a shutdown zone during the shutdown period, the HRG equipment may not restart until that animal is confirmed outside the respective exclusion or until the appropriate time has passed from the last sighting of the marine mammal.
- After shutdown, ramp-up can be initiated once the shutdown zone are visually clear for the respective clearance timing.
- Shutdown is not required for small delphinids from genera *Delphinus, Lagenorhynchus, Stenella*, and Tursiops that are detected voluntarily approaching the vessel or towed equipment.
- If a PSO is unsure about the identification of a small delphinid, PSOs must use their professional judgement to decide as to whether shutdown should occur.

Pauses in HRG Sources

- If the acoustic source is shut down for reasons other than mitigation (e.g., mechanical difficulty) for less than 30 minutes, it may be re-activated without ramp-up only if PSOs have maintained constant observation and no detections of any marine mammal have occurred within the respective shutdown zone.
- Any shutdown exceeding 30 minutes must be followed by full ramp-up procedures.

11.8. Protected Species Observer and Trained Observers

As noted above, the Proponent will use NMFS-approved PSOs to monitor clearance and shutdown zones during pile driving and HRG survey activity as well as any UXO detonation. PSOs will use visual aids (e.g., range finders, binoculars, night vision devices, IR/thermal camera) when necessary. PSOs will have no tasks other than to conduct observations, collect and report data, and communicate with and instruct relevant vessel crew regarding the presence of marine mammals and mitigation requirements.

11.9. Equipment and Technology

The Proponent will consider the best commercially available equipment and technology for minimizing and avoiding impacts to marine mammals during construction and installation. This includes a variety of marine mammal detection and sound mitigation methodologies. Examples of potential technologies include passive acoustic monitoring (PAM) recorders, thermal cameras, and noise abatement systems. The Proponent may collaborate with BOEM and NOAA Fisheries to integrate practicable technology choices in mitigation equipment to meet the necessary standards for permitting and successful consultations. The Proponent expects to use a PAM system to support visual monitoring of mitigation zones. 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.

11.10. Environmental Training

All New England Wind personnel working offshore will receive standardized environmental awareness training, which will stress individual responsibility for marine mammal and marine debris awareness and reporting. Prior to commencing offshore activities associated with either construction or HRG surveys, team members participate in induction meetings where summary materials are presented in person and with video materials covering topics including the following:

- Code of Business Conduct including environmental commitments,
- Relevant regulatory statutes, laws, and permit requirements,
- Specific conditions and procedures related to offshore activities, e.g., marine debris protocols, marine mammal monitoring and mitigation, spill reporting, etc.,
- Protected species and trained crew observers procedures for sighting, reporting and protection of species including vessel strike avoidance and sound source management,
- Protected species identification, and
- Communication protocols.

All personnel are required to register their participation in the induction training. These records are auditable. Additional refresher training related to the protected species monitoring and mitigation plan is provided offshore, and individuals joining the project who did not attend the initial induction training will be required to participate in a separate training session, with their participation recorded for the project.

Environmental Management Plans (EMPs) will be created for construction operations and HRG surveys. The EMP includes all of the induction training components, including full copies of relevant permits and permit-required plans, protected species identification materials, communication flow charts and contact information, etc. These materials are all retained in accessible areas on all project vessels

11.11. Summary of Monitoring and Mitigation Measures

Table 70 summarizes the acoustic and non-acoustic monitoring and mitigation measures currently proposed for Phases 1 and 2 of New England Wind to be implemented if applicable. The table does not include standard compliance or mitigation measures that may be stipulated by BOEM or NOAA in permit conditions. While protection of marine fauna 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.

Table 70. Proposed monitoring and mitigation measures for New England Wind.

Monitoring & Mitigation Measure	Description
Seasonal Restrictions on Pile Installation Activities	New England Wind expects to establish a restriction on impact and vibratory pile driving and drilling between January 1 and April 30.
Pile Driving Sound Reduction Technology	New England Wind expects to implement noise attenuation technology to reduce pile driving activity sound levels by a target of 12 dB or greater. Sound field verification measures (see Appendix C) will aim to verify that this reduction is met.
Sound Field Verification	Sound levels are expected to be recorded for a minimum of three monopiles and a minimum of two jackets for comparison with model results. Additional locations may be added if site characteristics or hammer energies vary significantly from the selected locations for sound field verification. See Appendix C for more details.
Ramp-up/Soft-Start	Soft-start will be implemented during pile driving and HRG surveys at the initiation of the activity and when there is a pause in sound production for a period of 30 minutes or more.
Protective Zones (radius from pile center/survey vessel)	Clearance and shutdown zones will be established for pile driving activities, UXO detonation, and HRG survey activities, where appropriate (see Table 65 through Table 69).
Shutdowns and Reduced Hammer Energy	Pile driving activities and HRG source shutdown of regulated sources, and reduced hammer energy protocols will be established in consultation with regulatory agencies, recognizing technical and health and safety constraints.
Protected Species Observers (PSOs)	NOAA Fisheries-approved PSOs will monitor before and during piling activities, UXO detonations, and during HRG surveys, using visual aids when necessary.
Passive Acoustic Monitoring	A PAM system will be used during piling; the system will be identified prior to construction and in consultation with BOEM and NOAA Fisheries.
Vessel Strike Avoidance	As safe and practicable, the Proponent will adhere to NOAA guidelines for vessel strike avoidance during all New England Wind project activities, including vessel speed restrictions and separation distances, that are applicable at the time of construction and during HRG surveys. All NMFS speed restrictions with respect to NARW will be followed. Vessel separation distances (see Table 65 and Table 66) will be maintained.
Monitoring for the Presence of NARW	New England Wind personnel/vessel captains will monitor NARW reporting systems and USCG VHF Channel 16 for notifications of any NARW sightings.
Environmental Training	All New England Wind personnel working offshore will receive environmental training, which will stress individual responsibility for marine mammal awareness and reporting as well as marine debris awareness.
Reporting of Marine Mammal Impacts	New England Wind will report impacts to marine mammals to jurisdictional/interested agencies, including NOAA Fisheries and BOEM, as required.
NARW Specific Monitoring and Mitigation	New England Wind expects to develop additional monitoring and mitigation measures for NARW protection in consultation with regulatory agencies and interested stakeholders.

[a] This restriction is intended to minimize the amount of pile driving that occurs when the migratory NARW is likely to be in the Offshore Development Area and thus limit sound exposure for this Endangered species. Density data from Roberts et al. (2016a, 2021b) and survey data (both visual and acoustic) from Kraus et al. (2016) suggest that the highest density of NARWs in the SWDA occurs annually during March and April.

12. Mitigation Measures to Protect Subsistence Uses

Not applicable.

New England Wind will be developed 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 size of the mitigation zones described in Section 11 will help inform the appropriate monitoring methods that will be employed during activities. The suite of planned monitoring activities is detailed below and summarized in Table 70.

13.1. Sound Field Verification

To assess the efficacy of mitigation measures and to compare the in situ distance to pre-defined acoustic thresholds with modeled distances, New England Wind proposes to conduct a sound field verification (SFV) study when construction commences. Sound levels are expected to be recorded for a minimum of three monopiles and a minimum of two jackets for foundation installation techniques (i.e., drilling, vibratory hammering, impact hammering) that are used in the program. Additional SFV measurements may be taken if the Proponent obtains technical information that suggests a subsequent foundation, or foundations, may produce larger sound fields. Additional SFV positions with be agreed with the Federal agencies. Acoustic measurements will also be made during any potential UXO detonation. Measurements will provide verification of modeled ranges to the modeled harassment threshold isopleths and provide acoustic measurement data collected using International Organization for Standardization (ISO)-standard methodology for comparison among projects and to inform future projects.

SFV measurements will inform mitigation measure implementation for the remainder of the construction, including potential adjustments to clearance and exclusion zones. For more details about the SFV plan framework, see Appendix C.

13.2. Visual Monitoring

New England Wind intends to adhere to visual monitoring protocols as follows:

- Conduct briefings between construction supervisors and crews and the PSO team prior to the start of all HRG and pile-driving activities, and when new personnel join the project, to explain responsibilities, communication procedures, marine mammal monitoring protocols, and operational procedures. An informal guide will be included with the Marine Mammal Monitoring Plan to aid in identifying species if they are observed in the vicinity of the project area.
- PSOs must visually monitor to a minimum radius around monopile and jacket foundations equivalent to the calculated impact pile driving exposure range to Level B harassment thresholds using NMFS' unweighted 160 dB SPL, or as modified based on sound field verification.
- Due to the size of the zones, visual monitoring of the entire Level B zones for drilling and vibratory setting is not planned. To account for the potential presence of marine mammals that may be present within the Level B zone beyond the mitigation zones identified in Table 68, the ensonified area between the mitigation zones and Level B harassment threshold will be multiplied by the density estimate appropriate for each species for each activity (see Section 6.1.1) and rounded to the nearest integer to calculate assumed take for those species beyond the mitigation zones for purposes of reporting.
- Visual monitoring of the established HRG clearance and shutdown zones around regulated active acoustic sources (e.g. boomers and sparkers) will be performed by NMFS-approved PSOs for a

minimum of 30 minutes to ensure the shutdown zones are clear of marine mammals prior to commencement of ramp-up procedures and during acquisition. Clearance and shutdown zones will be established using the longest distance to disturbance calculated for the HRG equipment in use.

- During pile driving activities (i.e., impact pile driving, vibratory pile setting, and drilling), a minimum of two PSOs will be on active duty on a dedicated PSO vessel from 60 minutes before, during, and for 30 minutes after all pile installation activity. The dedicated PSO visual monitoring vessel must survey to the farthest extent possible, or as modified based on sound field verification, such that the distance to the perimeter of the large whale clearance and shutdown zone is visible. These PSOs will be located at the best vantage point(s) in order to ensure coverage of as much of the clearance, shutdown, and Level B harassment zones as possible, while still considering human safety.
- PSOs must not exceed four consecutive watch hours on duty at any time, must have a two-hour (minimum) break between watches, and must not exceed a combined watch schedule of more than 12 hours in a 24-hour period.
- PSOs will observe and collect standard survey data and data on marine mammals in and around the project area.
- PSOs must record all incidents of marine mammal occurrence, regardless of distance from the construction activity.
- For all pile driving activities, PSOs will document any behavioral reactions in concert with distance from the pile being driven.
- During all observation periods related to pile driving activities, PSOs will use high-magnification (25X), as well as standard handheld (7X) binoculars, and the naked eye to search continuously for marine mammals. During periods of low visibility (e.g., darkness, rain, fog, etc.), PSOs will use alternative technology (e.g., IR/Thermal camera) to monitor shutdown and clearance zones.
- For all activities, monitoring distances will be measured with range finders or reticle binoculars. Distances to marine mammals observed will be based on the best estimate of the PSO, relative to known distances to objects in the vicinity of the PSO. Bearings to animals must be determined using a compass.
- Two PSOs will visually survey the UXO clearance zone (Table 69) at least 60 minutes prior to a detonation event.
- Two PSOs will maintain watch at all times during the UXO pre-clearance period and 30 minutes after the detonation event.

The Proponent will ensure that PSOs record all observations of protected species using standard marine mammal observer data collection protocols. The required data elements for these reports are the following:

- Vessel name
- PSO’s names and affiliations
- Date, time, location (latitude/longitude) when survey begins and ends
- Average environmental conditions during visual surveys, including:
- Wind speed and direction
- Sea state and swell
- Overall visibility

- Species (or identification to lowest possible taxonomic level)
- Certainty of identification
- Total number of animals and juveniles
- Description of animals observed
- Direction of animal's travel relative to the vessel
- Behavior
- Activity of vessel when sighting occurred

13.3. Passive Acoustic Monitoring

The Proponent expects to use a PAM system to support visual monitoring efforts during all pile driving activities. PAM is not planned during HRG surveys. 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.

New England Wind intends to adhere to PAM protocols for all pile driving activities as follows:

- A PAM Plan will be submitted to NMFS and BOEM for review and approval at least 90 days prior to the planned start of pile driving. The Plan must describe all proposed PAM equipment, procedures, and protocols;
- The Plan will include a description of the PAM hardware and software used for marine mammal monitoring, including software version used, calibration data, bandwidth capability and sensitivity of hydrophone(s), any filters used in hardware or software, and limitations of the equipment, and other information;
- PAM will be conducted during all pile driving activities and UXO detonations;
- PAM will begin at least 60 minutes prior to initiation of pile driving activities of monopiles, continue throughout monopile installation, and extend at least 30 minutes post pile installation;
- PAM will begin at least 60 minutes prior to UXO detonation and extend at least 30 minutes after the event;
- The dedicated PAM PSO will inform the Lead PSO on duty of animal detections approaching or within applicable mitigation zones;
- PAM devices used may include independent (e.g., autonomous or moored remote) systems;
- PAM will be conducted by at least one dedicated PAM PSO. The PAM PSO(s) will have completed specialized training for operating the PAM system;
- The dedicated PAM PSO must acoustically monitor to a minimum radius of 4,620 m around monopile foundations and 4,490 m around jacket foundations during pile driving activity. In the unlikely event that a 13 m monopile would need to be installed at 6,000 kJ, the PAM PSO must acoustically monitor to a minimum radius of 5,500 m around the monopile foundation;
- PAM PSO(s) will be on watch for a maximum of four consecutive hours followed by a break of at least two hours between watches; and

- PAM PSO(s) will immediately communicate all detections of marine mammals to visual PSOs, including any determination regarding species identification, distance, bearing and the degree of confidence in the determination.

For all acoustic detections of marine mammals, the following must be recorded:

- Identification, location, and depth of recording unit;
- Time zone for sound files and recorded date/times in data and metadata;
- Duration of recording (start/end dates and times);
- Type of recording (continuous/duty cycled);
- Hydrophone sensitivity;
- Bandwidth/sampling rate;
- Species identification (if possible);
- Call type (if known);
- Temporal aspects of vocalization (date, time, duration, etc.);
- Comparison with any concurrent visual sightings;
- Name of observer/data collector/analyst;
- A record of the PAM PSO's review of any acoustic detections; and
- Location (if geometry/density of bottom-mounted or sonobuoy array allows) or directionality (directional hydrophones and/or lateral information from towed array) of detected calls including references to location of coincident human sound-producing activities.

13.4. Reporting of Marine Mammal Impacts

New England Wind will report impacts to marine mammals to jurisdictional/interested agencies, as required. These agencies include, but are not limited to, NOAA Fisheries and BOEM. The Proponent is expected to provide notification of commencement and completion of construction activities and will provide all required documentation and reports for permitted activities to the jurisdictional agencies.

New England Wind intends to adhere to Reporting protocols for all pile driving activities as follows:

- If a NARW is observed at any time by PSOs or personnel on or in the vicinity of any pile-driving or HRG vessel, dedicated PSO vessel, construction survey vessel, or during vessel transit, New England Wind will immediately report sighting information to the NMFS North Atlantic Right Whale Sighting Advisory System (866) 755–6622, to the US Coast Guard via channel 16, and through the WhaleAlert app (http://www.whalealert/org/) as soon as feasible but no longer than 24 hours after the sighting. Information reported must include, at a minimum: time of sighting, location, and number of NARWs observed.
- If a NARW is detected via New England Wind PAM, the date, time, location (i.e., latitude and longitude of recorder) of the detection as well as the recording platform that had the detection must be reported to nmfs.pacmdata@noaa.gov as soon as feasible, but no longer than 24 hours after the detection. Full detection data and metadata must be submitted monthly on the 15th of every month for the previous month via the webform on the NMFS North Atlantic right whale Passive Acoustic Reporting System

website (https://www.fisheries.noaa.gov/resource/document/passive-acoustic-reportingsystem-templates). For assistance, contact nmfs.pacmdata@noaa.gov.

- Prior to initiation of project activities, New England Wind will demonstrate in a report submitted to NMFS that all required training for personnel (including vessel crew and captains, and PSOs) has been completed.
- New England Wind will compile and submit weekly PSO and PAM reports to NMFS (at PR.ITP.monitoring reports@noaa.gov) that document the daily start and stop of all pile-driving activities, the start and stop of associated observation periods by PSOs, details on the deployment of PSOs, a record of all detections of marine mammals, any mitigation actions (or if mitigation actions could not be 25 taken, provide reasons why), and details on the noise attenuation system(s) used and its performance. Weekly reports are due on Wednesday for the previous week (Sunday – Saturday).
- New England Wind will compile and submit monthly reports that include a summary of all information in the weekly reports, including project activities carried out in the previous month, vessel transits (number, type of vessel, and route), number of piles installed, and all observations of marine mammals. Monthly reports are due on the 15th of the month for the previous month.
- New England Wind will submit its draft final report(s) on all visual and acoustic monitoring conducted under the IHA within 90 calendar days of the completion of activities occurring under this IHA. A final report must be prepared and submitted within 30 calendar days following receipt of any NMFS comments on the draft report. If no comments are received from NMFS within 30 calendar days of NMFS' receipt of the draft report, the report will be considered final. g.
- All draft and final monitoring reports must be submitted to PR.ITP.MonitoringReports@noaa.gov.
- Sound Field Verification Reporting: Initial results of the SFV measurements will be provided to NMFS in an interim report as soon as they are available but no later than 48 hours after each installation. Final Results of SFV of monopile and jacket installations will be submitted as soon as possible, but no later than within 90 days following completion of pile driving. The final report will include, at minimum, the following:
    - Peak sound pressure level (SPLpk), root-mean-square sound pressure level that contains 90% of the acoustic energy (SPLrms), single strike sound exposure level (SELss), integration time for SPLrms, SELss spectrum, and 24-hour cumulative SEL. All these levels will be reported in the form of (1) median, (2) mean, (3) maximum, and (4) minimum. The SEL and SPL power spectral density and one-third octave band levels (usually calculated as decidecade band levels) at the receiver locations should be reported;
    - The sound levels reported will be in median and linear average (i.e., average in linear space), and in dB;
    - A description of depth and sediment type, as documented in the Construction and Operation Plan, at the recording and pile-driving locations;
    - Hammer energies required for pile installation and the number of strikes per pile;
    - Hydrophone equipment and methods (i.e., recording device, bandwidth/sampling rate, distance from the pile where recordings were made; depth of recording device(s));
    - Description of the SFV PAM hardware and software, including software version used, calibration data, bandwidth capability and sensitivity of hydrophone(s), any filters used in hardware or software, any limitations with the equipment, and other relevant information;

  - Local environmental conditions, such as wind speed, transmission loss data collected on-site (or the sound velocity profile), baseline pre- and post-activity ambient sound levels (broad-band and/or within frequencies of concern);
  - Spatial configuration of the noise attenuation device(s) relative to the pile;
  - The extents of the Level A harassment and Level B harassment zones; and
  - A description of the noise attenuation devices and operational parameters (e.g., bubble flow rate, distance deployed from the pile, etc.) and any action taken to adjust noise attenuation devices.
- Reporting injured or dead marine mammals:
  - In the event that personnel involved in the activities covered by the LOA discover an injured or dead marine mammal, New England Wind will immediately report the observation to the NOAA Fisheries Marine Mammal and Sea Turtle Stranding and Entanglement Hotline (866-755-6622) or alternative electronic reporting systems as approved by the NOAA stranding program, as well as the US Coast Guard. In addition, New England Wind will report the observation to NMFS Office of Protected Resources (OPR) within 24 hours (PR.ITP.MonitoringReports@noaa.gov). If the death or injury was clearly caused by the specified activity, the Proponent will immediately cease all activities until NMFS OPR is able to review the circumstances of the incident and determine what, if any, additional measures are appropriate to ensure compliance with the terms of this LOA. The report will include the following information:
    - Time, date, and location (latitude/longitude) of the first discovery (and updated location information if known and applicable);
    - Species identification (if known) or description of the animal(s) involved;
    - Condition of the animal(s) (including carcass condition if the animal is dead);
    - Observed behaviors of the animal(s), if alive;
    - If available, photographs or video footage of the animal(s); and
    - General circumstances under which the animal was discovered.
  - In the event of a vessel strike of a marine mammal by any vessel involved in the activities covered by the LOA, New England Wind will immediately report the incident to the NOAA Fisheries Marine Mammal and Sea Turtle Stranding and Entanglement Hotline (866-755-6622) or alternative electronic reporting systems as approved by the NOAA stranding program, as well as the US Coast Guard. The incident will also be immediately reported to NMFS OPR (301-427-8401). New England Wind will immediately cease all activities until NMFS OPR is able to review the circumstances of the incident and determine what, if any, additional measures are appropriate to ensure compliance with the terms of this LOA. The report will include the following information:
    - Time, date, and location (latitude/longitude) of the incident;
    - Species identification (if known) or description of the animal(s) involved;
    - Vessel's speed leading up to and during the incident;
    - Vessel's course/heading and what operations were being conducted (if applicable);
    - Status of all sound sources in use;
    - Description of avoidance measures/requirements that were in place at the time of the strike and what additional measures were taken, if any, to avoid strike;

- Environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, visibility) immediately preceding the strike;
- Estimated size and length of animal that was struck;
- Description of the behavior of the marine mammal immediately preceding and following the strike;
- If available, description of the presence and behavior of any other marine mammals immediately preceding the strike;
- Estimated fate of the animal (e.g., dead, injured but alive, injured and moving, blood or tissue observed in the water, status unknown, disappeared); and
- To the extent practicable, photographs or video footage of the animal(s).

14. Suggested Means of Coordination

In addition to monitoring and mitigation specific to New England Wind (see Sections 9.1 and 13), the Proponent is establishing the Offshore Wind Protected Marine Species Mitigation Fund as part of Phase 1 of New England Wind.

As described in Section 11.5, 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.

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Appendix A. Assessing the Potential Acoustic Impact on Marine Fauna during Construction of New England Wind

Assessing the Potential Acoustic Impact on Marine Fauna during Construction of New England Wind

JASCO Applied Sciences (USA) Inc.

22 June 2022

Submitted to:

Maria Hartnett

Epsilon Associates, Inc.

Amendment #2

Authors:

Elizabeth T. Küsel
Michelle J. Weirathmueller
Susan G. Dufault
Karlee E. Zammit
Molly L. Reeve
Madison E. Clapsaddle
Katy E. Limpert
David G. Zeddies

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Executive Summary

New England Wind is the proposal to develop offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0534 along with associated offshore and onshore cabling, onshore substations, and onshore operations and maintenance (O&M) facilities. New England Wind will be developed in two Phases with a maximum of 130 wind turbine generator (WTG) and electrical service platform (ESP) positions. Two positions may potentially have co-located ESPs (i.e., two foundations installed at one grid position[1]), resulting in 132 foundations. Four or five offshore export cables will transmit electricity generated by the WTGs to onshore transmission systems in the Town of Barnstable, Massachusetts. Figure 1 provides an overview of New England Wind. Park City Wind LLC, a wholly owned subsidiary of Avangrid Renewables, LLC, is the Proponent and will be responsible for the construction, operation, and decommissioning of New England Wind.

New England Wind's offshore renewable wind energy facilities are located immediately southwest of Vineyard Wind 1, which is located in Lease Area OCS-A 0501. New England Wind will occupy all of Lease Area OCS-A 0534 and potentially a portion of Lease Area OCS-A 0501 in the event that Vineyard Wind 1 does not develop "spare" or extra positions included in Lease Area OCS-A 0501 and Vineyard Wind 1 assigns those positions to Lease Area OCS-A 0534. For the purposes of the COP, the Southern Wind Development Area (SWDA) is defined as all of Lease Area OCS-A 0534 and the southwest portion of Lease Area OCS-A 0501, as shown in Figure 1.

The SWDA may be approximately 411–453 square kilometers (km^2) (101,590–111,939 acres) in size depending upon the final footprint of Vineyard Wind 1. At this time, the Proponent does not intend to develop the two positions in the separate aliquots located along the northeastern boundary of Lease Area OCS-A 0501 as part of New England Wind (see Figure 1). The SWDA (excluding the two separate aliquots that are closer to shore) is just over 32 kilometers (km) (20 miles [mi]) from the southwest corner of Martha's Vineyard and approximately 38 km (24 mi) from Nantucket.[2] The WTGs and ESPs in the SWDA will be oriented in an east-west, north-south grid pattern with one nautical mile (NM) (1.85 km) spacing between positions.

Each Phase of New England Wind will be developed and permitted using a Project Design Envelope (the "Envelope"). This allows the Proponent to properly define and bracket the characteristics of each Phase for the purposes of environmental review while maintaining a reasonable degree of flexibility with respect to the selection of key components, such as the WTGs, foundations, offshore cables, and ESPs. To assess potential impacts and benefits to various resources, a "maximum design scenario," or the design scenario with the maximum impacts anticipated for that resource, is established considering the Envelope parameters for each Phase. Two impact piling construction schedules were established based on the characteristics described within the Envelope that have the potential to cause the greatest effect. For some resources, this approach overestimates potential environmental impacts as the maximum design scenario is not the scenario that the Proponent is likely to employ.

[1] If co-located ESPs are used, each ESP's monopile foundation would be located within 76 m (250 ft) of one of the potential ESP grid locations (i.e. the monopiles would be separated by up to 152 m [500 ft]).

[2] Within the SWDA, the closest WTG is approximately 34 km (21 mi) from Martha's Vineyard and 40 km (25 mi) from Nantucket.

Phase 1 of New England Wind (Park City Wind)

Phase 1, also known as Park City Wind, will be developed immediately southwest of the Vineyard Wind 1 Project. The Phase 1 Envelope allows for 41 to 62 WTGs and one or two ESP(s). Depending upon the capacity of the WTGs, Phase 1 will occupy 150–231 km^2 (37,066–57,081 acres) of the SWDA. The Phase 1 Envelope includes two WTG foundation types: monopiles and piled jackets. Strings of WTGs will connect with the ESP(s) via a submarine inter-array cable transmission system. The ESP(s) will include step-up transformers that increase the voltage of power generated by the WTGs prior to transmission and other electrical equipment. The ESP(s) will also be supported by a monopile or jacket foundation. Two high-voltage alternating current (HVAC) offshore export cables up to 101 km (54 NM) in length (per cable) installed within the SWDA and an Offshore Export Cable Corridor (OECC) will transmit electricity from the ESP(s) to a landfall site at the Craigville Public Beach or Covell's Beach in the Town of Barnstable. Underground onshore export cables, located principally in roadway layouts, will connect the landfall site to a new Phase 1 onshore substation in Barnstable. Grid interconnection cables will then connect the Phase 1 onshore substation to the ISO New England (ISO-NE) electric grid at Eversource's existing 345 kilovolt substation in West Barnstable.

Phase 2 of New England Wind (Commonwealth Wind)

Phase 2, also known as Commonwealth Wind, will be immediately southwest of Phase 1 and will occupy the remainder of the SWDA. Phase 2 may include one or more Projects, depending on market conditions. The footprint and total number of WTG and ESP positions in Phase 2 depends upon the final footprint of Phase 1; Phase 2 is expected to contain 64 to 88 WTG/ESP positions (up to three positions will be occupied by ESPs) within an area ranging from 222–303 km^2 (54,857– 74,873 acres). The Phase 2 Envelope includes three general WTG foundation types: monopiles, jackets (with piles or suction buckets), or bottom-frame foundations (with piles or suction buckets). Inter-array cables will transmit electricity from the WTGs to the ESP(s).

Two or three HVAC offshore export cables, each with a maximum length of 116–124 km (63–67 NM) per cable, will transmit power from the ESP(s) to shore. The Proponent intends to install all Phase 2 offshore export cables within the same OECC as the Phase 1 cables from the northwestern corner of the SWDA to within approximately 2–3 km (1–2 mi) of shore, at which point the OECC for each Phase will diverge to reach separate landfall sites in Barnstable. However, the Proponent has also identified two variations of the Phase 2 OECC in the event that technical, logistical, grid interconnection, or other unforeseen issues arise during the COP review and engineering processes that preclude one or more Phase 2 offshore export cables from being installed within all or a portion of the OECC. These variations of the Phase 2 OECC—the Western Muskeget Variant and the South Coast Variant—are shown on Figure 2.

Underground onshore export cables, located primarily within existing roadway layouts, will connect the landfall site(s) to one or two new onshore substations in the Town of Barnstable. Grid interconnection cables will then connect the onshore substation site(s) to the West Barnstable Substation. If the Phase 2 OECC South Coast Variant is employed and electricity generated by Phase 2 is delivered to a second grid interconnection point, Phase 2 could include one onshore transmission system in Barnstable and/or an onshore transmission system(s) in proximity to the second grid interconnection point.

For both Phases, to support construction and operation activities, the Proponent will use a combination of North Atlantic ports in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and/or Canada. During appropriate time periods, New England Wind-related vessels traveling to/from Salem Harbor will transit at 18.4 km per hour (10 knots) or less within NOAA-designated North Atlantic right whale critical habitat and outside critical habitat.

The primary sound source associated with New England Wind is impact (impulsive) pile driving during construction. Other sound sources include potential vibratory pile setting, which may be required during installation before impact hammering begins to ensure the pile is stable in the seabed and level for impact hammering; potential drilling, which may be required during pile installation to remove boulders and in cases of pile refusal; high-resolution geophysical (HRG) surveys to verify site conditions, ensure proper installation of components, and inspect depth of cable burial or foundations; and potential detonation of unexploded ordnance (UXO) if encountered and avoidance, physical removal, or alternative combustive removal techniques (e.g., deflagration) are not feasible. Other activities associated with cable-laying and construction vessels could contribute non-impulsive (dredging, dynamic positioning [DP] thrusters) and continuous (vessel propulsion) sound to the environment, but these sounds are considered secondary and are not expected to exceed typical background levels.

During Phase 1 of New England Wind, the Proponent is proposing to install monopile foundations with pile diameters up to 12 meters (m). In Phase 2 of New England Wind, an up to 13 m diameter monopile foundation pile is included in the Envelope. Although the maximum monopile diameter for Phase 2 is 13 m, it is expected that the average size of monopiles in Phase 2 will be close to 12 m. In both Phases, jacket foundations supported by 4 m diameter piles may also be installed. Therefore, for this acoustic analysis, JASCO Applied Sciences (JASCO) modeled the potential acoustic impact resulting from the installation of jacket foundations with 4 m diameter piles and 12 m and 13 m monopile foundations. The 12 m monopile was modeled at 5000 kJ and 6000 kJ hammer energy levels, and the 13 m monopile was modeled at 5000 kJ. Initial source modeling showed minimal difference between the 12 m and 13 m monopile. Given these similarities, the 13 m monopile was not modeled at 6000 kJ for this acoustic assessment and the 12 m monopile with 6000 kJ hammer energy was assumed to be a reasonable replacement in exposure calculations. Acoustic modeling was done at two locations representative of minimum and maximum water depths in the SWDA.

Forcing functions for pile driving were computed for each pile type using GRLWEAP, Pile Dynamics (2010). The resulting forcing functions were used as inputs to JASCO's pile driving source models to estimate equivalent acoustic source characteristics. Acoustic sound fields were estimated using JASCO's Marine Operations Noise model (MONM) and Full Wave Range Dependent Acoustic Model (FWRAM). To account for sound reduction resulting from noise attenuation systems such as bubble curtains, the modeling study included hypothetical broadband attenuation levels of 6, 12, and 18 dB for all impact pile driving.

Results of the acoustic modeling of piling activities are presented as single-strike ranges to a series of nominal sound pressure levels (SPL), sound exposure levels (SEL), and zero-to-peak pressure levels (PK). Range tables are provided for the modeled hammer energies for each pile diameter for an average summer sound speed profile and reported for different species' hearing group frequency weighting functions. These acoustic ranges to various sound isopleths were estimated for permitting and monitoring and mitigation purposes. JASCO's Animal Simulation Model Including Noise Exposure (JASMINE) was used to estimate the ranges within which 95% of simulated animals (animats) may be exposed above the relevant regulatory-defined thresholds for injury and behavioral response for marine species that may be near, or in the vicinity of, the proposed piling operations. JASMINE Exposure ranges ($ER_{95\%}$) are reported for each of the three pile diameters and for each species, using an average summer sound speed profile.

The potential acoustic exposure for marine species was estimated by finding the accumulated sound energy (SEL) and maximum SPL and PK pressure level each animat received over the course of the simulation. Exposure criteria to marine mammal injury thresholds are based on relevant regulatory-defined thresholds (NMFS 2018). Injury (FHWG 2008, Andersson et al. 2007, Wysocki et al. 2007, Mueller-Blenkle et al. 2010, Purser and Radford 2011, Popper et al. 2014, Finneran et al. 2017) and behavioral (NOAA 2005, McCauley et al. 2000) thresholds for fish and sea turtles are derived from the best available science. The projected number of animals exposed to sound levels above threshold values was determined by scaling the number of animals exposed to a criterion in the model to reflect local populations using the Duke University Habitat-based Marine Mammal Density Model (Roberts et al. 2016a, 2016b, 2017, 2018, 2021) estimates for each species.

Animal aversion to sound and mechanism for recovery (or resetting) were included in JASMINE for comparison purposes only. Results for aversive versus non-aversive simulations are provided for two sensitive species: North Atlantic right whale (NARW, *Eubalaena glacialis*) and harbor porpoise (*Phocoena phocena*). Mitigation measures were not included in the aversion simulation modeling but are considered in the COP impact assessment.

The analysis for all pile types included noise mitigation and predicted the number of individual animals potentially exposed to sound levels above SEL and PK injury threshold criteria for Phases 1 and 2 of New England Wind. For NARW, a simulation with conservative assumptions and no mitigation other than 10 dB of noise attenuation resulted in fewer than four potential injurious exposures total combined for both Phases. Results from exposure simulations show that SEL threshold criteria may be exceeded at approximately 3.16 km.

Using the modeled sound fields in combination with behavioral thresholds and animal density data, sound levels were predicted to exceed behavioral threshold levels for a low number of individual animals for most species using mean animal densities. The model results predicted that fewer than 11 NARW might be exposed to levels of sound capable of eliciting behavioral response assuming 10 dB noise attenuation. The exposure range for NARW could range up to 6.0 km. In studies of mysticetes, received levels, distance from the source, and behavioral context are known to influence the probability of behavioral response (Dunlop et al. 2017).

All species of sea turtles that may be present in the SWDA are listed as threatened or endangered. Many species of sea turtle prefer coastal waters; however, both the loggerhead and leatherback are known to occupy deep water habitats. The SWDA falls within the critical habitat for loggerhead sea turtles. Impact pile driving produces low frequency sounds, with most energy below 1 kHz, which is within the hearing range of sea turtles. Sea turtle injury is evaluated using the dual criteria (PK and SEL) suggested by Finneran et al. (2017) and sea turtle behavior is evaluated using the 175 dB re 1 µPa SPL threshold (McCauley et al. 2000, Finneran et al. 2017). Using abundance numbers calculated from density data, less than one sea turtle was predicted to receive an acoustic exposure above injury threshold criteria with exposure ranges up to 200 m.

The Proponent will implement monitoring and mitigation measures including time of year restrictions, piling energy ramp up, use of Protected Species Observers (PSOs) and Passive Acoustic Monitoring (PAM), and species-specific protective zones. The Proponent plans to implement additional enhanced monitoring and mitigation measures identified through consultation with regulatory agencies to further reduce the potential for negative impacts from anthropogenic sound to marine fauna. After mitigative measures are implemented, the potential residual risk of impacts is expected to be significantly reduced.

Acronyms and Abbreviations

AMAPPS	Atlantic Marine Assessment Program for Protected Species
ANSI	American National Standards Institute
ASA	Acoustical Society of America
ASA	Acoustical Society of America
BIA	Biologically Important Area
BOEM	Bureau of Ocean Energy Management
CeTAP	Cetacean and Turtle Assessment Program
COP	Construction and Operations Plan
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPA	closest point of approach
dB	decibel
DP	dynamic positioning
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
$ER_{95\%}$	95% Exposure Range (defined in Section 2.7)
ER_{max}	maximum Exposure Range (defined in Section 2.7)
ESA	Endangered Species Act
ESP	electrical service platform
ft	feet
FWRAM	Full Wave Range Dependent Acoustic Model
G&G	Geophysical and geotechnical
GARFO	Greater Atlantic Regional Fisheries Office
h	hour
HESS	High Energy Seismic Survey
HF	high frequency (cetacean hearing group)
HVAC	high-voltage alternating current
Hz	hertz
IHA	Incidental Harassment Authorization
in	inch
ISO	International Standards Association
ISO-NE	ISO New England
IWC	International Whaling Commission
JASMINE	JASCO Animal Simulation Model Including Noise Exposure
kg	kilogram
kHz	kilohertz
kJ	kilojoule
km	kilometer
km^2	square kilometer
L_E	cumulative sound exposure level
$L_{E,24h}$	cumulative 24-hour sound exposure level
LF	low frequency (cetacean hearing group)
L_p	sound pressure level
L_{pk}	peak sound pressure level
m	meter
m/s	meter per second
MA	Massachusetts
MF	mid-frequency (cetacean hearing group)
mi	mile
μPa	micropascal
MMPA	Marine Mammal Protection Act
MN	meganewton
MONM	Marine Operations Noise Model
NARW	North Atlantic right whale
NAS	noise abatement system
NEFSC	Northeast Fisheries Science Center
NLPSC	Northeast Large Pelagic Survey Collaborative
NM	nautical mile
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NODE	US Navy Operating Area Density Estimate
NSF	National Science Foundation
O&M	operations and maintenance
OBIS-SEAMAP	Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations
OCS	Outer Continental Shelf
OECC	Offshore Export Cable Corridor
OSP	Optimum Sustainable Population
PAM	passive acoustic monitoring
Park City Wind	Park City Wind, LLC
PDF	probability distribution function

PDSM	Pile Driving Source Model
PK	peak sound pressure level
PSO	Protected Species Observer
PTS	permanent threshold shift
PW	phocid in water (hearing group)
$R_{95\%}$	95% acoustic Range (defined in 5.3.F.5)
RCS	reactive compensation station
RI	Rhode Island
R_{max}	maximum acoustic Range (defined in 5.3.F.5)
rms	root mean square
RWSAS	Right Whale Sighting Advisory System
RWSAS	Right Whale Sightings Advisory System
SAR	stock assessment reports
SEFSC	Southeast Fisheries Science Center
SEL	sound exposure level
SELcum	cumulative sound exposure level
SERDP-SDSS	Strategic Environmental Research and Development Program Spatial Decision Support System
SPL	sound pressure level
SPUE	sightings per unit effort
SRTM	Shuttle Radar Topography Mission
SWDA	Southern Wind Development Area
TP	transition piece
TTS	temporary threshold shift
U.S.C.	United States Code
US	United States
USFWS	US Fish and Wildlife Service
WDA	Wind Development Area
WEA	Wind Energy Area
WTG	wind turbine generator

1. Overview of Assessed Activity

1.1. New England Wind Summary

New England Wind is the proposal to develop offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0534 along with associated offshore and onshore cabling, onshore substations, and onshore operations and maintenance (O&M) facilities.

New England Wind will be developed in two Phases with a maximum of 130 wind turbine generator (WTG) and electrical service platform (ESP) positions. Two positions may potentially have co-located ESPs (i.e., two foundations installed at one grid position[3]), resulting in 132 foundations. Four or five offshore export cables will transmit electricity generated by the WTGs to onshore transmission systems in the Town of Barnstable, Massachusetts. Figure 1 provides an overview of New England Wind. Park City Wind LLC, a wholly owned subsidiary of Avangrid Renewables, LLC, is the Proponent and will be responsible for the construction, operation, and decommissioning of New England Wind.

Species that occur within the United States (US) Atlantic Exclusive Economic Zone (EEZ) are discussed generally with an evaluation of their likely occurrence in and near the SWDA, while species more likely to be present in the vicinity of New England Wind Project activities are described in detail. Potential impacts are assessed for the maximum Project envelope of New England Wind South assuming a full build-out of Phase 1 (also known as Park City Wind) and Phase 2 (also known as Commonwealth Wind) over multiple years, including up to 132 wind turbine generator (WTG)/electrical service platform (ESP) foundations.

New England Wind's offshore renewable wind energy facilities are located immediately southwest of the Vineyard Wind 1 Project in Lease Area OCS-A 0501. New England Wind will occupy all of Lease Area OCS-A 0534 and potentially a portion of Lease Area OCS-A 0501 in the event that Vineyard Wind 1 does not develop "spare" or extra positions included in Lease Area OCS-A 0501 and Vineyard Wind 1 assigns those positions to Lease Area OCS-A 0534. For the purposes of the Construction and Operations Plan (COP), the Southern Wind Development Area (SWDA) is defined as all of Lease Area OCS-A 0534 and the southwest portion of Lease Area OCS-A 0501, as shown in Figure 1.

The SWDA may be approximately 411–453 square kilometers (km^2) (101,590–111,939 acres) in size depending upon the final footprint of Vineyard Wind 1. At this time, the Proponent does not intend to develop the two positions in the separate aliquots located along the northeastern boundary of Lease Area OCS-A 0501 as part of New England Wind. The SWDA (excluding the two separate aliquots that are closer to shore) is just over 32 kilometers (km) (20 miles [mi]) from the southwest corner of Martha's Vineyard and approximately 38 km (24 mi) from Nantucket.[4] The WTGs and ESPs in the SWDA will be oriented in an east-west, north-south grid pattern with one nautical mile (NM) (1.85 km) spacing between positions.

3 If co-located ESPs are used, each ESP's monopile foundation would be located within 76 m (250 ft) of one of the potential ESP grid locations (i.e. the monopiles would be separated by up to 152 m [500 ft]).

4 Within the SWDA, the closest WTG is approximately 34 km (21 mi) from Martha's Vineyard and 40 km (25 mi) from Nantucket.

Each Phase of New England Wind will be developed and permitted using a Project Design Envelope (the "Envelope"). This allows the Proponent to properly define and bracket the characteristics of each Phase for the purposes of environmental review while maintaining a reasonable degree of flexibility with respect to the selection of key components, such as the WTGs, foundations, offshore cables, and ESPs. To assess potential impacts and benefits to various resources, a two impact piling construction schedules were established considering the Envelope parameters for each Phase that have the potential to cause the greatest effect. For some resources, this approach overestimates potential environmental impacts as the maximum design scenario is not the scenario the Proponent is likely to execute.

Phase 1 of New England Wind (Park City Wind)

Phase 1, also known as Park City Wind, will be developed immediately southwest of the Vineyard Wind 1 Project. The Phase 1 Envelope allows for 41 to 62 WTGs and one or two ESP(s). Depending upon the capacity of the WTGs, Phase 1 will occupy 150–231 km^2 (37,066–57,081 acres) of the SWDA. The Phase 1 Envelope includes two WTG foundation types: monopiles and piled jackets. Strings of WTGs will connect with the ESP(s) via a submarine inter-array cable transmission system. The ESP(s) will include step-up transformers that increase the voltage of power generated by the WTGs prior to transmission and other electrical equipment. The ESP(s) will also be supported by a monopile or jacket foundation. Two high-voltage alternating current (HVAC) offshore export cables up to 101 km (54 NM) in length (per cable) installed within the SWDA and an Offshore Export Cable Corridor (OECC) will transmit electricity from the ESP(s) to a landfall site at the Craigville Public Beach or Covell's Beach in the Town of Barnstable. Underground onshore export cables, located principally in roadway layouts, will connect the landfall site to a new Phase 1 onshore substation in Barnstable. Grid interconnection cables will then connect the Phase 1 onshore substation to the ISO New England (ISO-NE) electric grid at Eversource's existing 345 kilovolt substation in West Barnstable.

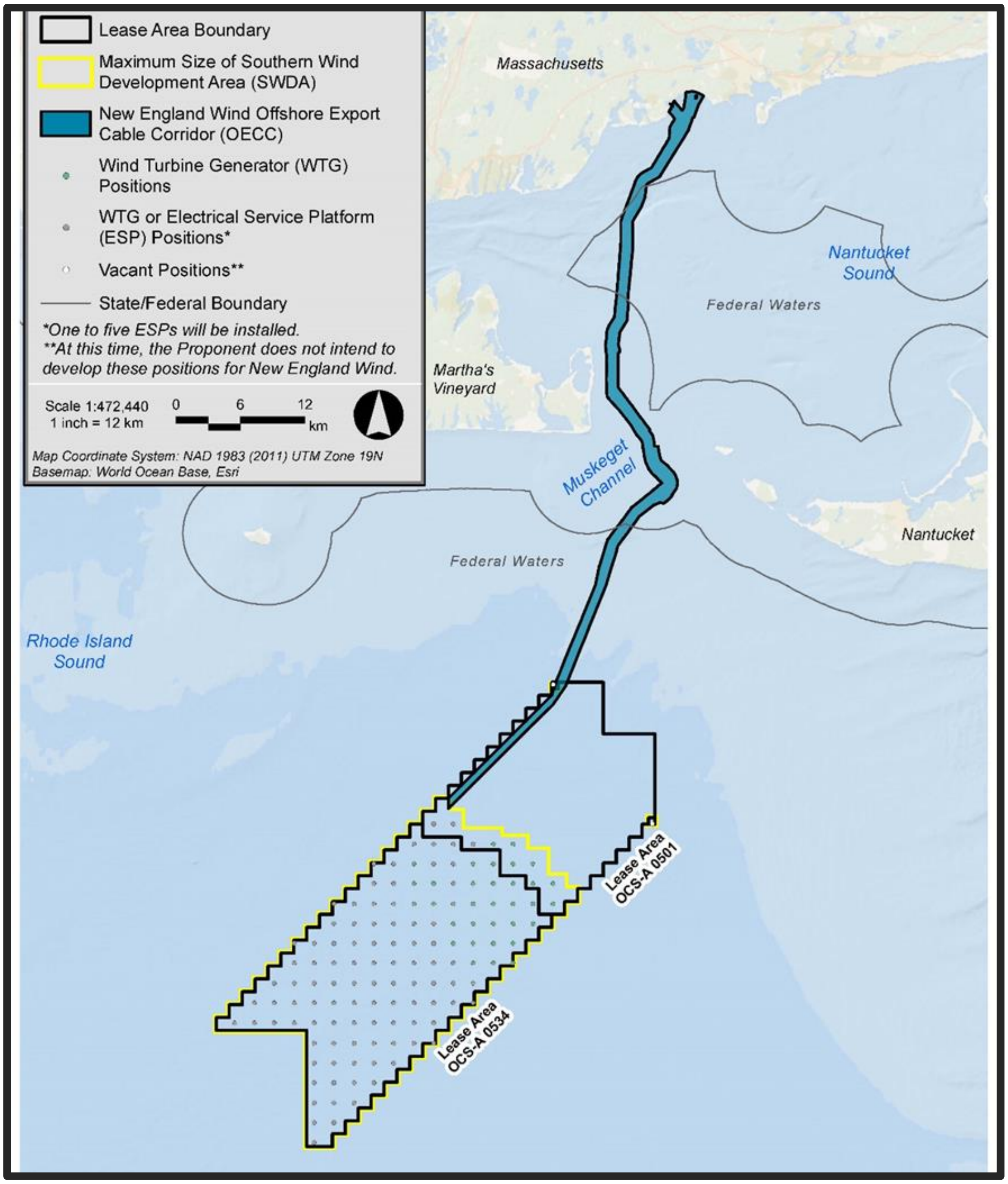

Figure 1. Site of the proposed New England Wind Project in Southern Wind Development Area (SWDA) (Lease Area OCS-A 0534).

Phase 2 of New England Wind (Commonwealth Wind)

Phase 2, also known as Commonwealth Wind, will occupy the remainder of the SWDA. Phase 2 may include one or more Projects, depending on market conditions. The footprint and total number of WTG and ESP positions in Phase 2 depends upon the final footprint of Phase 1; Phase 2 is expected to contain 64 to 88 WTG/ESP positions (up to three positions will be occupied by ESPs) within an area ranging from 222–303 km^2 (54,857–74,873 acres). The Phase 2 Envelope includes three general WTG foundation types: monopiles, jackets (with piles or suction buckets), or bottom-frame foundations (with piles or suction buckets). Inter-array cables will transmit electricity from the WTGs to the ESP(s). The ESP(s) will also be supported by a monopile or jacket foundation (with piles or suction buckets).

Two or three HVAC offshore export cables, each with a maximum length of 116–124 km (63–67 NM) per cable, will transmit power from the ESP(s) to shore. The Proponent intends to install all Phase 2 offshore export cables within the same OECC as the Phase 1 cables from the northwestern corner of the SWDA to within approximately 2–3 km (1–2 mi) of shore, at which point the OECC for Phase 2 will diverge to reach the Dowses Beach Landfall Site and/or Wianno Avenue Landfall Site in Barnstable. However, the Proponent has also identified two variations of the Phase 2 OECC in the event that technical, logistical, grid interconnection, or other unforeseen issues arise during the COP review and engineering processes that preclude one or more Phase 2 offshore export cables from being installed within all or a portion of the OECC. These variations of the Phase 2 OECC—the Western Muskeget Variant and the South Coast Variant—are shown on Figure 2.

Underground onshore export cables, located primarily within in roadway layouts, will connect the landfall site(s) to one or two new onshore substations in the Town of Barnstable. Grid interconnection cables will then connect the onshore substation site(s) to the West Barnstable Substation. If the Phase 2 OECC South Coast Variant is employed and electricity generated by Phase 2 is delivered to a second grid interconnection point, Phase 2 could include one onshore transmission system in Barnstable and/or an onshore transmission system(s) in proximity to the second grid interconnection point.

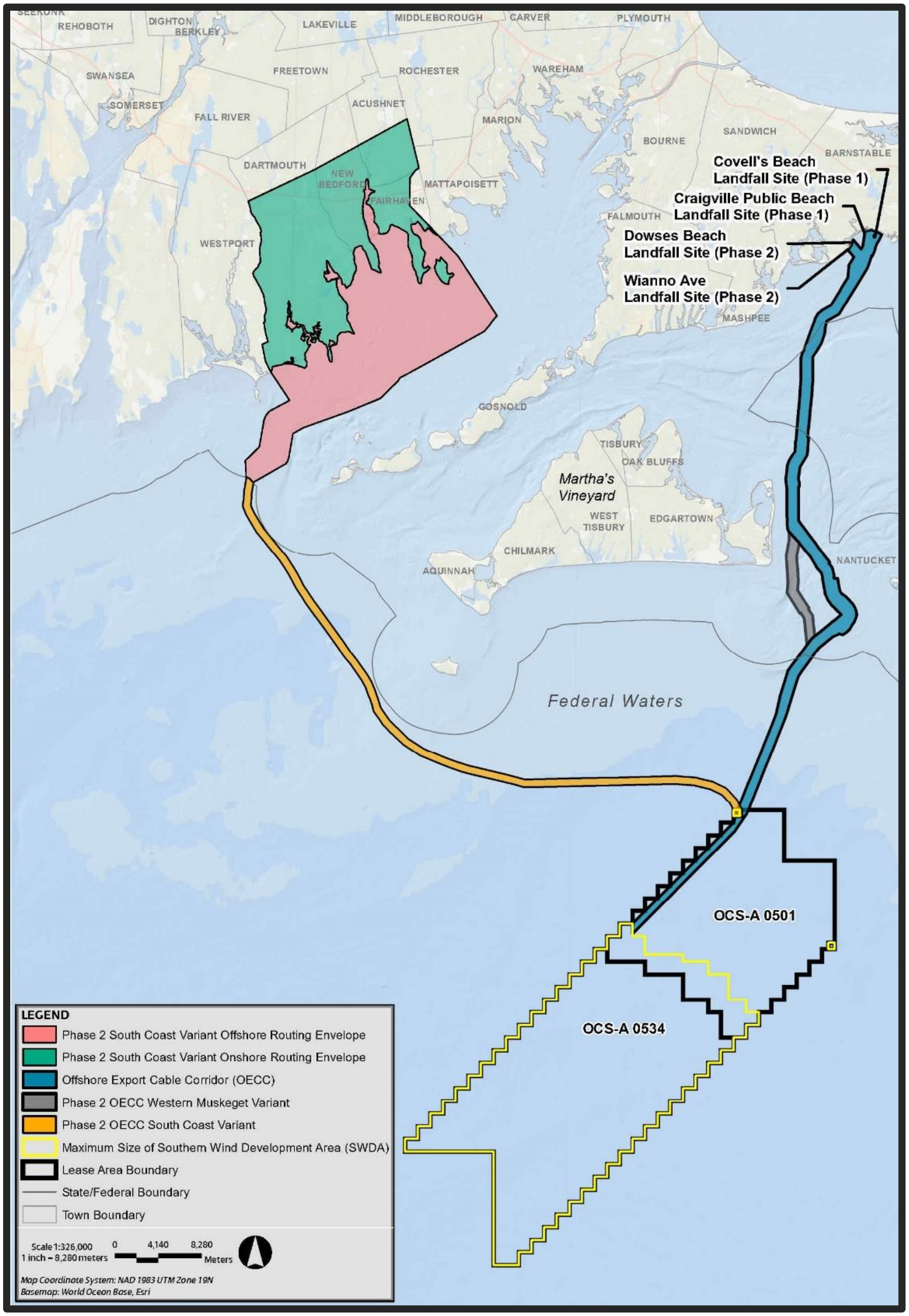

Figure 2. Phase 2 offshore export cable variants.

For both Phases, to support construction and operation activities, the Proponent will use a combination of North Atlantic ports in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and/or Canada. During appropriate time periods New England Wind-related vessels traveling to/from Salem Harbor will transit at 18.4 km per hour (10 knots) or less within NOAA-designated North Atlantic right whale critical habitat and outside critical habitat.

The primary sound source associated with the New England Wind Project is impact (impulsive) pile driving during foundation installation in the construction phase. Other sound sources include potential vibratory pile setting, which may be required during installation before impact hammering begins to ensure the pile is stable in the seabed and level for impact hammering; potential drilling, which may be required during pile installation to remove boulders and in cases of pile refusal; high-resolution geophysical (HRG) surveys to verify site conditions, ensure proper installation of components, and inspect depth of cable burial or foundations; and potential detonation of unexploded ordnance (UXO) if encountered and avoidance, physical removal, or alternative combustive removal techniques (e.g., deflagration) are not feasible. Other activities associated with cable-laying and construction vessels could contribute non-impulsive (dredging, dynamic positioning [DP] thrusters) and continuous (vessel propulsion, turbine operation) sound to the environment, but these sounds are considered secondary and are not expected to exceed typical background levels. Vessel noise will continue into the operations and maintenance, and decommissioning phases of the Project, but to a lesser extent than during construction. The sound level that results from turbine operation is of low intensity (Madsen et al. 2006), with energy concentrated at low frequencies (below a few kilohertz) (Tougaard et al. 2008).

During Phase 1 of New England Wind, the Proponent is proposing to install monopile foundations with pile diameters up to 12 m. In Phase 2 of New England Wind, a monopile foundation pile up to 13 m diameter is included in the Envelope. In both Phases, jacket foundations supported by 4 m diameter piles may also be installed.

Potential impacts are assessed for the maximum size of New England Wind assuming total build-out of Phases 1 and 2 over multiple years. Specifically, the assessment considers 132 foundations: 130 WTG/ESP grid positions, with two positions potentially having co-located ESPs (i.e., two monopile foundations installed at one grid position[5]).[6]

For this acoustic analysis, JASCO Applied Sciences (JASCO) modeled the potential acoustic impact resulting from monopile and jacket foundations. Following consultation with BOEM, 12 m monopiles were modeled for both Phases 1 and 2 with the majority of the piles being 12 m in diameter. The 13 m was modeled for Phase 2. A modeling comparison of the 12 and 13 m diameter monopile installed with the same maximum hammer energy had similar results. The maximum jacket foundation pile size included in both Phases (4 m [13 ft]) was also assessed.

[5] If co-located ESPs are used, each ESP's monopile foundation would be located within 76 m (250 ft) of one of the potential ESP grid locations (i.e. the monopiles would be separated by up to 152 m [500 ft]).

[6] A total of 132 foundations are presently proposed, which includes 130 WTG/ESP grid positions with two positions potentially having co-located ESPs (i.e., two foundations installed at one grid position). New England Wind previously also included one additional foundation for a potential reactive compensation station (RCS), bringing the total to 133 foundations. All hydroacoustic modeling was conducted for 133 foundations prior to the elimination of the potential RCS, which reduced the number of foundations to 132. The reduction to 132 foundations was determined to have a negligible effect on the predicted number of exposures, so the modeling was not redone.

1.2. Modeling Scope and Assumptions

The objectives of this modeling study were to predict the acoustic ranges to regulatory-defined acoustic thresholds associated with injury and behavioral disturbance for various marine fauna, including marine mammals, sea turtles, and fish that may occur near the SWDA during pile driving in the construction stage of the SWDA. JASCO also used the results of animal movement and exposure modeling to estimate potential exposure ranges ($ER_{95\%}$; see Section 2.7) and exposure numbers for marine mammals and sea turtles.

There are several potential anthropogenic sound sources associated with New England Wind; however, the primary sound source is impact (impulsive) pile driving during foundation installation in the construction stage. Foundation types proposed for the SWDA include monopiles, jacket, and bottom-frame foundations. Monopile foundations consist of a single pile (Figure 3), while jacket (Figure 5) and bottom-frame (Figure 6) foundations use three or four piles (pin piles) to secure the structure.

1.2.1. Monopile Foundation

A monopile is a single hollow cylinder fabricated from steel that is secured in the seabed. The monopiles modeled in the acoustic assessment are 12 m in diameter (an example monopile design for Phase 1 is shown on Figure 3), representing the maximum size monopile that may be installed in Phase 1 and an average size monopile in Phase 2. The maximum size monopile that may be installed in Phase 2 is a 13 m monopile (an example monopile design for Phase 1 is shown on Figure 4). The 12 m monopiles were modeled at 5000 kJ and 6000 kJ hammer energy levels, and the 13 m monopile was modeled at 5000 kJ. Initial source modeling showed minimal difference between the 12 m and 13 m monopiles. Given these similarities, the 13 m monopile was not modeled at 6000 kJ for this acoustic assessment, and the results for the 12 m monopiles for the 6000 kJ hammer are expected to be representative of the 13 m monopile at 6000 kJ. 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 3350 units installed (Wind Europe 2017). Monopile foundations may be used for both WTGs and ESPs in both Phases of New England Wind.

1.2.2. Jacket Foundation

The jacket foundation design concept typically consists of a large lattice jacket structure and an integrated transition piece (TP) (Figure 5 shows an example piled jacket design for a Phase 2 ESP). The jacket structure is supported/secured by three to four 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. The pile diameter modeled in the acoustic assessment was 4 m, which is the maximum size included in both the Phase 1 and Phase 2 Envelope.

1.2.3. Bottom-Frame Foundation

The bottom-frame foundation (for Phase 2 WTGs only) is similar to the jacket foundation, with the same maximum 4 m pile diameter (Figure 6) so was not modeled separately in the acoustic assessment. It is assumed that the potential acoustic impact of the bottom-frame foundation installation is equivalent to or less than that predicted for the jacket foundation.

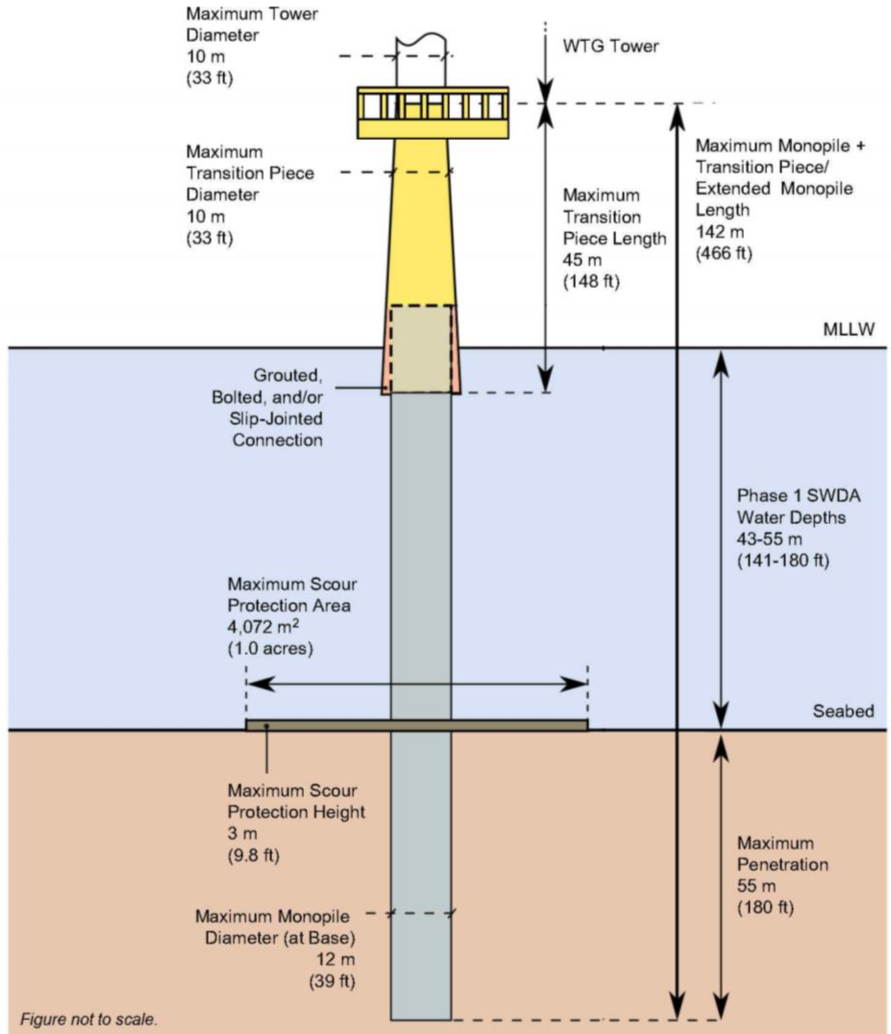

Figure 3. Schematic drawing of a 12 m monopile foundation for wind turbine generators (WTGs).

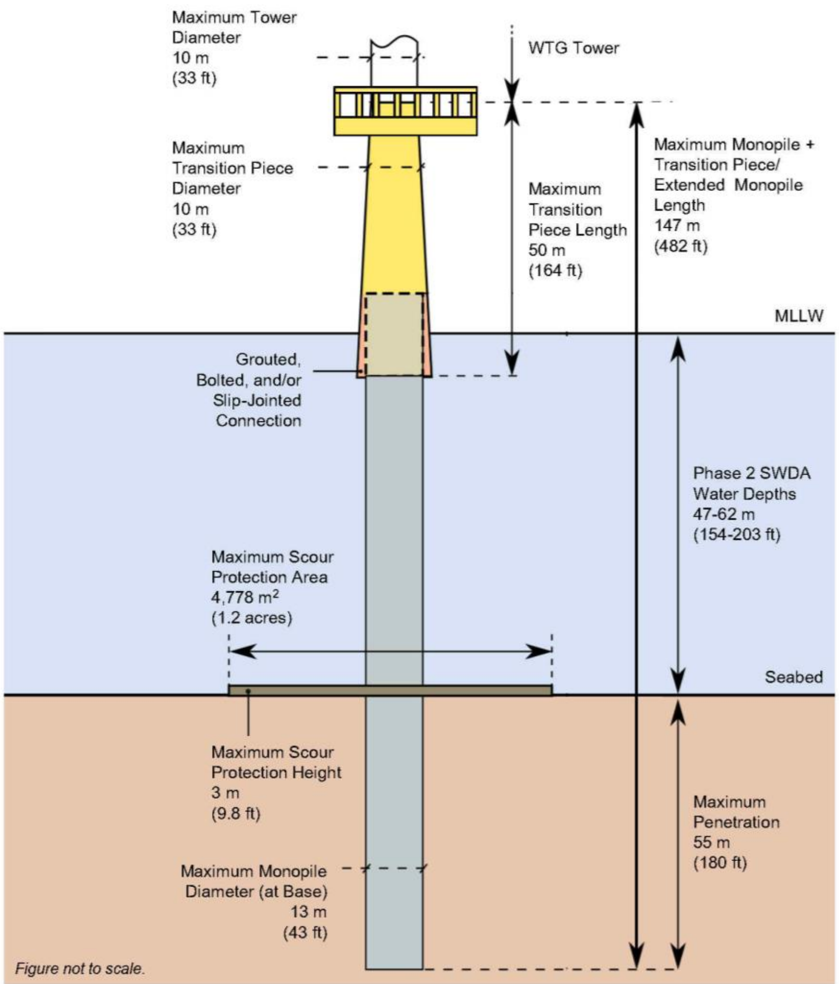

Figure 4. Schematic drawing of a 13 m monopile foundation for wind turbine generators (WTGs).

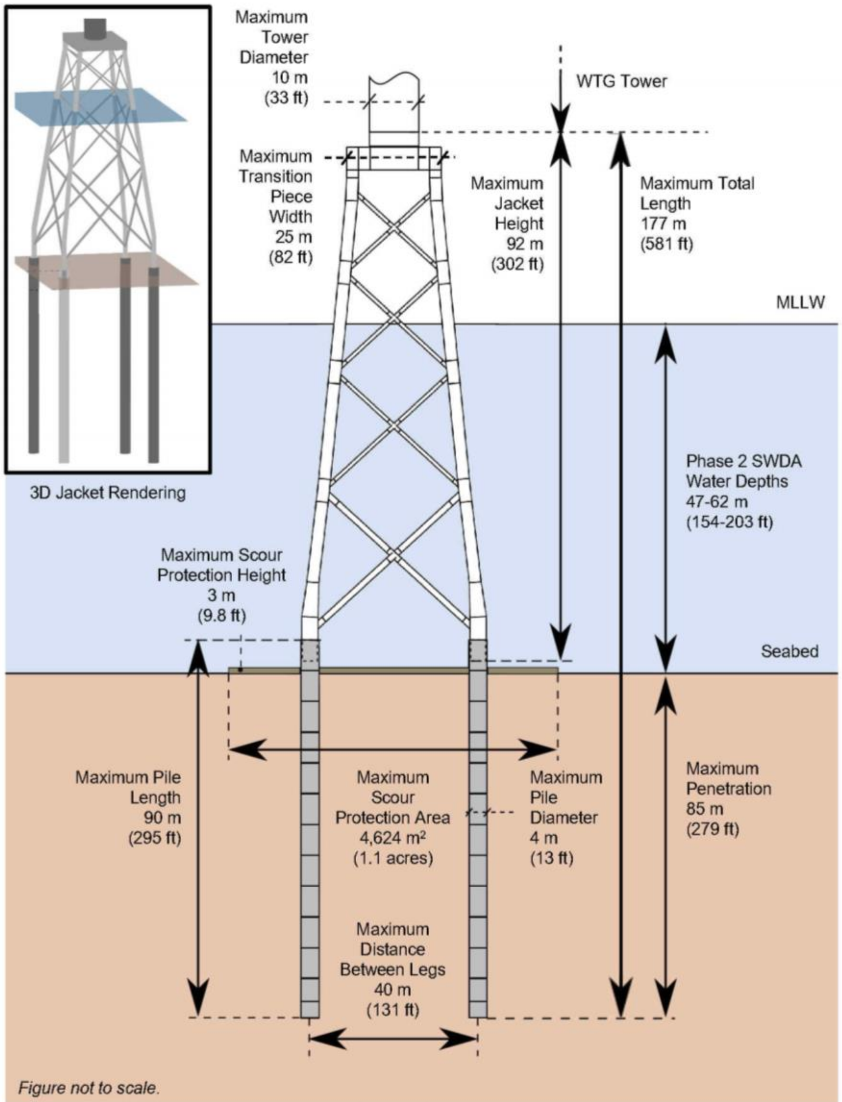

Figure 5. Schematic drawing of a jacket foundation.

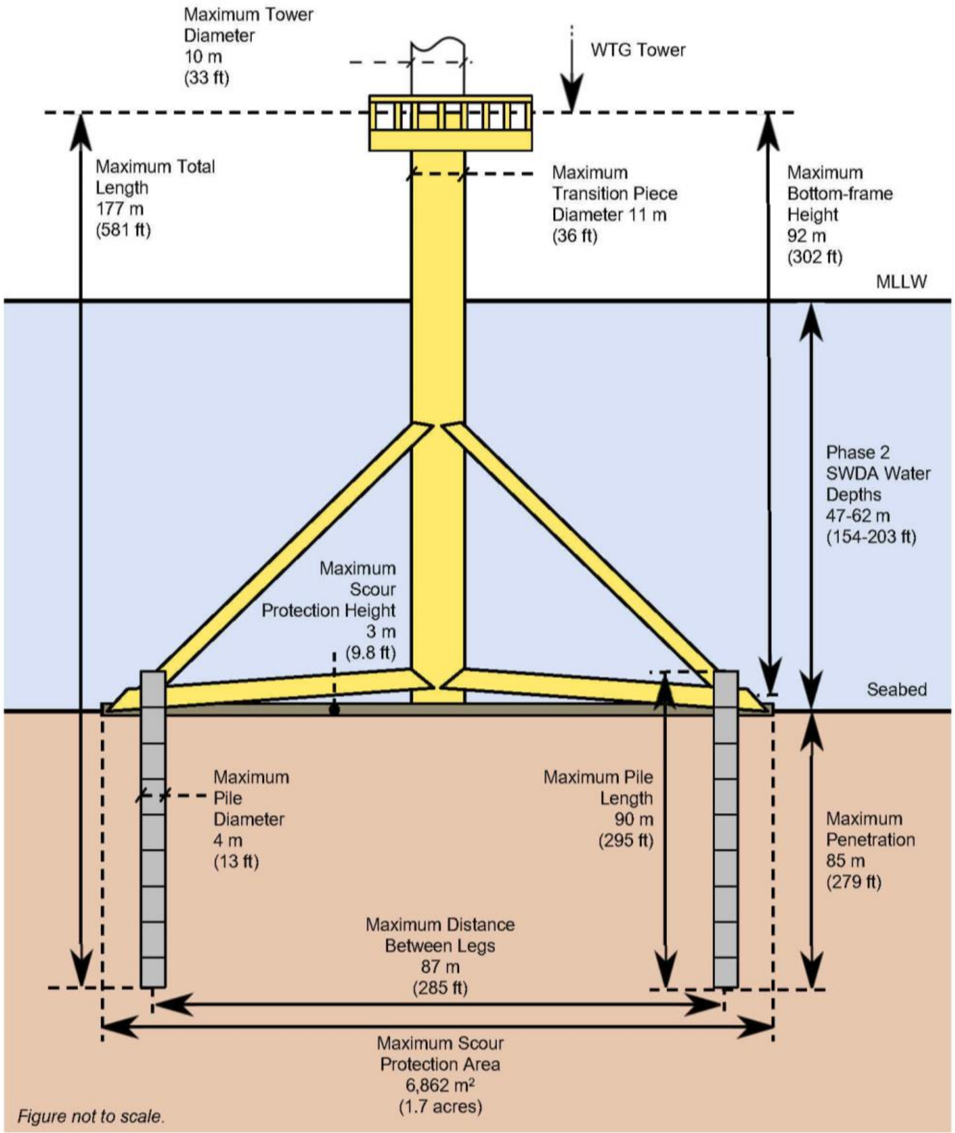

Figure 6. Schematic drawing of a bottom-frame foundation.

The amount of sound generated during foundation installation varies with the energy required to drive the piles to the desired depth, which depends on the sediment resistance encountered. Sediment types with greater resistance require hammers that deliver higher energy strikes and/or an increased number of hammer strikes relative to installations in softer sediment. Maximum sound levels from foundation installation usually occur during the last stage of pile driving (Betke 2008). The representative make and model of impact hammers, and the representative hammering energy schedule used in the acoustic modeling effort were provided by the Proponent and two potential Project hammer suppliers. Key modeling assumptions for monopile and jacket foundations are provided in Appendix B. The representative hammer energy schedule is detailed in Table 1. Both monopile and jacket foundation piles are modeled with a vertical installation using a finite-difference structural model of pile vibration based on thin-shell theory. The acoustic assessment assumed no concurrent piling. Additional modeling details are provided in Appendix B of this report.

1.2.4. Modeled Foundation Parameters

The Proponent is proposing to install up to 132 WTG/ESP foundations in the SWDA. Due to the range of buildout scenarios for Phases 1 and 2 where certain parts of the SWDA could be included in either Phase, the total buildout of New England Wind was considered in the modeling effort (i.e., a total buildout of 132 WTG/ESP foundations). While a total of 132 foundations are presently proposed, New England Wind previously also included one additional foundation for a potential reactive compensation station (RCS), bringing the total to 133 foundations. All hydroacoustic modeling was conducted for 133 foundations prior to the elimination of the potential RCS. The reduction to 132 foundations was determined to have a negligible effect on the predicted number of exposures, so the modeling was not redone and the below analysis is based on 133 foundations.

The New England Wind envelope consisted of 12 and 13 m WTG monopile foundations and 4 m jacket foundations. Modeling for monopile foundations assumed one and two piles per day whereas jacket foundations assumed four pin piles per day for each jacket. It was also assumed that no concurrent pile driving will be performed. The estimated pile driving schedules used for animal movement modeling were provided by the Proponent's engineers and created based on the number of expected suitable weather days available per month in which pile driving may occur and potential construction vessel sequencing. The number of suitable weather days per month was obtained from historical weather data. See Table 1 for a summary of the modeled foundations.

Table 1. Hammer energy and modeled number of blows at each energy level for each modeled foundation.

12 m monopile 5000 kJ hammer			13 m monopile 5000 kJ hammer			12 m monopile 6000 kJ hammer			4 m pin pile 3500 kJ hammer			13 m monopile 6000 kJ hammer[a]		
Energy level (kJ)	Strike count	Pile penetration (%)	Energy level (kJ)	Strike count	Pile penetration (%)	Energy level (kJ)	Strike count	Pile penetration (%)	Energy level (kJ)	Strike count	Pile penetration (%)	Energy level (kJ)	Strike count	Pile penetration (%)
1000	690	25	**1000**	745	25	**1000**	750	25	**525**	875	25	**1000**	850	25
1000	1930	25	**1000**	2095	25	**2000**	1250	25	**525**	1925	25	**2000**	1375	25
2000	1910	20	**2000**	2100	20	**3000**	1000	20	**1000**	2165	14	**3000**	1100	20
3000	1502	20	**3000**	1475	20	**4500**	1000	20	**3500**	3445	26	**4500**	1100	20
5000	398	10	**5000**	555	10	**6000**	500	10	**3500**	1395	10	**6000**	550	10
Total	6430	100	**Total**	6970	100	**Total**	4500	100	**Total**	9805	100	**Total**	4975	100
Strike rate		30.0 bpm	**Strike rate**		30.0 bpm	**Strike rate**		25.0 bpm	**Strike rate**		30.0 bpm	**Strike rate**		27.6 bpm

[a] Although the project may install the 13 m monopiles at a maximum of 6000 kJ, this is not modeled beyond acoustic source modeling (see Section 4.1) and is not considered in the construction schedules (see Tables 3 and 4).

1.2.5. Acoustic Environment

New England Wind is located in a continental shelf environment characterized by predominantly sandy seabed sediments. Water depths in the Southern Wind Development Area vary between 42–62 m. From May through October, the average temperature of the upper 10–15 m of the water column is higher, resulting in an increased surface layer sound speed. This creates a downward refracting environment in which propagating sound interacts with the seafloor more than in a well-mixed environment. Increased wind mixing combined with a decrease in solar energy in November and December results in a sound speed profile that is more uniform with depth. The average summer sound speed profile was used in New England Wind acoustic propagation modeling. See Appendix F for more details on the environmental parameters used in acoustic propagation and exposure modeling.

1.2.6. Modeling Locations

Acoustic propagation modeling was conducted for 4 m diameter jacket foundation piles assuming a site (J1) in the central area of the SWDA in 53 m water depth. Two sites (M1 and M2) were chosen for modeling the 12 m diameter monopile foundations – M1 in the northwest section of the SWDA in 44 m water depth and M2 in the southeast section of the SWDA in 52 m water depth (Table 2; Figure 7). These locations were chosen based on the phasing plans of New England Wind, which involves the installation of 12 m diameter monopiles in Phase 1 and 13 m diameter monopiles in Phase 2, with jacket foundations planned for both phases. The 13 m diameter piles were only considered for modeling of the source functions for comparison with the 12 m diameter piles, which showed minimal difference in the forcing function and source spectra output for the two sizes. As the 12 m monopile represents the maximum size monopile for Phase 1 of New England Wind and the average size monopile for Phase 2, propagation modeling continued with the 12 m monopile. The water depth at the site locations were extracted from the bathymetry file provided by the Proponent and Shuttle Radar Topography Mission (SRTM), referred to as SRTM-TOPO15+ (Becker et al. 2009). Because of changes to the planned construction area which shifted the boundary of the SWDA farther south following completion of the modeling, one of the acoustic modeling locations and four of the animat modeling locations were located slightly north of the revised SWDA boundary. These modeling sites were not relocated since they remain representative of the average acoustic characteristics within the SWDA.

Table 2. Propagation modeling sampling locations used in the acoustic assessment.

Sound source	Site	Latitude (° N)	Longitude (° E)	Water depth (m)[a]
12 m monopile	M1	41.035501217	−70.571798180	44
13 m monopile	M2	40.834461320	−70.632933892	52
4 m pin pile	J1	40.934831948	−70.613405411	53

[a] Vertical datum for water depth is Earth Gravitational Model 1996 (EGM96).

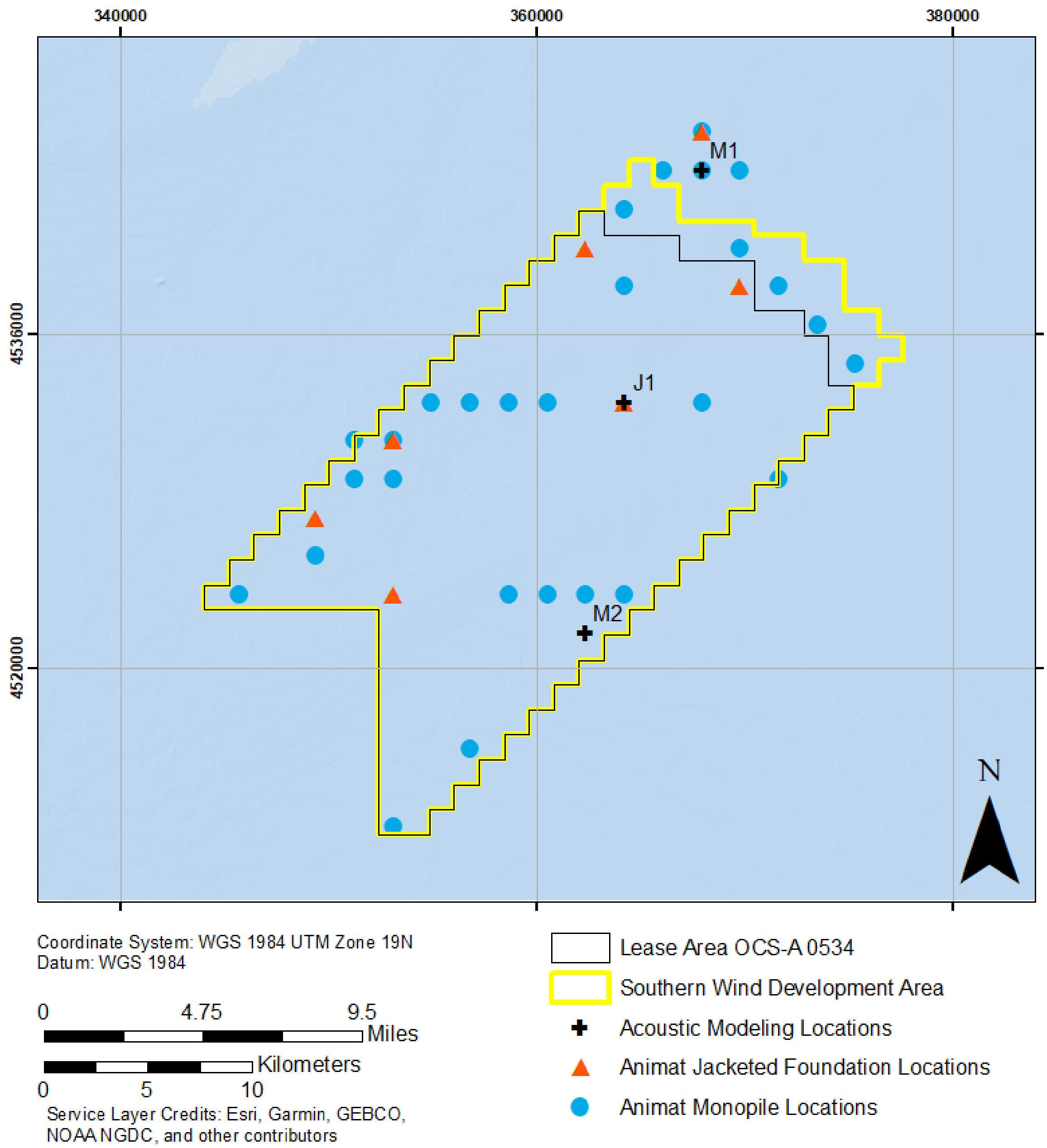

Figure 7. Project pile locations with acoustic propagation modeling and animal movement modeling locations (animat locations) highlighted in the Southern Wind Development Area (SWDA).

1.2.7. Assumed Piling Construction Schedule for Modeling

To allow some flexibility in the final design and during installation operations, two proposed construction schedules were used to evaluate potential impacts to marine mammals and sea turtles. Schedule A assumes that 89 monopile foundations and two jacket foundations are installed in Year 1 and up to 18 monopiles and 24 jacket foundations are installed in Year 2. The first year of Schedule A includes the potential installation of 13 m monopiles using a 6000 kJ hammer. This specific configuration was not modeled beyond acoustic source modeling because initial source modeling showed minimal difference between the 12 m and 13 m monopiles, and therefore the 12 m monopile with 6000 kJ hammer energy was assumed to be a reasonable replacement in exposure calculations. See Table 16 in Section 4.1 for a comparison of the broadband source levels between the 12 m and 13 m monopile.

Construction schedule A assumes that foundations for all of Phase 1 (Park City Wind) and a portion of Phase 2 (Commonwealth Wind) are installed in year 1, and that the remaining Phase 2 foundations are installed in year 2.

Schedule B is spread over 3 years where Year 1 includes 55 monopile and 3 jacket foundations and Years 2 and 3 include 53 and 22 jacket foundations, respectively. In years 2 and 3 of Schedule B, jacket foundations are assumed for all positions because they provide a conservative envelope for any of the assessed monopile foundations, up to and including a 13 m diameter monopile with a 6000 kJ hammer. Construction schedule B assumes that foundations for all of Phase 1 (Park City Wind) are installed in year 1 and that the Phase 2 (Commonwealth Wind) foundations are installed in years 2 and 3.

The construction schedules used to calculate exposures for the entire project duration are summarized in Tables 3 and 4. For construction schedules and animal movement modeling results separated by year, please reference Appendix H.2.

Table 3. Construction Schedule A, All Years Summed: The number of potential piling days per month under the maximum envelope used to estimate the total number of marine mammal and sea turtle acoustic exposures for New England Wind.

Construction month	12 m Monopile, 5000 kJ		12 m Monopile, 6000 kJ		13 m Monopile, 5000 kJ		4 m Pin Pile, 3500 kJ
	1 pile/day	2 piles/day	1 pile/day	2 piles/day	1 pile/day	2 piles/day	4 pin piles/day
May	4	0	4	0	0	0	0
June	2	5	0	3	0	0	0
July	0	9	0	4	0	0	0
August	0	9	0	0	0	0	8
September	0	1	0	0	1	6	9
October	0	0	0	0	0	6	6
November	0	0	0	0	0	3	2
December	0	0	0	0	4	0	1
Total	**6**	**24**	**4**	**7**	**5**	**15**	**26**

Table 4. Construction Schedule B, All Years Summed: The number of potential piling days per month under the maximum envelope used to estimate the total number of marine mammal and sea turtle acoustic exposures for New England Wind.

Construction month	12 m Monopile, 5000 kJ		4 m Pin Pile, 3500 kJ
	1 pile/day	2 piles/day	4 pin piles/day
May	4	0	2
June	6	4	13
July	0	7	19
August	1	5	20
September	0	3	14
October	1	1	6
November	2	0	3
December	1	0	1
Total	**15**	**20**	**78**

1.3. Other Sound Sources During Construction and Installation

The primary sources of underwater sound associated with New England Wind construction occur during the installation of monopile and jacket pile foundations. These include impact pile driving, potential vibratory setting of piles, and potential drilling used during pile installation to remove obstacles. Impact pile driving sounds are the focus of the modeling presented in the main text of this report. Vibratory setting of piles and drilling during pile installation were not modeled, but density-based exposure estimates of these two sound sources were calculated for marine mammals and are provided in Appendix K and Appendix L, respectively. Additionally, Appendix I provides exposure estimates of marine mammals for HRG survey sounds and Appendix J provides exposure estimates of marine mammals for potential UXO detonation.

1.3.1. Secondary Sound Sources

Secondary sound sources are anthropogenic sound sources that are only likely to cause behavioral responses and short-term stress in marine fauna. Secondary sound sources are expected to be of very low or low risk (see Table 5), and, because of their limited risk, a qualitative (instead of quantitative) evaluation of these sound sources was undertaken and is detailed for each source type below. For more information on the impacts of anthropogenic sounds to marine mammals and sea turtles during operations and maintenance of New England Wind, see Sections 6.7 and 6.8 of the COP.

Anthropogenic sounds from vessel traffic associated with New England Wind are likely to be similar in frequency characteristics and sound levels to existing commercial traffic in the region. Vessel sound may arise from cable laying operations, piling installation vessels, and transit into and out of the SWDA during construction. Potential sound 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 during normal operation. Robinson et al. (2011) concluded that because of the operation of the propulsion system, sound radiated at less than 500 Hz is similar to that of a merchant vessel “travelling at modest speed (i.e., between 8 and 16 knots)” (for self-propelled dredges). During dredging operations, additional sound energy is generated by the impact and abrasion of the sediment passing through the draghead, suction pipe, and pump is radiated in the 1–2 kHz frequency band. These acoustic 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 sound generated by using vibracores, CPTs, and drilling small boreholes diminishes below the NMFS Level B harassment thresholds (120 dB for continuous sound sources) relatively near to the sound source and is unlikely to cause harassment to marine mammals (NMFS 2009, Reiser et al. 2011, TetraTech 2014). Based on these studies, sounds from cable laying activities are anticipated to be comparable to potential vessel sound impacts expected in the SWDA for other general construction and installation vessel activities, and commercial fishing and shipping activities.

It is estimated that an average of approximately 30 vessels may operate in the SWDA or along the OECC at any given time during the construction of each Phase of New England Wind. Some of these vessels may remain in the SWDA, holding their positions using DP thrusters during pile driving or other construction activities. The dominant underwater sound source on DP vessels arises from cavitation on the propeller blades of the thrusters (Leggat et al. 1981). The sound produced from the propellers is proportional to the number of blades, the propeller diameter, and the propeller tip speed. Sound levels generated by vessels under DP are dependent on the operational state and weather conditions. Zykov et al. (2013) and McPherson et al. (2019) report a maximum broadband sound pressure level (SPL) for numerous vessels with varying propulsion power under DP of up to 192 dB re 1 µPa (for a pipe-laying vessel in deep water).

All vessels emit sound from propulsion systems while in transit. Non-project vessel traffic in the SWDA includes recreational vessels, fishing vessels, cargo vessels, tankers, passenger vessels, and others. Marine mammals in the region surrounding the SWDA are regularly subjected to commercial shipping activity and would potentially be habituated to vessel sound as a result of this exposure (BOEM 2014b). Because sound from vessel traffic associated with construction activities is likely to be similar to background vessel traffic sound, potential risk of impacts from vessel sound to marine mammals is expected to be low relative to the risk of impact from pile-driving sound.

Table 5. Definitions of impact risk, exposure, and vulnerability used in impact assessment.

Risk level	Exposure	Individual vulnerability
Very low	• No or limited observations of the species in or near the proposed Project infrastructure and acoustic exposure zones (low expected occurrence), and/or • Species tends to occur mainly in other habitat (e.g., deeper water or at lower/higher latitudes), and/or • No indication that the Lease Area has regional importance as it pertains to a particular species life history characteristics	• Literature and/or research suggest the affected species and timing of the stressor are not likely to overlap, and/or • Literature suggests limited sensitivity to the stressor, and/or • Little or no evidence of impacts from the stressor in the literature
Low	• Few observations of the species in or near the proposed Project infrastructure and noise exposure zones (occasional occurrence), and/or • Seasonal pattern of occurrence in or near the proposed Project infrastructure and acoustic exposure zones	• Literature and/or research suggest the affected species and timing of the stressor may overlap and/or • Literature suggests some low sensitivity to the stressor and/or • Literature suggests impacts are typically short-term (end within days or weeks of exposure) and/or • Literature describes mitigation/best management practices (BMPs) that reduce risk
Moderate	• Moderate year-round use of the areas associated with proposed Project infrastructure and acoustic exposure zones	• Literature and/or research suggest the affected species and timing of the stressor are likely to overlap, and/or • Literature and/or research suggest a moderate susceptibility to the stressor exists in the region and/or from similar activities elsewhere, and • Literature does not describe mitigation/BMPs that reduce risk
High	• Significant year-round use of the areas associated with proposed Project infrastructure and acoustic exposure zones	• Literature and/or research suggest the affected species and timing of the stressor will overlap, and • Literature suggests significant use of wind turbine areas, export cable corridor, and acoustic exposure zones for feeding, breeding, or migration, and • Literature does not describe mitigation/BMPs that reduce risk

2. Acoustic Modeling Methods Summary

Piles deform when driven with impulsive impact hammers, creating a bulge that travels down the pile and radiates sound into the surrounding air, water, and seabed. This sound may be received as a direct transmission from the sound source to biological receivers (such as marine mammals, sea turtles, and fish) through the water or as the result of reflected paths from the surface or re-radiated into the water from the seabed (Figure 8). Sound transmission depends on many environmental parameters, such as the sound speeds in water and substrates; 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.

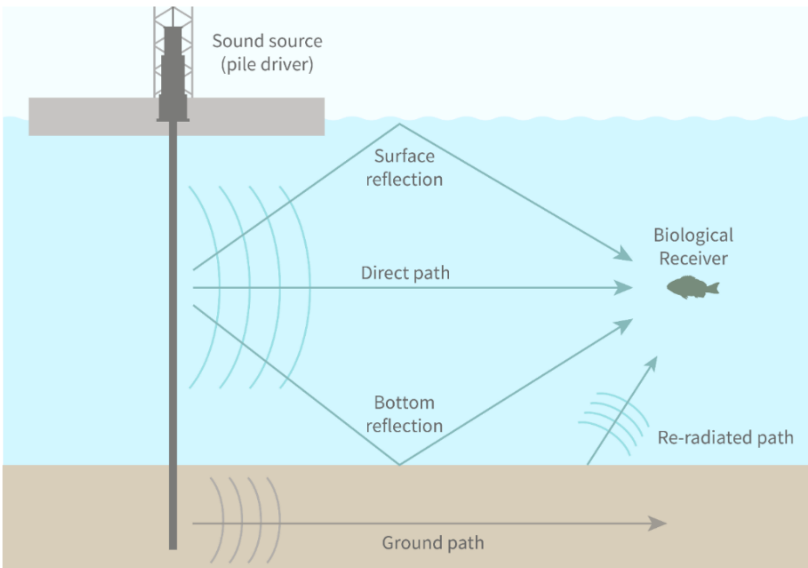

Figure 8. Sound propagation paths associated with pile driving (adapted from Buehler et al. 2015).

To estimate potential effects (e.g., injury, behavioral disturbance) to marine fauna from anthropogenic sound generated during New England Wind pile installation, 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).
2. Acoustic propagation modeling using JASCO's Marine Operations Noise (MONM) and Full Wave Range Dependent Acoustic (FWRAM) Models 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. For higher frequencies, additional losses resulting from absorption were added to the transmission loss model.
3. Animal movement modeling integrated the computed sound fields with species-typical behavioral parameters (e.g., dive patterns, swim speed) in the JASCO Animal Simulation Model Including Noise Exposure (JASMINE) model to estimate received sound levels for the modeled animals (i.e., animats) that may occur in the operational area.
4. Estimated the number of potential injurious and behavioral level exposures based on pre-defined acoustic thresholds/criteria (e.g., NMFS 2018).

2.1. Source Modeling

JASCO's physical model of pile vibration and near-field sound radiation (MacGillivray 2014) was used in conjunction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010) to predict source levels associated with impact pile driving activities. The sound radiating from the pile itself was simulated using a vertical array of discrete point sources. These models account for several parameters that describe the operation—pile type, material, size, and length—the pile driving equipment, and approximate pile penetration depth. See Appendix E for a more detailed description.

Forcing functions were computed for 4 m diameter jacket foundation piles and monopile foundations, with 12 m and 13 m diameter piles using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010). The model assumed direct contact between the representative hammers, helmets, and piles (i.e., no cushion material). The forcing functions serve as the inputs to JASCO's pile driving source models (PDSM) used to estimate equivalent acoustic source characteristics detailed in Appendix E. Decidecade spectral source levels for each pile type, hammer energy and modeled location, using an average summer sound speed profile are provided in Appendix F.

2.2. Sound Propagation Modeling

Acoustic propagation modeling used JASCO's Marine Operations Noise Model (MONM) and Full Wave Range Dependent Acoustic Model (FWRAM) that combine the outputs of the source model with the spatial and temporal environmental context (e.g., location, oceanographic conditions, and seabed type) to estimate sound fields. The lower frequency bands were modeled using MONM-RAM, which is based on the parabolic equation method of acoustic propagation modeling. For higher frequencies, additional losses resulting from absorption were added to the transmission loss model. See Appendix F for a more detailed description.

2.3. Sound Level Attenuation Methods

The main goal for mitigating potential impacts from pile driving sound on marine fauna is to minimize, as much as possible, the sound levels from the pile driving source. Doing so reduces the zone of potential impact, thus reducing the number of animals exposed and the sound levels to which they might be exposed. These reductions may be achieved with various technologies.

Noise abatement systems (NASs) are often used to decrease the sound levels in the water near a source by inserting a local impedance change that acts as a barrier to sound transmission. Attenuation by impedance change can be achieved through a variety of technologies, including bubble curtains, evacuated sleeve systems (e.g., IHC-Noise Mitigation System (NMS)), encapsulated bubble systems (e.g., HydroSound Dampers (HSD)), or Helmholtz resonators (AdBm NMS). The effectiveness of each system is frequency dependent and may be influenced by local environmental conditions such as current and depth. For example, the size of the bubbles determines the effective frequency band of an air bubble curtain, with larger bubbles needed for lower frequencies.

Small bubble curtains (bubble curtains positioned within a small radius around the pile) have been measured to reduce sound levels from ~10 dB to more than 20 dB but are highly dependent on water depth and current and how the curtain is configured and operated (Koschinski and Lüdemann 2013, Bellmann 2014, Austin and Li 2016). Larger bubble curtains tend to perform better and more reliably, particularly when deployed with two rings (Koschinski and Lüdemann 2013, Bellmann 2014, Nehls et al.

2016). A California Department of Transportation (CalTrans) study tested several small, single, bubble-curtain systems and found that the best attenuation systems resulted in 10–15 dB of attenuation. Buehler et al. (2015) concluded that attenuation greater than 10 dB could not be reliably predicted from small, single, bubble curtains because sound transmitted through the seabed and re-radiated into the water column is the dominant source of sound in the water for bubble curtains deployed immediately around (within 32 ft [10 m] of) the pile (Buehler et al. 2015).

A recent analysis by Bellmann et al. (2020) of NASs performance measured during impact driving for wind farm foundation installation provides expected performance for common NASs configurations. Measurements with a single bubble curtain and an air supply of 0.3 m^3/min resulted in 7 to 11 dB of broadband attenuation for optimized systems in up to 131 ft (40 m) water depth. Increased air flow (0.5 m^3/min) may improve the attenuation levels up to 11 to 13 dB (M. Bellmann, personal communication, 2019). Double bubble curtains add another local impedance change and, for optimized systems, can achieve 15 to 16 dB of broadband attenuation (measured in up to 131.25 ft [40 m] water depth). The IHC-NMS can provide 15 to 17 dB of attenuation but is currently limited to piles <8 m diameter. Other NASs such as the AdBm NMS achieved 6 to 8 dB (M. Bellmann, personal communication, 2019), but HSDs were measured at 10 to 12 dB attenuation and are independent of depth (Bellmann et al. 2020). Systems may be deployed in series to achieve higher levels of attenuation.

The NAS must be chosen, tailored, and optimized for site-specific conditions. NAS performance of 10 dB broadband attenuation was chosen for this study as an achievable reduction of sound levels produced during pile driving when one NAS is in use, noting that a 10 dB decrease means the sound energy level is reduced by 90%. For exposure modeling, several hypothetical broadband attenuation levels (0, 6, 10, and 12 dB) were included for comparison purposes, with 10 dB attenuation used to gauge the effects of noise reduction systems on the potential number of acoustic exposures and estimated exposure ranges, assuming this minimum achievable level of attenuation. The Proponent expects to implement noise attenuation mitigation technology to reduce sound levels by a target of approximately 12 dB or greater, which will significantly decrease the range over which pile driving sound will travel.

Potential mitigation measures that could be considered to achieve these sound reductions for New England Wind include equipment selection that is optimized for sound reduction such as an Integrated Pile Installer (i.e., a large metal tube through which a pile can guided and driven through), and underwater noise abatement systems (e.g., Hydro-sound Damper, AdBm encapsulated bubble sleeve), and/or bubble curtains, deployed near to the pile and farther from the source. For additional details on the potential impacts of varying levels of attenuation on sound propagation see Appendix G.

2.4. Acoustic Thresholds used to Evaluate Potential Impacts to Marine Mammals

The MMPA prohibits the take of marine mammals. The term “take” is defined 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 the Project operations. These are:

- **Level A**: any act of pursuit, torment, or annoyance that 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 New England Wind-associated sound sources, it is necessary to first establish the acoustic exposure criteria used by United States (US) regulators to estimate marine mammal takes. In 2016, NMFS issued a Technical Guidance document that provides acoustic thresholds for onset of PTS in marine mammal hearing for most sound sources, which was updated in 2018 (NMFS 2016, 2018). The Technical Guidance document also recognizes two main types of sound sources: impulsive and non-impulsive. Non-impulsive sources are further broken down into continuous or intermittent categories.

NMFS 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 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 acoustic analysis applies the most recent sound exposure criteria utilized by NMFS to estimate acoustic harassment (NMFS 2018).

Sound levels thought to elicit disruptive behavioral response are described using the SPL metric. NMFS currently uses behavioral response thresholds of 160 dB re 1 µPa for intermittent sounds and 120 dB re 1 µPa for continuous sounds for all marine mammal species (NOAA 2005, 2019). Alternative thresholds used in this acoustic assessments include a graded probability of response approach and take into account the frequency-dependence of animal hearing sensitivity (Wood et al. 2012). The SPL 160 dB re 1 µPa threshold (NOAA 2005, 2019) for impulsive sounds and the Wood et al. (2012) are used in this acoustic assessment. The publication of ISO 18405 Underwater Acoustics–Terminology (ISO 2017) provided a dictionary of underwater bioacoustics (the previous standard was ANSI and ASA S1.1-2013). In the remainder of this report, we follow the definitions and conventions of ISO (2017) except where stated otherwise (Table 6).

Table 6. Summary of relevant acoustic terminology used by United States (US) regulators and in the modeling report.

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

The SEL_{cum} metric used by the NMFS describes the sound energy received by a receptor over a period of 24 h. Accordingly, following the ISO standard, this will be denoted as SEL in this report, except for in tables and equations where L_E will be used.

2.4.1. 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 (Richardson et al. 1995, Wartzok and Ketten 1999, Southall et al. 2007, Au and Hastings 2008). While hearing measurements are available for a small number of species based on captive animal studies, there are no direct measurements of many odontocetes or any mysticetes. 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 (Houser et al. 2001, Parks et al. 2007, Tubelli et al. 2012, Cranford and Krysl 2015); vocalizations (see reviews in Richardson et al. 1995, Wartzok and Ketten 1999, Au and Hastings 2008); taxonomy; and behavioral responses to sound (Dahlheim and Ljungblad 1990, see review in Reichmuth et al. 2007). In 2007, Southall et al. proposed that marine mammals be divided into hearing groups. This division was updated in 2016 and 2018 by the NMFS using more recent best available science (Table 7).

Southall et al. (2019) published an updated set of Level A sound exposure criteria (i.e., for onset of TTS and PTS in marine mammals). While the authors propose a new nomenclature and classification for the marine mammal functional hearing groups, the proposed thresholds and weighting functions do not differ in effect from those proposed by NMFS (2018). The new hearing groups proposed by Southall et al. (2019) have not yet been adopted by NOAA. The NMFS (2018) hearing groups presented in Table 7 are used in this analysis.

Table 7. Marine mammal hearing groups (Sills et al. 2014, NMFS 2018).

Faunal group	Relevant species or species' groups	Generalized hearing range[a]
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)[b]		50 Hz to 36 kHz

[a] The generalized hearing range is for all species within a group. Individual hearing will vary.
[b] Sound from piling will not reach NMFS thresholds for behavioral disturbance of seals in air (90 dB [rms] re 20 μPa for harbor seals and 100 dB [rms] re 20 μPa for all other seal species) at the closest land-based sites where seals may spend time out of the water. Thus in-air hearing is not considered further.

2.4.2. Marine Mammal Auditory Weighting Functions

The potential for anthropogenic sound 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 and Turnpenny 1998, 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) (Southall et al. 2007, Erbe et al. 2016, Finneran 2016). Marine mammal auditory weighting functions for all hearing groups (Table 7) published by Finneran (2016) are included in the NMFS (2018) Technical Guidance for use in conjunction with corresponding permanent threshold shift (PTS [Level A]) onset acoustic criteria (Table 8).

The application of marine mammal auditory weighting functions emphasizes the importance of taking measurements and characterizing sound sources in terms of their overlap with biologically important frequencies (e.g., frequencies used for environmental awareness, communication, and the detection of predators or prey), and not only the frequencies that are relevant to achieving the objectives of the sound producing activity (i.e., context of sound source; NMFS 2018).

2.4.3. Marine Mammals Auditory Injury 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 hearing independent of duration, so an additional metric of peak pressure (PK) is also used to assess acoustic exposure injury risk. A PTS in hearing may be 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, and PTS onset may be extrapolated from TTS onset level and an assumed growth function (Southall et al. 2007). The NMFS (2018) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy accumulated over 24 h (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 8). If a non-impulsive sound has the potential to exceed the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

Table 8. Summary of relevant permanent threshold shift (PTS) onset acoustic thresholds for marine mammal hearing groups (NMFS 2018).

Faunal group	Impulsive signals[a]		Non-impulsive signals
	Unweighted L_{pk} (dB re 1 µPa)	Frequency weighted $L_{E,24h}$ (dB re 1 µPa^{2}s)	Frequency weighted $L_{E,\,24hr}$ (dB re 1 µPa^{2}s)
Low-frequency (LF) cetaceans	219	183	199
Mid-frequency (MF) cetaceans	230	185	198
High-frequency (HF) cetaceans	202	155	173
Phocid seals in water (PW)	218	185	201

[a] Dual metric acoustic thresholds for impulsive sounds: The largest isopleth result of the two criteria are used 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 have also been considered.

2.4.4. Marine Mammals Behavioral Response 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. It is recognized that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison et al. 2012). Due to the complexity and variability of marine mammal behavioral responses to acoustic exposure, the NMFS has not yet released technical guidance on behavioral thresholds for calculating animal exposures (NMFS 2018). The NMFS currently uses a step function to assess behavioral impact (NOAA 2005). A 50% probability of inducing behavioral responses at an SPL of 160 dB re 1 µPa was derived from the High Energy Seismic Survey (HESS 1999) report, which was based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1983, 1984). The HESS team recognized that behavioral responses to sound may occur at lower levels, but substantial 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 Appendix B). Southall et al. (2007) 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. Southall et al. (2021) suggested new methodological developments for. studying behavioral responses however, no new behavioral exposure criteria were recommended. In 2012, Wood et al. proposed a graded probability of response for impulsive sounds using a frequency weighted SPL metric. Wood et al. (2012) also designated behavioral response categories for sensitive species (including harbor porpoises and beaked whales) and for migrating mysticetes. For this analysis, both the unweighted NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria are used to estimate Level B exposures to impulsive pile-driving sounds (Table 9).

Table 9. Acoustic thresholds used in this assessment to evaluate potential behavioral impacts to marine mammals. Units are sound pressure level. Probabilities are not additive.

Marine mammal group	Frequency weighted probabilistic response [a] (L_p, dB re 1 µPa)				Unweighted threshold [b] (L_p, dB re 1 µPa)
	120	140	160	180	160
Beaked whales and harbor porpoises	50%	90%	–	–	100%
Migrating mysticete whales	10%	50%	90%	–	100%
All other species	–	10%	50%	90%	100%

[a] Wood et al. (2012).
[b] NMFS recommended threshold (NOAA 2005).

2.5. Acoustic Thresholds Used to Evaluate Potential Impacts to Sea Turtles and Fish

In a cooperative effort between Federal and State transportation and resource agencies, interim criteria were developed to assess the potential for injury to fish exposed to pile driving sounds (Stadler and Woodbury 2009) and described by the Fisheries Hydroacoustic Working Group (FHWG 2008). Injury and behavioral response thresholds were based on past literature that was compiled and listed in the NOAA Fisheries Greater Atlantic Regional Fisheries Office acoustics tool (GARFO 2020) for assessing the potential effects to Endangered Species Act (ESA) listed animals exposed to elevated levels of underwater sound from pile driving. Dual acoustic thresholds for physiological injury included in the tool are 206 dB re 1 µPa PK and either 187 dB re 1 µPa^2·s SEL (>2 grams [g] fish weight) or 183 dB SEL (<2 g fish weight) (FHWG 2008, Stadler and Woodbury 2009) (Table 10). The behavioral threshold for fish is ≥150 dB SPL (Andersson et al. 2007, Wysocki et al. 2007, Mueller-Blenkle et al. 2010, Purser and Radford 2011).

A technical report by an American National Standards Institute (ANSI) registered committee (Popper et al. 2014) reviewed available data and suggested metrics and methods for estimating acoustic impacts for fish. Their report includes thresholds for potential injury but does not define sound levels that may result in behavioral response, though it does indicate a high likelihood of response near impact pile driving (tens of meters), a moderate response at intermediate distances (hundreds of meters), and a low response far (thousands of meters) from the pile (Popper et al. 2014).

Injury, impairment, and behavioral thresholds for sea turtles were developed for use by the US Navy (Finneran et al. 2017) based on exposure studies (e.g., McCauley et al. 2000). Dual criteria (PK and SEL) have been suggested for PTS and TTS, along with auditory weighting functions published by Finneran et al. (2017) used in conjunction with SEL thresholds for PTS and TTS . The behavioral threshold recommended in the GARFO acoustic tool (GARFO 2020) is an SPL of 175 dB re 1 µPa (McCauley et al. 2000, Finneran et al. 2017) (Table 10).

Table 10. Acoustic metrics and thresholds for fish and sea turtles currently used by National Marine Fisheries Service (NMFS) Greater Atlantic Regional Fisheries Office (GARFO) and Bureau of Ocean Energy Management (BOEM) for impulsive pile driving.

Faunal group	Injury		Impairment		Behavior
	PTS		TTS		
	L_{pk}	$L_{E,\ 24h}$	L_{pk}	$L_{E,\ 24h}$	L_p
Fish equal to or greater than 2 g[a,b]	206	187	-	-	150
Fish less than 2 g[a,b]		183	-	-	
Fish without swim bladder[c]	213	216	-	-	-
Fish with swim bladder not involved in hearing[c]	207	203	-	-	-
Fish with swim bladder involved in hearing[c]	207	203	-	-	-
Sea turtles[d,e]	232	204	226	189	175

L_{pk} = peak sound pressure (dB re 1 µPa); L_E = sound exposure level (dB re 1 µPa^2·s); L_p = root mean square sound pressure (dB re 1 µPa).

PTS = permanent threshold shift; TTS = temporary threshold shift, which is a recoverable hearing effect.

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).

[b] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).

[c] Popper et al. (2014).

[d] Finneran et al. (2017).

[e] McCauley et al. (2000).

2.6. Animal Movement Modeling and Exposure Estimation

The JASCO Animal Simulation Model Including Noise (JASMINE) was used to estimate the probability of exposure of animals to threshold levels of sound arising from pile driving operations during construction of New England Wind. Sound exposure models such as JASMINE use simulated animals (animats) to sample the predicted 3-D sound fields with movement rules derived from animal observations (Appendix G.1). The parameters used for forecasting realistic behaviors (e.g., diving, foraging, aversion, and surface times) are determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species (Appendix G.1). The predicted sound fields are sampled by the model receiver in a way that real animals are expected to by programming animats to behave like marine species that may be present near the SWDA. The output of the simulation is the exposure history for each animat within the simulation. An individual animat's sound exposure level is summed over a specified duration, i.e., 24 h (Appendix H.1.1), to determine its total received acoustic energy (SEL) and maximum received PK and SPL. These received levels are then compared to the threshold criteria described in Section 2.4 within each analysis period. The number of animals predicted to receive sound levels exceeding the thresholds indicates the probability of such exposures, which is then scaled by the real-world density estimates for each species (Appendix H.1.3) to obtain the mean number of real-world animals estimated to potentially receive above-threshold sound levels. Appendix G.1 provides fuller description of animal movement modeling and the parameters used in the JASMINE simulations.

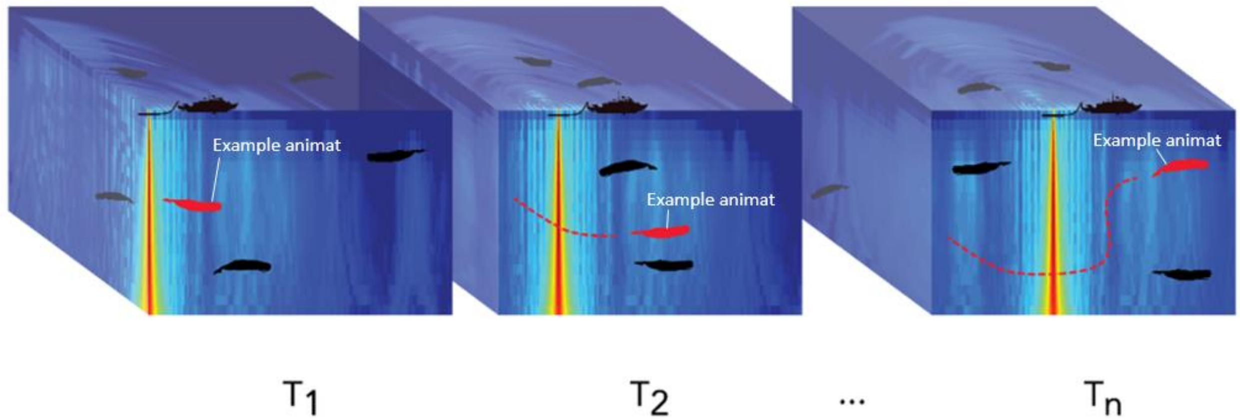

Figure 9. Depiction of animats in an environment with a moving sound field. Example animat (red) shown moving with each time step. The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

Figure 10 shows an example histogram of summary SEL exposures for each animat in a JASMINE simulation. The count above threshold is used to determine the predicted number of exposures above threshold for a given 24-hour scenario.

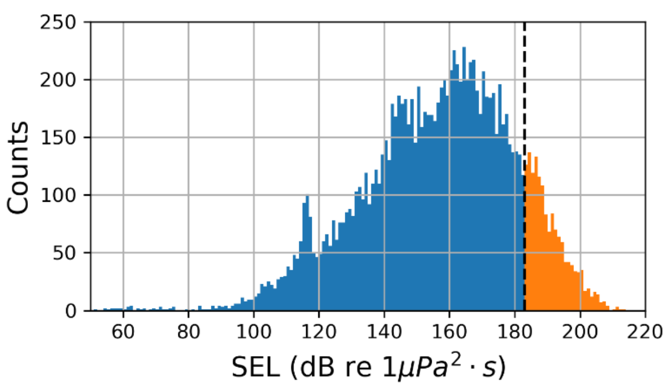

Figure 10. An example animat exposure histogram, showing the number of animats with sound exposure level (SEL) exposures at different levels for a single simulation. A vertical dashed line indicates an example sound level threshold, and the histogram bars above that threshold level are colored in orange.

Equation 1 describes how 24-h exposures x are calculated using the animat counts, the real-world density, and the sampling (seeding) density.

$$x = d_r \frac{x_{24h}}{d_s}, \quad (1)$$

where x_{24h} is the mean number of animats above threshold within a 24-hour period, d_r is the real-world animal density (e.g., from Roberts et al. 2016a), and d_s is the sampling density. As an example, consider the predicted 24-hour exposures x_A for NARW from an unattenuated 4-m jacket foundation assuming 2 piles are installed per day. The number of animats above threshold x_{24h} is 290.7, the real-world density d_r is 0.00276 animats/km^2, and the sampling density d_s is 0.597 animals/km^2:

$$x = 0.00276 \frac{290.7}{0.597} = 1.343\,. \quad (2)$$

In this case, the model predicts 1.343 animats will be exposed above threshold based on the installation of 2 unattenuated 4-m jacket foundations within a 24-hour period. To predict Project-level exposures, this calculation is repeated for each foundation type and for each month, assuming density estimates are available monthly. The total exposures x_{all} for the Project is calculated as a function of the 24-hour exposures for each month and foundation type (e.g., $x_{may,A}$), and the number of days of piling for each foundation type for each month (e.g., $n_{may,A}$). Note that that foundation type here refers to both the specific pile characteristics as well as the number of piles installed sequentially per 24-hour period. Construction schedules for the current Project are described in Tables 3 and 4. Equation 3 shows an example calculation where two foundation types, A and B, are installed over the period from May to August.

$$x_{all} = (n_{may,A} \cdot x_{may,A}) + (n_{jun,A} \cdot x_{jun,A}) + (n_{jul,A} \cdot x_{jul,A}) + (n_{aug,A} \cdot x_{aug,A}) + (n_{may,B} \cdot x_{may,B}) + (n_{jun,B} \cdot x_{jun,B}) + (n_{jul,B} \cdot x_{jul,B}) + (n_{aug,B} \cdot x_{aug,B}) \quad (3)$$

Due to shifts in animal density and seasonal sound propagation effects, the number of animals predicted to be impacted by the pile driving operations is sensitive to the number of foundations installed during each month.

2.6.1. Animal Aversion

While most results provided in this report do not include aversion or any mitigation measures other than sound attenuation, animal aversion to sound can be implemented in JASMINE and a subset of scenarios were run to provide a demonstration of the potential effect. Aversive results are included as a supplement and are presented for comparison purposes only (see Section 4.3.3).

Aversion is a common response of animals to sound, particularly at relatively high sound exposure levels (Ellison et al. 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 (Dunlop et al. 2017). 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 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 11 and 12). 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 11 and 12). 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 11 and 12 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 11. 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 (L_p, dB re 1 µPa)	Change in course (°)	Duration of aversion (s)
10%	140	10	300
50%	160	20	60
90%	180	30	30

Table 12. 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 (L_p, dB re 1 µPa)	Change in course (°)	Duration of aversion (s)
50%	120	20	60
90%	140	30	30

2.7. Exposure-based Range Estimation

Monitoring zones used for mitigation purposes have traditionally been estimated by determining the distance to injury and behavioral thresholds based only on acoustic information (see Appendix G). This traditional method tacitly assumes that all receivers (animals) in the area remain stationary for the duration of the sound event. Because both where an animal is in a sound field, and the pathway it takes through the sound field, determine the received level of the animal, treating animals as stationary may not produce realistic estimates for monitoring zones.

Animal movement modeling can be used to account for the movement of receivers when estimating distances for monitoring zones. The closest point of approach (CPA) for each of the species-specific animats (simulated animals) in a simulation is recorded and then the CPA distance that accounts for 95% of the animats that exceed an acoustic impact threshold is determined (Figure 11). The $ER_{95\%}$ (95% exposure range) is the horizontal distance that includes 95% of the CPAs of animats exceeding a given impact threshold. $ER_{95\%}$ is reported for marine mammals and sea turtles. If used as an exclusion zone, keeping animals farther away from the source than the $ER_{95\%}$ will reduce exposure estimates by 95%.

Unlike marine mammals and sea turtles for which animal movement modeling was performed, fish were considered static (not moving) receivers, so exposure ranges were not calculated. Instead, the acoustic ranges to fish impact criteria thresholds were calculated by determining the isopleth at which thresholds could be exceeded.

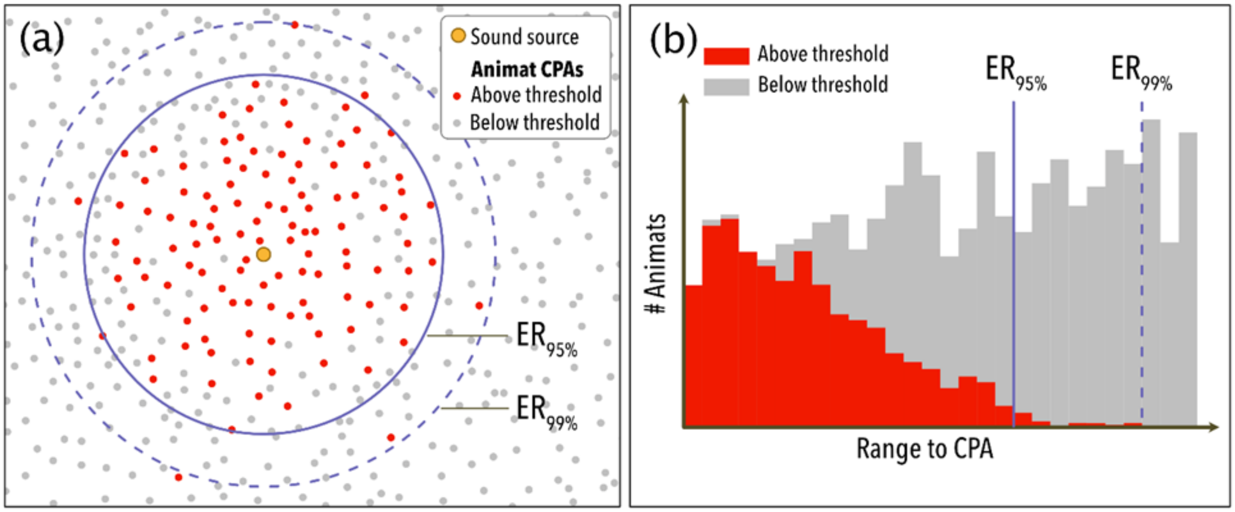

Figure 11. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows the distribution of ranges to animat CPAs. The 95% and maximum Exposure Ranges ($ER_{95\%}$ and ER_{max}) are indicated in both panels.

3. Marine Fauna included in this Acoustic Assessment

Marine fauna included in the acoustic assessment are marine mammals (cetaceans and pinnipeds), sea turtles, fish, and invertebrates.

All marine mammal species are protected under the MMPA. Some marine mammal stocks may be designated as Strategic under the MMPA (2015), which requires the jurisdictional agency (NMFS for the Atlantic offshore species considered in this application) to impose additional protection measures. A stock is considered Strategic if:

- Direct human-caused mortality exceeds its Potential Biological Removal (PBR) level (defined as the maximum number of animals, not including natural mortality, that can be removed from the stock while allowing the stock to reach or maintain its optimum sustainable population level);
- It is listed under the ESA;
- It is declining and likely to be listed under the ESA; or
- It is designated as depleted under the MMPA.

A depleted species or population stock is defined by the MMPA as any case in which:

- The Secretary, after consultation with the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals established under MMPA Title II, determines that a species or population stock is below its optimum sustainable population;
- A State, to which authority for the conservation and management of a species or population stock is transferred under Section 109 of the MMPA, determines that such species or stock is below its optimum sustainable population; or
- A species or population stock is listed as an endangered or threatened species under the ESA. Some species are further protected under the ESA (2002).

Under the ESA, a species is considered endangered if it is "in danger of extinction throughout all or a significant portion of its range." A species is considered threatened if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (ESA 2002).

3.1. Marine Mammals that may Occur in the Area

Thirty-nine marine mammal species (whales, dolphins, porpoise, seals, and manatees) comprising 39 stocks have been documented as present (some year–round, some seasonally, and some as occasional visitors) in the Northwest Atlantic Outer Continental Shelf (OCS) region (CeTAP 1982, USFWS 2014, Roberts et al. 2016a, Hayes et al. 2021). All 39 marine mammal species identified in Table 13 are protected by the MMPA and some are also listed under the ESA. The five ESA-listed marine mammal species known to be present year-round, seasonally, or occasionally in southern New England waters are the sperm whale (*Physeter macrocephalus*), NARW, fin whale (*Balaenoptera physalus physalus*), blue whale (*Balaenoptera musculus*), and sei whale (*Balaenoptera borealis borealis*). The humpback whale (*Megaptera novaeangliae*), which may occur year-round, has been delisted as an endangered species.

Southern New England waters (including the SWDA (Figure 1)) are primarily used as opportunistic feeding areas or habitat during seasonal migration movements that occur between the more northern feeding areas and the more southern breeding areas typically used by some of the large whale species.

Along with cetaceans, seals are protected under the MMPA. The four species of phocids (true seals) that have ranges overlapping the Project area, are harbor seals (*Phoca vitulina*), gray seals (*Halichoerus grypus*), harp seals (*Pagophilus groenlandicus*), and hooded seals (*Cystophora cristata*) (Hayes et al. 2019). One species of sirenian, the Florida manatee (*Trichechus manatus latirostris*), is an occasional visitor to the region during summer months (USFWS 2019). The manatee is listed as threatened under the ESA and is protected under the MMPA along with the other marine mammals.

The expected occurrence of each marine mammal species in the SWDA is listed in Table 13. Many of the listed marine mammal species do not commonly occur in this region of the Atlantic Ocean. Species categories include:

- Common - Occurring consistently in moderate to large numbers;
- Regular - Occurring in low to moderate numbers on a regular basis or seasonally;
- Uncommon - Occurring in low numbers or on an irregular basis; and
- Rare - There are limited species records for some years; range includes the Offshore Development Area but due to habitat preferences and distribution information, species are generally not expected to occur in the SWDA, though rare sightings are a possibility.

Species that are identified as rare are not included in the animal movement and exposure modeling. The likelihood of incidental exposure for each species based on its presence, density, and overlap of proposed activities is described in Section 4.3.

Table 13. Marine mammals that may occur in the Southern Wind Development Area (SWDA).

Species	Scientific name	Stock	Regulatory status[a]	SWDA occurrence	Abundance[b]
Baleen whales (Mysticeti)					
Blue whale	*Balaenoptera musculus*	Western North Atlantic	ESA-Endangered	Rare	402
Fin whale	*Balaenoptera physalus*	Western North Atlantic	ESA-Endangered	Common	6802
Humpback whale	*Megaptera novaeangliae*	Gulf of Maine	MMPA	Common	1396
Minke whale	*Balaenoptera acutorostrata*	Canadian Eastern Coastal	MMPA	Common	21,968
North Atlantic right whale	*Eubalaena glacialis*	Western	ESA-Endangered	Common	368[c]
Sei whale	*Balaenoptera borealis*	Nova Scotia	ESA-Endangered	Common	6292
Toothed whales (Odontoceti)					
Sperm whales (Physeteroidae)					
Sperm whale	*Physeter macrocephalus*	North Atlantic	ESA-Endangered	Uncommon	4349
Dwarf sperm whale	*Kogia sima*	Western North Atlantic	MMPA	Rare	7750[d]
Pygmy sperm whale	*Kogia breviceps*	Western North Atlantic	MMPA	Rare	7750[d]
Dolphins (Delphinidae)					
Atlantic spotted dolphin	*Stenella frontalis*	Western North Atlantic	MMPA	Uncommon	39,921
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	Western North Atlantic	MMPA	Common	93,233
Bottlenose dolphin	*Tursiops truncatus*	Western North Atlantic, offshore[e]	MMPA	Common	62,851
		Western North Atlantic, Northern Migratory Coastal	MMPA- Strategic	Rare	6639
Clymene dolphin	*Stenella clymene*	Western North Atlantic	MMPA	Rare	4237
False killer whale	*Pseudorca crassidens*	Western North Atlantic	MMPA	Rare	1791
Fraser's dolphin	*Lagenodelphis hosei*	Western North Atlantic	MMPA	Rare	Unknown
Killer whale	*Orcinus orca*	Western North Atlantic	MMPA	Rare	Unknown
Melon-headed whale	*Peponocephala electra*	Western North Atlantic	MMPA	Rare	Unknown
Pantropical spotted dolphin	*Stenella attenuata*	Western North Atlantic	MMPA	Rare	6593
Pilot whale, long-finned	*Globicephala melas*	Western North Atlantic	MMPA	Uncommon	39,215
Pilot whale, short-finned	*Globicephala macrorhynchus*	Western North Atlantic	MMPA	Uncommon	28,924
Pygmy killer whale	*Feresa attenuata*	Western North Atlantic	MMPA	Rare	Unknown
Risso's dolphin	*Grampus griseus*	Western North Atlantic	MMPA	Uncommon	35,215
Rough-toothed dolphin	*Steno bredanensis*	Western North Atlantic	MMPA	Rare	136
Short-beaked common dolphin	*Delphinus delphis*	Western North Atlantic	MMPA	Common	172,974
Spinner dolphin	*Stenella longirostris*	Western North Atlantic	MMPA	Rare	4102
Striped dolphin	*Stenella coeruleoalba*	Western North Atlantic	MMPA	Rare	67,036
White-beaked dolphin	*Lagenorhynchus albirostris*	Western North Atlantic	MMPA	Rare	536,016
Monodontid whales (Monodontidae)					
Beluga whale	*Delphinapterus leucas*	None defined for US Atlantic	MMPA	Rare	Unknown[f]

Species	Scientific name	Stock	Regulatory status[a]	SWDA occurrence	Abundance[b]
Beaked whales (Ziphiidae)					
Cuvier's beaked whale	*Ziphius cavirostris*	Western North Atlantic	MMPA	Rare	5744
Blainville's beaked whale	*Mesoplodon densirostris*	Western North Atlantic	MMPA	Rare	10,107[g]
Gervais' beaked whale	*Mesoplodon europaeus*	Western North Atlantic	MMPA		
Sowerby's beaked whale	*Mesoplodon bidens*	Western North Atlantic	MMPA		
True's beaked whale	*Mesoplodon mirus*	Western North Atlantic	MMPA		
Northern bottlenose whale	*Hyperoodon ampullatus*	Western North Atlantic	MMPA	Rare	Unknown
Porpoises (Phocoenidae)					
Harbor porpoise	*Phocoena phocoena*	Gulf of Maine/Bay of Fundy	MMPA	Common	95,543
Earless seals (Phocidae)					
Gray seal	*Halichoerus grypus*	Western North Atlantic	MMPA	Common	27,300[h]
Harbor seal	*Phoca vitulina*	Western North Atlantic	MMPA	Regular	61,336
Harp seal	*Pagophilus groenlandicus*	Western North Atlantic	MMPA	Uncommon	Unknown[i]
Hooded seal	*Cystophora cristata*	Western North Atlantic	MMPA	Rare	Unknown

[a] Denotes the highest federal regulatory classification. A strategic stock is defined as any marine mammal stock: 1) for which the level of direct human-caused mortality exceeds the potential biological removal level; 2) that is declining and likely to be listed as Threatened under the ESA; or 3) that is listed as Threatened or Endangered under the ESA or as depleted under the MMPA (NOAA Fisheries 2019).

[b] Best available abundance estimate is from NOAA Fisheries Stock Assessment Reports (NOAA Fisheries 2021b).

[c] Best available abundance estimate is from NOAA Fisheries Stock Assessment (NOAA Fisheries 2021b). NARW consortium has released the 2021 report card results estimating a NARW population of 336 for 2020 (Pettis et al. 2022). However, the consortium "alters" the methods of Pace et al. (2017, 2021) to subtract additional mortality. This method is used in order to estimate all mortality, not just the observed mortality, therefore the NOAA Fisheries (2021b) stock assessment report (SAR) will be used to report an unaltered output of the Pace et al. (2017, 2021) model (DoC and NOAA 2020).

[d] This estimate includes both dwarf and pygmy sperm whales. Source: NOAA Fisheries (2021b).

[e] Bottlenose dolphins occurring in the Offshore Development Area likely belong to the Western North Atlantic Offshore stock (NOAA Fisheries 2021b).

[f] NMFS does not provide abundance estimates of beluga whales in US waters because there is no stock defined for the US Atlantic. Belugas occurring off the US Atlantic coast are likely vagrants from one of the Canadian populations (COSEWIC 2020).

[g] This estimate includes all undifferentiated Mesoplodon spp. beaked whales in the Atlantic. Sources: Kenney and Vigness-Raposa (2009), Rhode Island Ocean Special Area Management Plan (2011), Waring et al. (2011, 2013, 2015), Hayes et al. (2017, 2018, 2019, 2020).

[h] Estimate of gray seal population in US waters. Data are derived from pup production estimates; NOAA Fisheries (2021b) notes that uncertainty about the relationship between whelping areas along with a lack of reproductive and mortality data make it difficult to reliably assess the population trend.

[i] NOAA Fisheries (2021b) report insufficient data to estimate the population size of harp seals in US waters; the best estimate for the entire western North Atlantic population is 7.6 million.

3.2. Mean Monthly Marine Mammal Density Estimates

Mean monthly marine mammal density estimates (animals per 100 square kilometers [animals/100 km^2]) for all modeled species are provided in Table 14. These were obtained using the Duke University Marine Geospatial Ecology Laboratory model (Roberts et al. 2016a, 2016b, 2017, 2018, 2021) and include recently updated model results for the NARW. The 2021 updated model includes new estimates for NARW abundance in Cape Cod Bay in December. Additionally, model predictions are summarized over three eras, 2003–2018, 2003–2009, and 2010–2018, to reflect the apparent shift in NARW distribution around 2010. The modeling conducted in support of this LOA application used the 2010–2018 density predictions.

Densities were calculated within a 6.2 km buffered polygon around the SWDA perimeter. The buffer size was selected as the largest 10 dB-attenuated exposure range over all species, scenarios, and threshold criteria, with the exception of the Wood et al. (2012) thresholds. Wood et al. (2012) exposure ranges were not considered in this estimate since they include a small subset of very long ranges for migrating mysticetes and harbor porpoise. The mean density for each month was determined by calculating the unweighted mean of all 10 × 10 km (5 × 5 km for NARW) grid cells partially or fully within the analysis polygon (Figure 12). Densities were computed monthly, annually, and for the May–December period to coincide with proposed pile driving activities. For long- and short-finned pilot whales, monthly densities are unavailable from Roberts et al. (2016a, 2016b, 2017), so annual mean densities were used instead. Additionally, Roberts et al. (2016a, 2016b, 2017) provide density for pilot whales as a guild that includes both species. To obtain density estimates for long-finned and short-finned pilot whales, the guild density from Roberts et al. (2016a, 2016b, 2017) was scaled by the relative stock sizes based on the best available abundance estimate from NOAA Fisheries stock assessment reports (SARs) (NOAA Fisheries 2021b). Equation 4 shows an example of how abundance scaling is applied to compute density for short-finned pilot whales:

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned}+a_{long-finned}}\right), \quad (4)$$

where a represents abundance and d represents density. Similarly, densities are provided for seals as a guild consisting primarily of harbor and gray seals (Roberts et al. 2016a, 2018). Gray and harbor seal densities were scaled by relative NOAA Fisheries SARs (NOAA Fisheries 2021b) abundance. However, density estimates are unavailable for the harp seal in the SWDA, so the lower gray density was used as a surrogate density for that species as a conservative measure. This is likely to overestimate impacts to harp seals because they are thought to be uncommon in the area and generally are only present in New England waters during January through May (Harris et al. 2002). Because of seasonal construction restrictions, pile driving is limited to May through December, meaning harp seals would only be exposed to pile driving during the month of May.

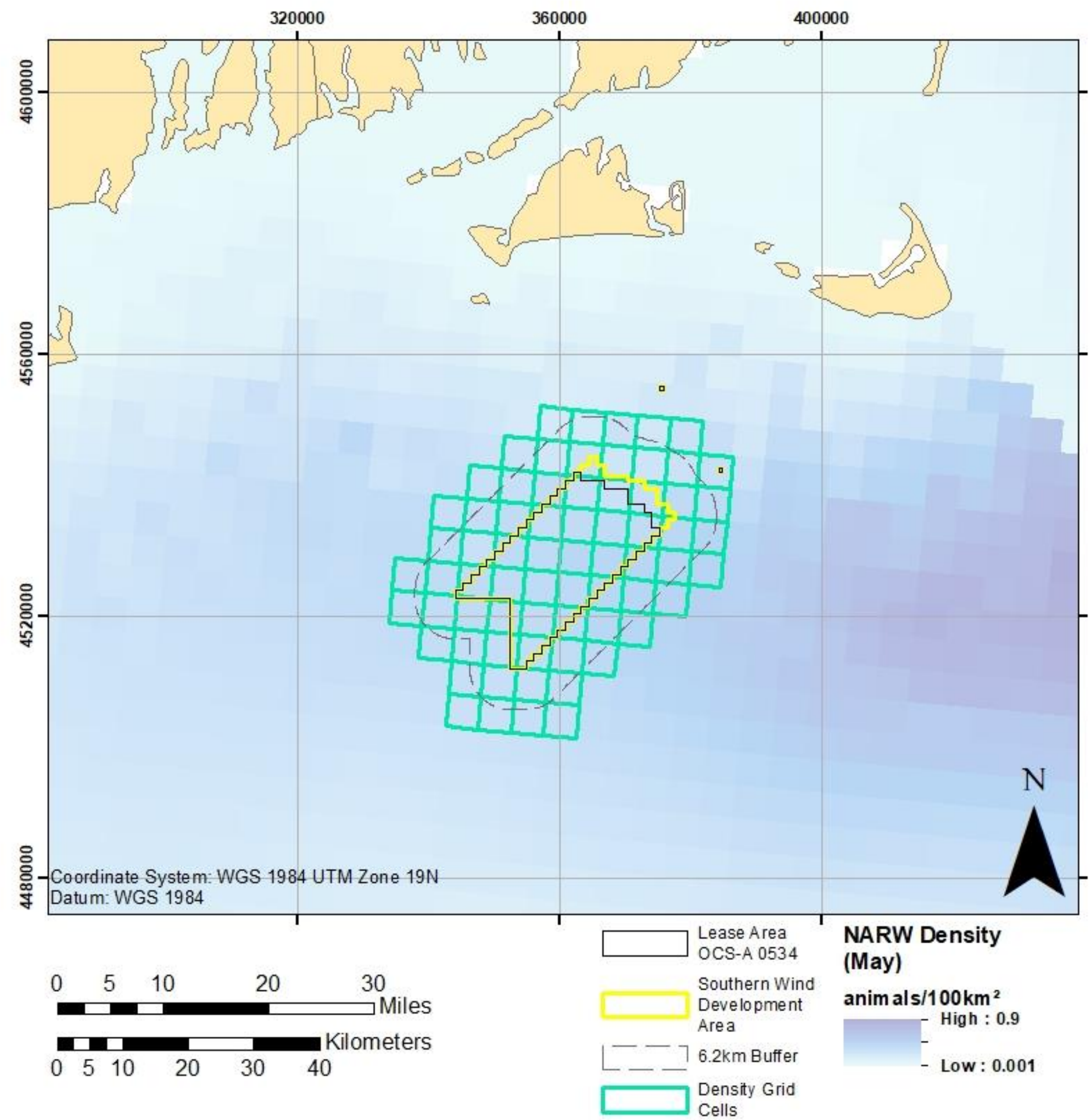

Figure 12. Marine mammal (e.g., North Atlantic right whale (NARW)) density map showing highlighted grid cells used to calculate mean monthly species estimates within a 6.2 km buffer around New England Wind (Roberts et al. 2016a, 2021). Note that the modeled densities are in units of animals/100 km^2, even when grid cells are 5 × 5 km.

Table 14. Mean monthly marine mammal density estimates for all species in a 6.2 km buffer around New England Wind.

Species of interest	Monthly densities (animals/100 km^2)												Annual mean	May to December mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Fin whale[a]	0.214	0.184	0.178	0.325	0.368	0.369	0.390	0.352	0.280	0.157	0.152	0.159	0.261	0.278
Minke whale	0.065	0.081	0.083	0.181	0.263	0.243	0.087	0.061	0.063	0.074	0.033	0.047	0.107	0.109
Humpback whale	0.030	0.018	0.030	0.221	0.179	0.170	0.123	0.063	0.236	0.196	0.063	0.026	0.113	0.132
North Atlantic right whale[a]	0.660	0.780	0.811	0.904	0.362	0.023	0.004	0.003	0.004	0.010	0.051	0.264	0.323	0.090
Sei whale[a]	0.002	0.002	0.001	0.047	0.047	0.027	0.007	0.004	0.007	0.001	0.002	0.002	0.012	0.012
Atlantic white-sided dolphin	3.881	2.083	2.242	4.317	8.263	7.805	5.504	3.109	2.957	3.698	4.042	5.834	4.478	5.152
Atlantic spotted dolphin	0.002	0.002	0.003	0.013	0.025	0.034	0.070	0.124	0.137	0.124	0.075	0.009	0.052	0.075
Short beaked common dolphin	16.930	2.935	1.174	3.016	5.785	5.909	6.401	11.882	20.783	23.516	16.500	29.286	12.010	15.008
Common Bottlenose dolphin	0.678	0.042	0.013	0.485	0.556	0.650	1.336	1.338	2.671	3.296	1.497	0.768	1.111	1.514
Risso's dolphin	0.016	0.007	0.003	0.003	0.011	0.012	0.029	0.056	0.043	0.015	0.025	0.042	0.022	0.029
Long-finned pilot whale	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.000	0.625	0.625
Short-finned pilot whale	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.000	0.461	0.461
Sperm whale	0.002	0.003	0.002	0.002	0.003	0.008	0.036	0.038	0.008	0.008	0.008	0.002	0.010	0.014
Harbor porpoise	4.592	8.200	15.828	10.293	4.762	0.932	0.669	0.648	0.538	0.260	0.862	1.980	4.130	1.331
Gray seal	0.653	2.225	2.470	2.818	3.070	0.267	0.047	0.027	0.059	0.091	0.055	0.349	1.011	0.496
Harbor seal	1.466	4.999	5.549	6.331	6.897	0.599	0.106	0.061	0.132	0.205	0.124	0.784	2.271	1.114
Harp seal	0.653	2.225	2.470	2.818	3.070	0.267	0.047	0.027	0.059	0.091	0.055	0.349	1.011	0.496

[a] Listed as Endangered under the ESA.

3.3. Sea Turtles and Fish Species of Concern that May Occur in the Area

Four species of sea turtles may occur in the SWDA, and all are listed as threatened or endangered: loggerhead sea turtle (*Caretta caretta*), Kemp's ridley sea turtle (*Lepidochelys kempii*), green sea turtle (*Chelonia mydas*), and leatherback sea turtle (*Dermochelys coriacea*). Many species of sea turtle prefer coastal waters; however, both the leatherback and loggerhead sea turtles are known to occupy deep-water habitats and are considered common during summer and fall in the SDWA. Kemp's Ridley sea turtles are thought to be regular visitors during those seasons. Green sea turtles are rare in the SWDA, generally preferring tropical and subtropical habitats, and are not considered further.

There are four federally listed threatened or endangered fish species that may occur off the northeast Atlantic coast, including the shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), Atlantic salmon (*Salmo salar)*, and giant manta ray (*Manta birostris*).

Atlantic sturgeon distribution varies by season, but they are primarily found in shallow coastal waters (bottom depth less than 20 m) during the summer months (May to September) and move to deeper waters (20-50 m) in winter and early spring (December to March) (Dunton et al. 2010). Shortnose sturgeon occur primarily in fresh and estuarine waters and occasionally enter the coastal ocean. Adults ascend rivers to spawn from February to April, and eggs are deposited over hard bottom, in shallow, fast-moving water (Dadswell et al. 1984). Because of their preference for mainland rivers and fresh and estuarine waters, shortnose sturgeon are unlikely to be found in the vicinity of the SWDA. Atlantic salmon is an anadromous species that historically ranged from northern Quebec southeast to Newfoundland and southwest to Long Island Sound. The Gulf of Maine distinct population segment (DPS) of the Atlantic salmon that spawns within eight coastal watersheds within Maine is federally listed as endangered. In 2009, the DPS was expanded to include all areas of the Gulf of Maine between the Androscoggin River and the Dennys River (NOAA Fisheries 2022). It is possible that adult Atlantic salmon may occur off the Massachusetts coast while migrating to rivers to spawn. However, only certain Gulf of Maine populations are listed as endangered, and Gulf of Maine salmon are unlikely to be encountered south of Cape Cod (BOEM 2014a). The giant manta ray is found worldwide in tropical, subtropical, and temperate bodies of water and is commonly found offshore, in oceanic waters, and near productive coastlines. As such, giant manta rays can be found in cool water, as low as 19°C, although temperature preference appears to vary by region. For example, off the US East Coast, giant manta rays are commonly found in waters from 19 to 22°C, whereas those off the Yucatan peninsula and Indonesia are commonly found in waters between 25 to 30°C. Individuals have been observed as far north as New Jersey in the Western Atlantic basin indicating that the Offshore Development Area is located at the northern boundary of the species' range (NOAA Fisheries 2021a).

3.4. Sea Turtle Density Estimates

There are limited density estimates for sea turtles in the lease area. For this analysis, sea turtle densities were obtained from the US Navy Operating Area Density Estimate (NODE) database on the Strategic Environmental Research and Development Program Spatial Decision Support System (SERDP-SDSS) portal (DoN, 2012, 2017) and from the Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles (Kraus et al. 2016). These data are summarized seasonally (winter, spring, summer, and fall). Since the results from Kraus et al. (2016) use data that were collected more recently, those were used preferentially where possible.

Sea turtles were most commonly observed in summer and fall, absent in winter, and nearly absent in spring during the Kraus et al. (2016) surveys of the MA WEA and RI/MA WEAs. Because of this, the more conservative winter and spring densities from SERDP-SDSS are used for all species. It should be noted that SERDP-SDSS densities are provided as a range, where the maximum density will always exceed zero, even though turtles are unlikely to be present in winter. As a result, winter and spring sea turtle densities in the lease area, while low, are likely still overestimated.

For summer and fall, the more recent leatherback and loggerhead densities extracted from Kraus et al. (2016) were used. These species were the most commonly observed sea turtle species during aerial surveys by Kraus et al. (2016) in the MA/RI and MA WEAs. However, Kraus et al. (2016) reported seasonal densities for leatherback sea turtles only, so the loggerhead densities were calculated for summer and fall by scaling the averaged leatherback densities from Kraus et al. (2016) by the ratio of the seasonal sighting rates of the two species during the surveys. The Kraus et al. (2016) estimates of loggerhead sea turtle density for summer and fall are slightly higher than the SERDP-SDSS densities, and thus more conservative.

Kraus et al. (2016) reported only six total Kemp's ridley sea turtle sightings, so the estimates from SERDP-SDSS were used for all seasons. Green sea turtles are rare in this area and there are no density data available for this species, so the Kemp's ridley sea turtle density is used as a surrogate to provide a conservative estimate.

Sea turtle densities used in exposure estimates are provided in Table 15.

Table 15. Sea turtle density estimates for all modeled species in the Southern Wind Development Area (SWDA).

Common name	Density (animals/100 km^2 [38.6 mi^2])[a]			
	Spring	Summer	Fall	Winter
Green sea turtle[b]	0.017	0.017	0.017	0.017
Leatherback sea turtle	0.022	0.630[c]	0.873[c]	0.022
Loggerhead sea turtle	0.103	0.206[d]	0.633[d]	0.103
Kemp's ridley sea turtle	0.017	0.017	0.017	0.017

[a] Density estimates are extracted from SERDP-SDSS NODE database within a 6.2 km buffer of the SWDA, unless otherwise noted.
[b] Kraus et al. (2016) did not observe any green sea turtles in the RI/MA WEA. Densities of Kemp's ridley sea turtles are used as a conservative estimate.
[c] Densities calculated as averaged seasonal densities from 2011 to 2015 (Kraus et al. 2016).
[d] Densities calculated as the averaged seasonal leatherback sea turtle densities scaled by the relative, seasonal sighting rates of loggerhead and leatherback sea turtles (Kraus et al. 2016).

4. Summary Results

Acoustic fields were modeled at one site for jacket foundations and two sites for monopiles, representing the range of water depths within the SWDA (Table 2; Figure 7). This section summarizes the source level modeling results (Section 4.1), both acoustic and exposure ($ER_{95\%}$) ranges (Sections 4.2 and 4.3). A summary of the number of marine mammals and sea turtles predicted to be exposed above regulatory acoustic sound level thresholds is provided in Section 4.3.

4.1. Modeled Acoustic Source Levels

Forcing functions (in meganewtons [MN]) were computed for each pile type at various hammer energies using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010) and are shown in Figures 13–15. The forcing functions serve as the inputs to JASCO's pile driving source models used to estimate equivalent acoustic source characteristics detailed in Appendix E. The representative hammer parameters for a 5500 kJ and 3500 kJ hammer were provided as estimates from on-going hammer design work. As no hammer parameters were available for either a 5000 or 6000 kJ hammer, the modeled energies of the 5500 kJ hammer were scaled to represent the effect of the forcing functions for the two different hammers approximated. Decidecade spectral source levels for each pile type, hammer energy, and modeled location for summer sound speed profiles are shown in Figures 16 to 18. A broadband source level comparison between the 12 m and 13 m monopile is provided in Table 16.

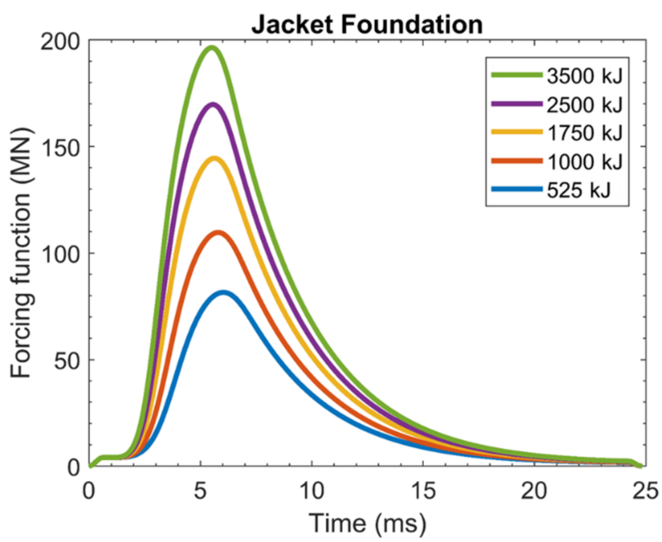

Figure 13. Modeled forcing functions versus time for a 4 m jacket foundation pile for each hammer energy using a 3500 kJ hammer.

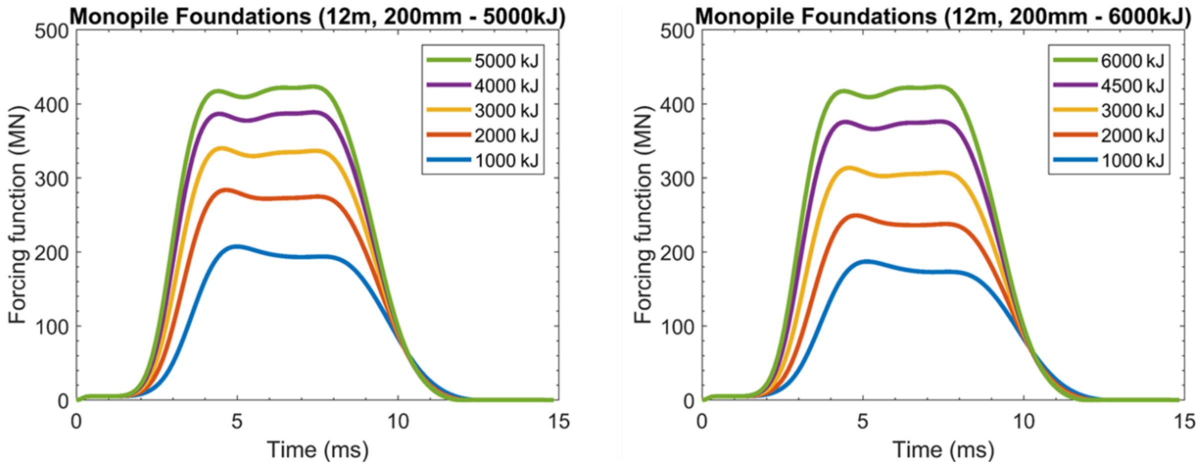

Figure 14. Modeled forcing functions versus time for a 12 m monopile at each hammer energy using a (left) 5000 kJ and (right) 6000 kJ hammer.

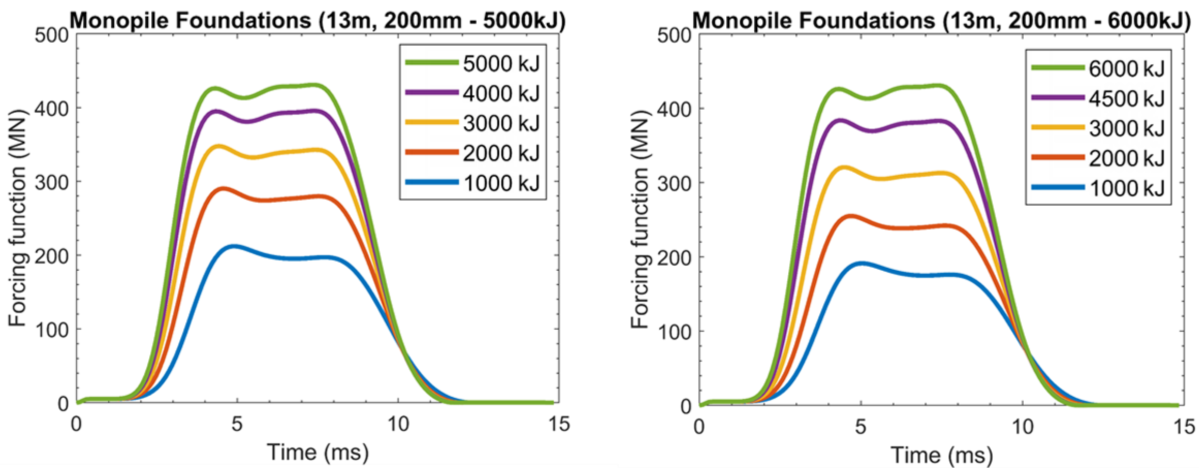

Figure 15. Modeled forcing functions versus time for a 13 m monopile at each hammer energy using a (left) 5000 kJ and (right) 6000 kJ hammer.

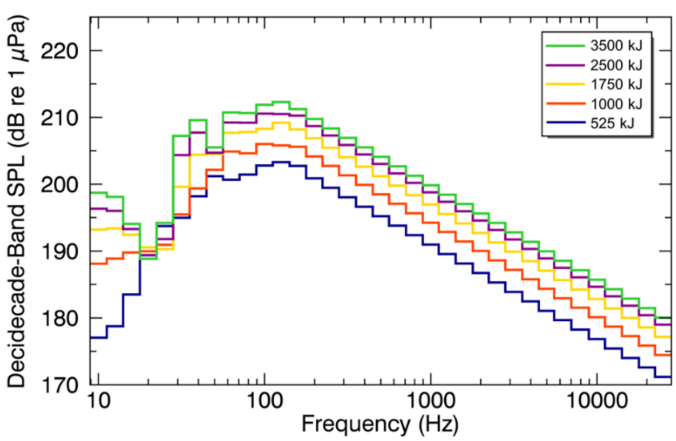

Figure 16. Decidecade band spectral source levels for 4 m jacket foundation pile installation at each hammer energy using a 3500 kJ hammer at site J1 (Figure 7) with an average summer sound speed profile at 1 m from the pile.

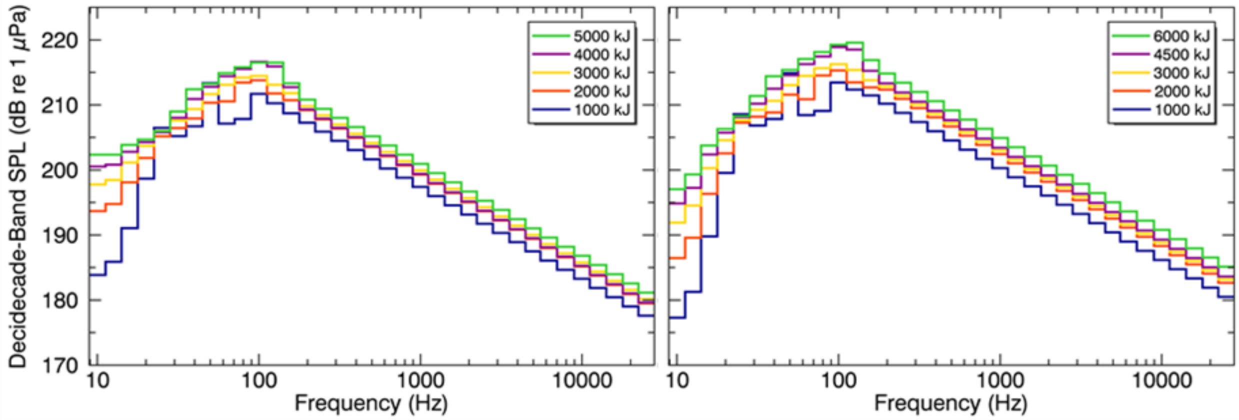

Figure 17. Decidecade band spectral source levels for 12 m monopile installation at each hammer energy using a (left) 5000 kJ and (right) 6000 kJ hammer at site M1 (Figure 7) with an average summer sound speed profile at 1 m from the pile.

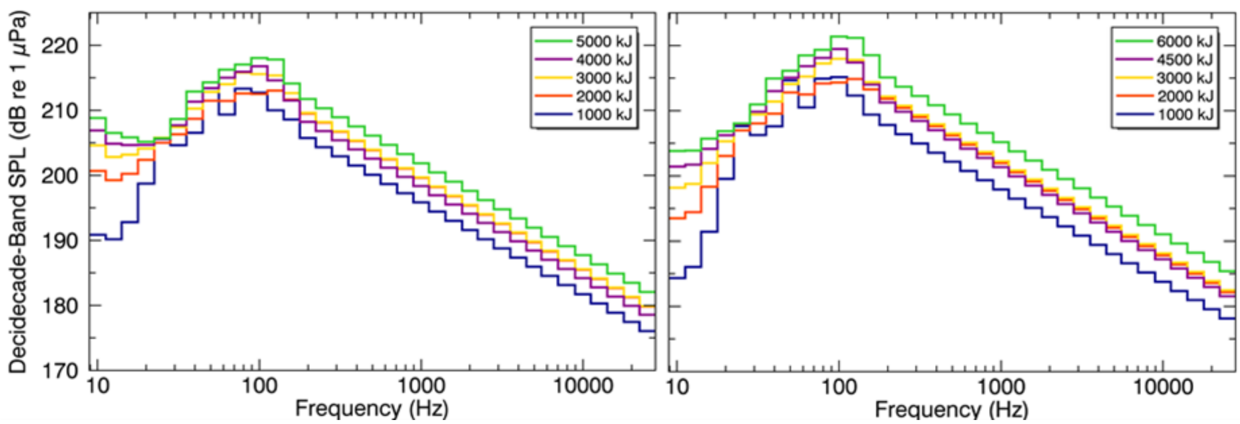

Figure 18. Decidecade band spectral source levels for 13 m monopile installation at each hammer energy using a (left) 5000 kJ and (right) 6000 kJ hammer at site M2 (Figure 7) with a summer sound speed profile at 1 m from the pile.

Table 16. Broadband source level comparison between the 12 m and 13 m monopile.

12 m Monopile		13 m Monopile		Broadband level difference (dB)[a]
Hammer energy level (kJ)	Broadband level (dB)[a]	Hammer energy level (kJ)	Broadband level (dB)[a]	
1000	221.94	1000	222.27	0.34
2000	223.30	2000	223.43	0.14
3000	224.56	3000	225.52	0.96
4500	226.31	4500	226.09	0.22
6000	227.32	6000	228.56	1.23

[a] Broadband levels are rounded to nearest 0.01 dB.

4.2. Modeled Ranges to Acoustic Thresholds Relevant for Impact Pile Driving

Though not used for exposure estimates in this assessment, acoustic ranges to exposure criteria thresholds are reported. For each sound level threshold, the maximum range (R_{max}) and the 95% range ($R_{95\%}$) were calculated. R_{max} is the distance to the farthest occurrence of the threshold level, at any depth. $R_{95\%}$ for a sound level is the radius of a circle, centered on the source, encompassing 95% of the sound at levels above threshold. Using $R_{95\%}$ reduces the sensitivity to extreme outlying values (the farthest 5% of ranges). A more detailed description of $R_{95\%}$ is found in Appendix F.5.

The following tables provide the ranges for marine fauna behavioral and auditory injury thresholds. The $R_{95\%}$ for SEL is inclusive of all the hammer energy levels, while the $R_{95\%}$ for PK is from the highest hammer energy level. The distances to SEL are calculated using the representative hammer energy schedules (Table 1) for driving one monopile or pin pile. The SEL ranges presented in Tables 17–20 are the distances from the foundation locations that would result in exposure above threshold if an animal remained stationary for the duration of one pile being driven into the bottom.

Table 17. PK ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for the 5000 kJ, 12 m monopile foundation. Ranges to PK thresholds are for the highest hammer energy level. Ranges to SEL thresholds represent the cumulative sound level for one 12 m monopile foundation with varying levels of noise attenuation.

Faunal group	Metric, pile per day	Threshold	Attenuation level (dB)		
			0	10	12
Low-frequency (LF) cetaceans	L_{pk}	219	79	11	8
	L_E	183	17437	7036	5549
Mid-frequency (MF) cetaceans	L_{pk}	230	9	3	3
	L_E	185	644	89	63
High-frequency (HF) cetaceans	L_{pk}	202	720	230	191
	L_E	155	11686	5126	4159
Phocid seals in water (PW)	L_{pk}	218	94	14	9
	L_E	185	5024	1121	1075
Sea turtles	L_{pk}	232	7	3	3
	L_E	204	2860	612	439
Fish without swim bladder	L_{pk}	213	210	47	36
	L_E	216	616	100	63
Fish with swim bladder not involved in hearing	L_{pk}	207	540	105	79
	L_E	203	3900	1047	760
Fish with swim bladder involved in hearing	L_{pk}	207	540	105	79
	L_E	203	3900	1047	760
Fish greater than or equal to 2 g	L_{pk}	206	580	157	94
	L_E	187	16282	7204	5960
Fish less than 2 g	L_{pk}	206	580	157	94
	L_E	183	21542	10290	8648

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).
Thresholds are taken from Tables 8 to 10.

Table 18. PK ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for the 6000 kJ, 12 m monopile foundation. Ranges to PK thresholds are for the highest hammer energy level. Ranges to SEL thresholds represent the cumulative sound level for one 12 m monopile foundation with varying levels of noise attenuation.

Faunal group	Metric, pile per day	Threshold	Attenuation level (dB)		
			0	10	12
Low-frequency (LF) cetaceans	L_{pk}	219	79	11	8
	L_E	183	20770	8924	7140
Mid-frequency (MF) cetaceans	L_{pk}	230	9	3	3
	L_E	185	1101	113	89
High-frequency (HF) cetaceans	L_{pk}	202	720	230	191
	L_E	155	13769	6414	5272
Phocid seals in water (PW)	L_{pk}	218	94	14	9
	L_E	185	6320	2037	1128
Sea turtles	L_{pk}	232	7	3	3
	L_E	204	3620	930	611
Fish without swim bladder	L_{pk}	213	210	47	36
	L_E	216	900	128	89
Fish with swim bladder not involved in hearing	L_{pk}	207	540	105	79
	L_E	203	4825	1365	982
Fish with swim bladder involved in hearing	L_{pk}	207	540	105	79
	L_E	203	4825	1365	982
Fish greater than or equal to 2 g	L_{pk}	206	580	157	94
	L_E	187	19149	8756	7242
Fish less than 2 g	L_{pk}	206	580	157	94
	L_E	183	24623	12283	10395

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s)
Thresholds are taken from Tables 8 to 10.

Table 19. PK ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for the 5000 kJ, 13 m monopile foundation. Ranges to PK thresholds are for the highest hammer energy level. Ranges to SEL thresholds represent the cumulative sound level for one 13 m monopile foundation with varying levels of noise attenuation.

Faunal group	Metric, pile per day	Threshold	Attenuation level (dB)		
			0	10	12
Low-frequency (LF) cetaceans	L_{pk}	219	93	14	10
	L_E	183	19473	7213	5716
Mid-frequency (MF) cetaceans	L_{pk}	230	13	5	5
	L_E	185	480	89	82
High-frequency (HF) cetaceans	L_{pk}	202	860	290	240
	L_E	155	11896	4955	3917
Phocid seals in water (PW)	L_{pk}	218	104	16	13
	L_E	185	4936	1246	656
Sea turtles	L_{pk}	232	8	5	4
	L_E	204	2987	560	412
Fish without swim bladder	L_{pk}	213	260	52	27
	L_E	216	560	108	80
Fish with swim bladder not involved in hearing	L_{pk}	207	580	114	93
	L_E	203	4198	1031	691
Fish with swim bladder involved in hearing	L_{pk}	207	580	114	93
	L_E	203	4198	1031	691
Fish greater than or equal to 2 g	L_{pk}	206	620	127	104
	L_E	187	19306	8133	6648
Fish less than 2 g	L_{pk}	206	620	127	104
	L_E	183	26101	11881	9815

L_{pk} = unweighted peak sound pressure (dB re 1 μPa); L_E = frequency-weighted sound exposure level (dB re 1 μPa^2·s)
Thresholds are taken from Tables 8 to 10.

Table 20. PK ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for the 3500 kJ, 4 m jacket foundation. Ranges to PK thresholds are for the highest hammer energy level. Ranges to SEL thresholds represent the cumulative sound level for one and four, 4 m pin pile(s) with varying levels of noise attenuation.

Faunal hearing group	Metric	Threshold	Attenuation level (dB) (1 Pile)			Attenuation level (dB) (4 Piles)		
			0	10	12	0	10	12
Low-frequency (LF) cetaceans	L_{pk}	219	33	2	0	33	2	0
	L_E	183	18049	6885	5248	29350	12677	10482
Mid-frequency (MF) cetaceans	L_{pk}	230	2	-	-	2	-	-
	L_E	185	481	89	80	1577	268	146
High-frequency (HF) cetaceans	L_{pk}	202	580	139	123	580	139	123
	L_E	155	11908	5726	4651	17577	8847	7339
Phocid seals in water (PW)	L_{pk}	218	87	2	2	87	2	2
	L_E	185	5738	1234	1174	10051	3510	2377
Sea turtles	L_{pk}	232	0	-	-	0	-	-
	L_E	204	2426	422	306	5224	1230	945
Fish without swim bladder	L_{pk}	213	131	8	5	131	8	5
	L_E	216	408	85	45	1216	201	144
Fish with swim bladder not involved in hearing	L_{pk}	207	410	100	33	410	100	33
	L_E	203	3437	721	490	6822	1852	1471
Fish with swim bladder involved in hearing	L_{pk}	207	410	100	33	410	100	33
	L_E	203	3437	721	490	6822	1852	1471
Fish greater than or equal to 2 g	L_{pk}	206	440	108	87	440	108	87
	L_E	187	16714	6807	5342	26323	11998	10043
Fish less than 2 g	L_{pk}	206	440	108	87	440	108	87
	L_E	183	22684	10021	8265	34586	16738	14285

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).
Thresholds are taken from Tables 8 to 10.
Dashes indicate that thresholds were not reached.

Table 21. SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 5000 kJ, 12 m monopile foundation. Ranges to SPL thresholds are for the highest hammer energy level.

Criteria source	L_p (dB re 1 µPa)	Frequency weighting	Faunal group	Attenuation level (dB)		
				0	10	12
NOAA (2005)	160	Unweighted	All species/behaviors	10867	4244	4026
Wood et al. (2012)	120	HF	Beaked whales and harbor porpoise	99797	57960	49856
	140	LF	Migrating mysticetes	38930	22062	19408
	160	LF	All other species/behaviors	10835	4235	4015
	160	MF		6181	3188	2896
	160	PW		7308	3716	3422
Finneran et al. (2017)	175	Unweighted	Sea turtles	3486	1365	984
McCauley et al. (2000)	166	Unweighted		6350	3349	3055
GARFO (2020)	150	Unweighted	Fish	22085	10867	9200

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 8 to 10.

Table 22. SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 6000 kJ, 12 m monopile foundation. Ranges to SPL thresholds are for the highest hammer energy level.

Criteria source	L_p (dB re 1 µPa)	Frequency weighting	Faunal group	Attenuation level (dB)		
				0	10	12
NOAA (2005)	160	Unweighted	All species/behaviors	14103	5827	4702
Wood et al. (2012)	120	HF	Beaked whales and harbor porpoise	110217	87785	68471
	140	LF	Migrating mysticetes	48731	27061	24105
	160	LF	All other species/behaviors	14073	5795	4671
	160	MF		9225	3821	3389
	160	PW		12081	4257	4048
Finneran et al. (2017)	175	Unweighted	Sea turtles	4025	2068	1513
McCauley et al. (2000)	166	Unweighted		8568	3826	3488
GARFO (2020)	150	Unweighted	Fish	27084	14103	12041

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 8 to 10.

Table 23. SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 5000 kJ, 13 m monopile foundation. Ranges to SPL thresholds are for the highest hammer energy level.

Criteria source	L_p (dB re 1 µPa)	Frequency weighting	Faunal group	Attenuation level (dB)		
				0	10	12
NOAA (2005)	160	Unweighted	All species/behaviors	12815	4636	4129
Wood et al. (2012)	120	HF	Beaked whales and harbor porpoise	117874	100049	88050
	140	LF	Migrating mysticetes	62209	27756	23899
	160	LF	All other species/behaviors	12759	4605	4121
	160	MF		6552	3112	2693
	160	PW		9754	3760	3347
Finneran et al. (2017)	175	Unweighted	Sea turtles	3441	1341	1000
GARFO (2020)	150	Unweighted	Fish	27802	12815	10708

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 8 to 10.

Table 24. SPL Ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 3500 kJ, 4 m jacket foundation. Ranges to SPL are for the highest hammer energy level.

Criteria source	L_p (dB re 1 µPa)	Frequency weighting	Faunal group	Attenuation level (dB)		
				0	10	12
NOAA (2005)	160	Unweighted	All species/behaviors	8424	3642	3414
Wood et al. (2012)	120	HF	Beaked whales and harbor porpoise	107076	79019	59400
	140	LF	Migrating mysticetes	40384	19704	16912
	160	LF	All other species/behaviors	8396	3638	3408
	160	MF		4696	2502	2193
	160	PW		6718	3224	2910
Finneran et al. (2017)	175	Unweighted	Sea turtles	2819	626	425
GARFO (2020)	150	Unweighted	Fish	19734	8424	6950

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 8 to 10.

4.3. Sound Exposure Estimates

4.3.1. Marine Mammal Exposure Estimates

The mean number of marine mammals predicted to experience sound levels exceeding injury and behavior thresholds are provided in Tables 25–26 assuming 0, 10, and 12 dB broadband attenuation. These exposure estimates are calculated using the schedules described in Section 1.2.7, which combine the proposed years of construction. Appendix H contains supplemental results reported separately for each Project year. Exposure estimates utilize habitat-based models to derive species densities. These numbers may not be reflective of the current state of certain species' current populations, e.g., NARW, but are the best available data.

Table 25. Construction Schedule A, All Years Summed: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	146.36	21.51	13.94	0.14	0.04	0.02	147.36	33.58	28.56	205.54	66.20	53.73
Minke whale	49.59	9.71	6.32	0.06	0.03	0.03	74.94	26.79	23.90	422.12	207.05	175.39
Humpback whale	81.08	13.69	9.09	0.13	0.05	0.05	68.89	16.46	14.11	97.99	31.83	25.69
North Atlantic right whale[c]	18.08	3.09	2.16	0.02	<0.01	<0.01	26.02	7.01	5.98	36.32	11.99	9.72
Sei whale[c]	3.60	0.53	0.36	0.01	<0.01	<0.01	5.44	1.29	1.09	42.29	20.13	16.86
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0.62	0.21	0.21	1.56	1.56	1.56	3610.99	1334.89	1189.53	2722.32	1021.70	814.92
Atlantic spotted dolphin	0	0	0	0	0	0	14.74	3.92	3.38	17.04	4.18	3.03
Short-beaked common dolphin	4.05	1.28	0	6.96	5.09	5.09	16247.71	6999.42	6371.06	11666.25	4697.60	3805.18
Bottlenose dolphin	1.13	0.15	0	0.62	0.62	0.62	825.16	387.83	331.24	690.84	246.92	194.13
Risso's dolphin	0.04	0.02	<0.01	0.04	0.03	0.03	19.27	6.23	5.59	16.53	5.65	4.45
Long-finned pilot whale	0.06	0.06	0	0.15	0.15	0.15	447.66	165.24	147.76	324.89	126.66	100.70
Short-finned pilot whale	0.05	<0.01	<0.01	0.24	0.24	0.24	337.97	121.26	108.08	251.74	94.85	74.60
Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	8.93	2.64	2.34	7.71	2.52	1.92
High-frequency cetaceans												
Harbor porpoise	359.73	97.62	67.84	34.26	5.91	3.87	758.01	258.58	227.94	11092.63	5509.56	4618.70
Pinnipeds in water												
Gray seal	10.12	1.07	0.54	<0.01	<0.01	<0.01	170.45	32.11	24.86	199.28	60.51	47.44
Harbor seal	29.00	1.95	0.91	0.28	0.18	0.18	321.18	75.85	61.00	402.88	123.09	96.25
Harp seal	12.51	0.94	0.36	0.10	0	0	187.66	37.64	30.42	225.05	67.95	53.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 26. Construction Schedule B, All Years Summed: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	251.74	37.72	25.35	0.31	0.09	0.02	160.68	41.87	37.77	236.43	78.58	64.38
Minke whale	97.69	20.59	13.10	0.10	0.03	0.03	115.38	50.89	46.74	617.91	300.67	253.54
Humpback whale	117.67	20.47	13.67	0.15	0.02	0.02	69.43	19.53	17.64	101.72	34.17	27.70
North Atlantic right whale[c]	19.76	3.92	2.77	0.02	<0.01	<0.01	19.26	6.92	6.23	25.98	9.34	7.75
Sei whale[c]	6.78	1.14	0.83	0.02	<0.01	<0.01	6.12	1.88	1.73	54.33	24.66	20.41
Mid-frequency cetaceans												
Atlantic white-sided dolphin	2.60	0.87	0.87	1.17	1.17	1.17	5332.04	2385.18	2160.55	4060.10	1638.66	1327.44
Atlantic spotted dolphin	0	0	0	0	0	0	17.42	4.31	3.75	21.26	5.24	3.76
Short-beaked common dolphin	7.55	2.52	0	5.72	5.16	5.16	19012.51	9012.55	8248.25	13432.98	5737.60	4697.05
Bottlenose dolphin	2.02	0.31	0	0.41	0.41	0.41	998.97	526.97	447.68	830.86	315.02	248.12
Risso's dolphin	0.05	0.03	<0.01	0.03	0.02	0.01	23.89	8.98	8.23	20.92	7.52	5.97
Long-finned pilot whale	0.18	0.18	0	0.14	0.14	0.14	601.70	260.80	237.32	432.84	181.87	146.36
Short-finned pilot whale	0.08	0.01	0	0.14	0.14	0.14	447.99	194.21	175.55	334.52	135.57	107.62
Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	13.09	4.60	4.19	11.90	4.04	3.13
High-frequency cetaceans												
Harbor porpoise	611.86	173.78	117.38	56.46	8.82	6.32	932.60	400.40	363.83	12817.69	5868.55	4939.12
Pinnipeds in water												
Gray seal	13.69	1.55	0.92	<0.01	<0.01	<0.01	103.73	21.91	19.94	131.69	41.14	31.52
Harbor seal	48.24	3.85	1.64	0.77	0.10	0.10	236.43	77.88	67.72	300.72	99.42	78.24
Harp seal	20.33	1.42	0.52	0.19	0	0	129.91	36.14	32.17	159.01	52.37	41.11

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

4.3.2. Sea Turtle Exposure Estimates

The mean number of sea turtles predicted to experience sound levels exceeding injury and behavior thresholds are provided in Tables 27 and 28 assuming 0, 10, and 12 dB broadband attenuation. These exposure estimates are calculated using the schedules described in Section 1.2.7, which combine the proposed years of construction. Appendix H.2.1 contains supplemental results reported separately for each Project year.

Table 27. Construction Schedule A, All Years Summed: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.24	<0.01	<0.01	<0.01	<0.01	<0.01	1.15	0.25	0.18
Leatherback turtle[a]	5.57	0.23	0.02	0.23	0.23	0.23	40.48	8.57	5.69
Loggerhead turtle	2.18	0.04	<0.01	0.08	0.08	0.08	22.56	4.57	3.23
Green turtle	0.49	0.01	<0.01	<0.01	<0.01	<0.01	1.26	0.32	0.20

[a] Listed as Endangered under the ESA.

Table 28. Construction Schedule B, All Years Summed: The mean number of sea turtles predicted to receive sound levels above exposure criteriawith sound attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.42	0.01	0	<0.01	<0.01	<0.01	1.64	0.35	0.27
Leatherback turtle[a]	8.07	0.18	0	0.17	0.17	0.17	55.79	10.09	6.82
Loggerhead turtle	2.64	0	0	0.09	0.09	0.09	27.72	5.24	3.88
Green turtle	0.77	0.02	<0.01	<0.01	<0.01	<0.01	1.69	0.42	0.23

[a] Listed as Endangered under the ESA.

4.3.3. Effect of Aversion

The exposure estimates tables above and in Appendices H.2.1 and H.2.2 do not account for aversion or the implementation of mitigation measures other than sound attenuation (e.g., pile driving shut-down or power down). However, to demonstrate the potential effect of aversion, a subset of the animat simulations (harbor porpoise and NARW) were run using the approach described in Section 2.6.1. For comparative purposes only, the results are shown with and without aversion (Table 29).

Table 29. Comparison of mean exposure estimates modeled for Construction Schedule A (all years summed) for harbor porpoises and North Atlantic right whales (NARWs) when aversion is included in animal movement models relative to models without aversion, assuming 10 dB attenuation.

Species	10 dB attenuation, no aversion				10 dB attenuation, with aversion			
	Injury		Behavior		Injury		Behavior	
	L_E	L_{pk}	L_p	L_p	L_E	L_{pk}	L_p	L_p
North Atlantic right whale	3.09	<0.01	7.01	11.99	0.52	<0.01	3.14	9.50
Harbor porpoise	97.62	5.91	258.58	5509.56	0.39	0	14.13	4270.28

4.3.4. Potential Impacts Relative to Species' Abundance

As described above, animal movement modeling was used to predict the number of individual animals that could receive sound levels above injury exposure thresholds. Those individual exposure numbers must then be assessed in the context of the species' populations or stocks.

Defining biologically significant impacts to a population of animals that result from injury or behavioral responses estimated from exposure models and acoustic thresholds remains somewhat subjective. The percent of the stock or population exposed has been commonly used as an indication of the extent of potential impact (e.g., NSF 2011). In this way, the potential number of exposed animals can be interpreted in an abundance context, which allows for consistency across different population or stock sizes. The exposure results provided in Section 4.3.1 are presented as a percent of total abundance for each species and each attenuation level in Tables 30 and 31. Abundance numbers used to calculate the percent of population estimated to receive threshold levels of sound are shown in Table 13.

Table 30. Construction Schedule A, All Years Summed: Marine mammal exposures as a percent of abundance with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	2.15	0.32	0.20	<0.01	<0.01	<0.01	2.17	0.49	0.42	3.02	0.97	0.79
Minke whale	0.23	0.04	0.03	<0.01	<0.01	<0.01	0.34	0.12	0.11	1.92	0.94	0.80
Humpback whale	5.81	0.98	0.65	<0.01	<0.01	<0.01	4.94	1.18	1.01	7.02	2.28	1.84
North Atlantic right whale[c]	4.91	0.84	0.59	<0.01	<0.01	<0.01	7.07	1.91	1.62	9.87	3.26	2.64
Sei whale[c]	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	0.02	0.02	0.67	0.32	0.27
Mid-frequency cetaceans												
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.87	1.43	1.28	2.92	1.10	0.87
Atlantic spotted dolphin	0	0	0	0	0	0	0.04	<0.01	<0.01	0.04	0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	0	<0.01	<0.01	<0.01	9.39	4.05	3.68	6.74	2.72	2.20
Bottlenose dolphin	<0.01	<0.01	0	<0.01	<0.01	<0.01	1.31	0.62	0.53	1.10	0.39	0.31
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.02	0.02	0.05	0.02	0.01
Long-finned pilot whale	<0.01	<0.01	0	<0.01	<0.01	<0.01	1.14	0.42	0.38	0.83	0.32	0.26
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.17	0.42	0.37	0.87	0.33	0.26
Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	0.21	0.06	0.05	0.18	0.06	0.04
High-frequency cetaceans												
Harbor porpoise	0.38	0.10	0.07	0.04	<0.01	<0.01	0.79	0.27	0.24	11.61	5.77	4.83
Pinnipeds in water												
Gray seal	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.62	0.12	0.09	0.73	0.22	0.17
Harbor seal	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	0.52	0.12	0.10	0.66	0.20	0.16
Harp seal	<0.01	<0.01	<0.01	<0.01	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 31. Construction Schedule B, All Years Summed: Marine mammal exposures as a percent of abundance with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	3.70	0.55	0.37	<0.01	<0.01	<0.01	2.36	0.62	0.56	3.48	1.16	0.95
Minke whale	0.44	0.09	0.06	<0.01	<0.01	<0.01	0.53	0.23	0.21	2.81	1.37	1.15
Humpback whale	8.43	1.47	0.98	0.01	<0.01	<0.01	4.97	1.40	1.26	7.29	2.45	1.98
North Atlantic right whale[c]	5.37	1.06	0.75	<0.01	<0.01	<0.01	5.23	1.88	1.69	7.06	2.54	2.11
Sei whale[c]	0.11	0.02	0.01	<0.01	<0.01	<0.01	0.10	0.03	0.03	0.86	0.39	0.32
Mid-frequency cetaceans												
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	5.72	2.56	2.32	4.35	1.76	1.42
Atlantic spotted dolphin	0	0	0	0	0	0	0.04	0.01	<0.01	0.05	0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	0	<0.01	<0.01	<0.01	10.99	5.21	4.77	7.77	3.32	2.72
Bottlenose dolphin	<0.01	<0.01	0	<0.01	<0.01	<0.01	1.59	0.84	0.71	1.32	0.50	0.39
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.03	0.02	0.06	0.02	0.02
Long-finned pilot whale	<0.01	<0.01	0	<0.01	<0.01	<0.01	1.53	0.67	0.61	1.10	0.46	0.37
Short-finned pilot whale	<0.01	<0.01	0	<0.01	<0.01	<0.01	1.55	0.67	0.61	1.16	0.47	0.37
Sperm whale[c]	<0.01	<0.01	0	<0.01	<0.01	<0.01	0.30	0.11	0.10	0.27	0.09	0.07
High-frequency cetaceans												
Harbor porpoise	0.64	0.18	0.12	0.06	<0.01	<0.01	0.98	0.42	0.38	13.42	6.14	5.17
Pinnipeds in water												
Gray seal	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	0.38	0.08	0.07	0.48	0.15	0.12
Harbor seal	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	0.39	0.13	0.11	0.49	0.16	0.13
Harp seal	<0.01	<0.01	<0.01	<0.01	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

4.4. Exposure-based Ranges to Thresholds for Impact Pile Driving

The following subsections contain tables of exposure ranges (ER95%) calculated to both injury and behavioral sound exposure thresholds described in Sections 2.4 and 2.5 for the 12 and 13 m monopile, and 4 m jacket foundations. Exposure ranges are computed using the simulated movements of individual animats within each species group considered in the animal movement and exposure modeling, so ER95% results are reported by species rather than hearing group.

4.4.1. Marine Mammals

Exposure ranges ($ER_{95\%}$) to acoustic thresholds for injury and behavior are presented for jacket and monopile foundations, assuming 0, 10, and 12 dB broadband attenuation. This section includes only the subset of foundations and installation schedules included in Construction Schedules A and B (see Section 1.2.7). Additional configurations are provided in Appendix H.2.4.

Table 32. 12 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	7.99	2.37	1.91	0.04	0.01	0.01	10.45	4.00	3.71	10.46	3.99	3.72
Minke whale	6.38	1.50	0.97	0.04	0.02	0.02	10.04	3.89	3.50	36.32	20.29	17.93
Humpback whale	9.08	2.76	2.12	0	0	0	10.45	3.99	3.74	10.47	3.99	3.74
North Atlantic right whale[c]	7.81	1.84	1.52	0	0	0	10.01	3.94	3.62	10.12	3.97	3.60
Sei whale[c]	7.20	1.95	1.26	<0.01	<0.01	<0.01	10.21	3.88	3.67	38.10	21.02	18.41
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0	0	0	0.01	0.01	0.01	9.76	3.78	3.48	5.52	2.75	2.35
Atlantic spotted dolphin	0	0	0	0	0	0	10.11	4.15	2.98	5.69	2.57	1.93
Short-beaked common dolphin	0	0	0	0.01	0.01	0.01	9.79	3.79	3.51	5.61	2.86	2.42
Bottlenose dolphin	0	0	0	0.01	0.01	0.01	9.35	3.40	2.97	5.03	2.34	1.74
Risso's dolphin	0.02	0	0	0.02	<0.01	<0.01	10.20	3.85	3.62	6.07	2.94	2.65
Long-finned pilot whale	0	0	0	0.02	0.02	0.02	9.90	3.85	3.53	5.55	2.93	2.39
Short-finned pilot whale	<0.01	<0.01	0	<0.01	<0.01	<0.01	9.91	3.83	3.56	5.56	2.86	2.39
Sperm whale[c]	0	0	0	0.02	0.02	0.02	10.18	3.90	3.72	5.71	2.96	2.32
High-frequency cetaceans												
Harbor porpoise	5.17	1.55	1.07	0.56	0.13	0.11	9.97	3.94	3.66	97.57	53.67	46.82
Pinnipeds in water												
Gray seal	2.23	0.51	0.42	0	0	0	10.73	4.13	3.95	8.67	3.56	3.28
Harbor seal	2.03	0.21	0.02	0.02	0.02	0.02	10.28	3.75	3.56	8.33	3.33	3.09
Harp seal	1.80	0.15	0.06	0.05	0	0	10.43	4.00	3.54	8.50	3.48	3.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 33. 12 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	9.66	2.79	2.19	0.02	0	0	10.31	3.98	3.80	10.37	4.00	3.82
Minke whale	7.29	1.67	1.29	0.07	0.02	0.02	9.67	3.80	3.55	36.30	20.44	17.74
Humpback whale	10.91	3.44	2.46	0.03	0.01	0.01	10.44	3.98	3.66	10.50	3.98	3.66
North Atlantic right whale[c]	8.81	2.34	1.69	0.04	<0.01	<0.01	9.99	3.75	3.52	10.10	3.76	3.53
Sei whale[c]	8.50	2.04	1.50	0.03	0.02	0.02	10.17	3.85	3.54	38.42	20.94	18.42
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0	0	0	0.02	0.02	0.02	9.47	3.74	3.35	5.48	2.77	2.32
Atlantic spotted dolphin	0	0	0	0	0	0	9.60	3.66	3.32	5.17	2.78	2.33
Short-beaked common dolphin	0	0	0	0.02	0.02	0.02	9.62	3.81	3.46	5.51	2.87	2.36
Bottlenose dolphin	<0.01	0	0	0.01	0.01	0.01	8.99	3.25	2.96	5.04	2.21	1.92
Risso's dolphin	0.02	<0.01	<0.01	0.02	0.02	0.01	10.01	3.80	3.55	5.82	2.85	2.49
Long-finned pilot whale	0	0	0	0.01	0.01	0.01	9.70	3.74	3.46	5.56	2.89	2.34
Short-finned pilot whale	0	0	0	0.02	0.02	0.02	9.71	3.78	3.48	5.58	2.85	2.31
Sperm whale[c]	0.29	0	0	<0.01	<0.01	<0.01	9.75	3.79	3.55	5.54	2.82	2.39
High-frequency cetacean												
Harbor porpoise	5.50	1.60	1.28	0.56	0.15	0.09	9.91	3.86	3.63	97.41	53.14	46.68
Pinnipeds in water												
Gray seal	2.51	0.56	0.38	0.01	0.01	0.01	10.49	4.17	3.94	8.58	3.68	3.28
Harbor seal	2.43	0.21	0.16	<0.01	<0.01	<0.01	10.20	3.81	3.63	8.32	3.45	3.14
Harp seal	2.20	0.31	0.09	0.06	0	0	10.40	4.01	3.60	8.36	3.54	3.12

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 34. 12 m monopile, 6000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	10.14	3.31	2.45	0.04	0.01	0.01	15.62	6.19	4.63	15.63	6.21	4.66
Minke whale	8.15	2.40	1.68	0.02	0.02	0.02	14.49	5.66	4.27	60.34	28.63	25.77
Humpback whale	11.12	3.81	2.89	0.08	0	0	15.58	5.95	4.87	15.57	5.88	4.87
North Atlantic right whale[c]	9.84	2.93	2.03	0	0	0	14.50	5.46	4.51	14.58	5.48	4.52
Sei whale[c]	9.31	2.47	2.16	<0.01	<0.01	<0.01	15.08	5.79	4.69	73.70	31.08	26.82
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0	0	0	0.01	0.01	0.01	14.21	5.35	4.34	8.81	3.31	2.93
Atlantic spotted dolphin	0	0	0	0	0	0	15.29	5.87	4.57	8.91	3.13	3.04
Short-beaked common dolphin	0	0	0	0.01	0.01	0.01	14.53	5.68	4.39	9.04	3.36	2.97
Bottlenose dolphin	0.11	0	0	0.01	0.01	0.01	14.04	4.77	3.94	8.13	3.02	2.72
Risso's dolphin	0.02	0.02	0	0.02	<0.01	<0.01	15.28	5.55	4.52	9.23	3.46	3.04
Long-finned pilot whale	0	0	0	0.02	0.02	0.02	14.61	5.55	4.44	8.81	3.37	3.00
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	14.46	5.57	4.55	8.97	3.30	3.03
Sperm whale[c]	0.01	0	0	0.02	0.02	0.02	15.19	5.73	4.59	8.98	3.47	3.00
High-frequency cetaceans												
Harbor porpoise	6.53	2.26	1.69	0.60	0.21	0.18	14.64	5.76	4.45	105.70	84.55	80.55
Pinnipeds in water												
Gray seal	2.96	0.84	0.52	0	0	0	15.61	6.06	5.03	13.09	4.38	3.88
Harbor seal	2.86	0.43	0.22	0.02	0.02	0.02	15.39	6.01	4.48	12.58	4.09	3.70
Harp seal	2.39	0.25	0.09	0.05	0	0	15.38	5.93	4.89	12.83	4.22	3.89

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 35. 12 m monopile, 6000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	12.55	3.90	2.86	0.02	0	0	15.82	6.01	4.91	15.86	5.97	4.90
Minke whale	9.23	2.59	1.82	0.02	0.02	0.02	14.65	5.33	4.39	66.79	29.19	25.67
Humpback whale	13.59	4.62	3.60	0.03	0.01	0.01	15.78	5.92	4.72	15.81	5.93	4.72
North Atlantic right whale[c]	11.16	3.16	2.49	0.04	<0.01	<0.01	14.51	5.60	4.45	14.61	5.65	4.45
Sei whale[c]	11.07	3.08	2.25	0.02	0.02	0.02	15.40	5.79	4.79	76.41	32.38	27.74
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0	0	0	0.02	0.02	0.02	14.09	5.40	4.29	8.54	3.22	2.83
Atlantic spotted dolphin	0	0	0	0	0	0	15.03	5.47	3.95	8.53	2.89	2.72
Short-beaked common dolphin	0.02	0	0	0.02	0.02	0.02	14.35	5.54	4.34	8.88	3.33	3.08
Bottlenose dolphin	0.19	0	0	0.01	0.01	0.01	14.12	4.93	3.77	8.39	2.92	2.57
Risso's dolphin	0.03	<0.01	<0.01	0.02	0.02	0.02	15.39	5.89	4.54	9.27	3.33	3.09
Long-finned pilot whale	0	0	0	0.01	0.01	0.01	14.65	5.50	4.43	8.80	3.26	2.95
Short-finned pilot whale	0.02	0	0	0.02	0.02	0.02	14.60	5.62	4.43	8.85	3.27	2.99
Sperm whale[c]	0.29	0	0	<0.01	<0.01	<0.01	14.98	5.84	4.58	8.81	3.42	2.96
High-frequency cetaceans												
Harbor porpoise	7.01	2.30	1.69	0.66	0.17	0.15	14.63	5.48	4.53	107.40	86.45	82.28
Pinnipeds in water												
Gray seal	3.29	1.01	0.56	0.01	0.01	0.01	15.83	6.05	4.92	13.02	4.31	4.07
Harbor seal	3.31	0.63	0.19	0.07	<0.01	<0.01	15.37	6.03	4.78	12.97	4.15	3.63
Harp seal	3.07	0.41	0.20	0	0	0	15.69	5.97	4.86	12.86	4.23	3.83

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 36. 13 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	8.78	2.56	1.90	0.02	0	0	12.46	4.29	3.88	12.46	4.24	3.88
Minke whale	6.30	1.50	1.17	0	0	0	11.63	3.98	3.63	48.40	24.76	21.91
Humpback whale	9.40	2.87	2.27	0.03	<0.01	<0.01	12.35	4.26	3.74	12.37	4.25	3.74
North Atlantic right whale[c]	8.05	2.26	1.54	0.03	<0.01	<0.01	12.11	4.11	3.70	12.21	4.17	3.70
Sei whale[c]	7.73	1.66	1.25	0.03	<0.01	<0.01	11.98	4.21	3.69	61.51	25.73	22.45
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0	0	0	0	0	0	11.47	3.95	3.58	5.68	2.55	2.27
Atlantic spotted dolphin	0	0	0	0	0	0	11.50	4.01	3.76	5.34	2.64	2.59
Short-beaked common dolphin	0	0	0	<0.01	0	0	11.57	3.99	3.48	6.15	2.64	2.31
Bottlenose dolphin	0	0	0	0	0	0	10.98	3.53	3.01	5.73	2.30	1.97
Risso's dolphin	0.01	<0.01	0	<0.01	0	0	12.15	4.26	3.77	6.28	2.62	2.39
Long-finned pilot whale	0	0	0	0	0	0	11.69	4.08	3.52	5.96	2.68	2.22
Short-finned pilot whale	0	0	0	<0.01	<0.01	<0.01	11.82	4.10	3.53	6.04	2.68	2.40
Sperm whale[c]	0	0	0	0	0	0	11.88	4.15	3.64	6.17	2.61	2.36
High-frequency cetacean												
Harbor porpoise	5.13	1.51	1.07	0.59	0.23	0.19	11.79	4.00	3.63	106.34	85.66	79.37
Pinnipeds in water												
Gray seal	2.16	0.59	0.12	0	0	0	12.56	4.53	4.08	9.67	3.73	3.30
Harbor seal	1.94	0.16	0	0	0	0	12.21	4.25	3.73	9.48	3.31	3.17
Harp seal	1.85	0.09	0	0	0	0	12.31	4.30	3.75	9.48	3.40	3.07

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 37. 13 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	10.98	3.14	2.24	0.02	0	0	12.35	4.20	3.84	12.35	4.20	3.84
Minke whale	7.37	1.65	1.20	0	0	0	11.51	3.82	3.55	49.23	24.59	21.59
Humpback whale	11.59	3.66	2.79	0.05	<0.01	<0.01	12.28	4.26	3.83	12.30	4.26	3.84
North Atlantic right whale[c]	9.52	2.53	1.79	0.02	<0.01	<0.01	11.65	4.03	3.51	11.76	4.07	3.55
Sei whale[c]	9.48	2.31	1.62	0.03	<0.01	<0.01	11.87	3.96	3.62	62.48	25.94	22.40
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0	0	0	0	0	0	11.12	3.84	3.31	5.76	2.43	2.20
Atlantic spotted dolphin	0	0	0	0	0	0	11.23	3.85	3.28	5.28	2.55	2.14
Short-beaked common dolphin	0	0	0	<0.01	0	0	11.28	3.95	3.43	5.96	2.65	2.31
Bottlenose dolphin	0	0	0	<0.01	<0.01	<0.01	10.63	3.37	2.91	5.37	2.22	2.10
Risso's dolphin	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	11.90	4.03	3.64	6.24	2.64	2.42
Long-finned pilot whale	0	0	0	0	0	0	11.51	3.90	3.51	5.80	2.63	2.23
Short-finned pilot whale	0	0	0	<0.01	<0.01	<0.01	11.58	3.95	3.50	5.95	2.64	2.31
Sperm whale[c]	0.30	0	0	<0.01	0	0	11.77	4.08	3.60	6.18	2.58	2.29
High-frequency cetaceans												
Harbor porpoise	5.48	1.50	1.20	0.61	0.21	0.19	11.46	3.95	3.58	107.93	85.98	79.39
Pinnipeds in water												
Gray seal	2.55	0.57	0.32	0	0	0	12.49	4.52	4.12	9.67	3.67	3.29
Harbor seal	2.69	0.19	0.08	0	0	0	12.02	4.25	3.70	9.31	3.34	3.20
Harp seal	2.22	0.32	0.05	0.06	0	0	12.11	4.29	3.73	9.40	3.49	3.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 38. 4 m pin pile, 3500 kJ hammer, four pin piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury						Behavior					
	L_E			L_{pk}			L_p [a]			L_p [b]		
	Attenuation (dB)						Attenuation (dB)					
	0	10	12	0	10	12	0	10	12	0	10	12
Low-frequency cetaceans												
Fin whale[c]	13.29	4.07	3.14	0.02	<0.01	0	8.47	3.56	3.29	8.49	3.58	3.30
Minke whale	7.87	1.83	1.26	0.01	0	0	8.00	3.34	3.20	37.71	19.07	16.46
Humpback whale	13.83	4.49	3.25	0.02	0	0	8.44	3.56	3.28	8.44	3.57	3.28
North Atlantic right whale[c]	10.37	2.54	1.74	0.02	0	0	8.15	3.34	3.16	8.23	3.38	3.19
Sei whale[c]	10.90	2.84	1.89	<0.01	0	0	8.22	3.39	3.23	40.08	19.61	16.97
Mid-frequency cetaceans												
Atlantic white-sided dolphin	0.01	0.01	0.01	0	0	0	8.02	3.27	3.12	4.43	2.33	1.97
Atlantic spotted dolphin	0	0	0	0	0	0	8.40	3.26	3.17	4.39	2.27	2.01
Short-beaked common dolphin	<0.01	<0.01	0	0	0	0	7.98	3.34	3.15	4.49	2.41	2.07
Bottlenose dolphin	0.08	0.01	0	0	0	0	6.44	2.87	2.59	3.79	1.90	1.50
Risso's dolphin	0.01	0.01	0.01	<0.01	0	0	8.27	3.38	3.16	4.59	2.42	2.06
Long-finned pilot whale	<0.01	<0.01	0	0	0	0	7.96	3.30	3.10	4.49	2.32	1.91
Short-finned pilot whale	0.01	0	0	0	0	0	7.95	3.37	3.16	4.40	2.38	1.96
Sperm whale[c]	<0.01	<0.01	0	0	0	0	8.17	3.36	3.11	4.61	2.35	1.89
High-frequency cetaceans												
Harbor porpoise	5.90	1.77	1.29	0.53	0.10	0.10	8.15	3.38	3.21	96.13	65.51	54.74
Pinnipeds in water												
Gray seal	4.35	1.31	0.96	0	0	0	8.52	3.49	3.38	6.83	3.30	2.91
Harbor seal	3.33	0.32	0.12	0.06	0	0	8.33	3.44	3.12	6.68	3.08	2.70
Harp seal	2.85	0.28	0.15	0.07	0	0	8.44	3.49	3.24	6.77	3.21	2.81

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

4.4.2. Sea Turtles

Similar to the results presented for marine mammals (Section 4.4.1), exposure ranges ($ER_{95\%}$) to acoustic thresholds for injury and behavior are presented for jacket and monopile foundations, assuming 0, 10, and 12 dB broadband attenuation. This section includes only the subset of foundations and installation schedules included in Construction Schedules A and B (see Section 1.2.7). Additional configurations are provided in Appendix H.2.5.

Table 39. 12 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.72	0.02	0	0	0	0	2.91	0.82	0.69
Leatherback turtle[a]	0.98	0	0	<0.01	<0.01	<0.01	2.76	0.78	0.44
Loggerhead turtle	0.12	0	0	0.02	0.02	0.02	2.65	0.75	0.38
Green turtle	1.03	0.02	0.02	0.01	0.01	0.01	3.19	1.03	0.77

[a] Listed as Endangered under the ESA.

Table 40. 12 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.60	0.02	0	0.02	0.02	0.02	3.05	0.83	0.60
Leatherback turtle[a]	0.58	0.02	0	0.02	0.02	0.02	2.67	0.68	0.65
Loggerhead turtle	0.40	0	0	0.01	0.01	0.01	2.53	0.58	0.40
Green turtle	1.38	<0.01	<0.01	<0.01	<0.01	<0.01	3.21	1.17	0.72

[a] Listed as Endangered under the ESA.

Table 41. 12 m monopile, 6000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.97	0.07	0.02	0	0	0	3.53	1.66	0.88
Leatherback turtle[a]	1.21	0.03	0	<0.01	<0.01	<0.01	3.12	1.39	0.91
Loggerhead turtle	0.75	0.02	<0.01	0.02	0.02	0.02	3.42	1.13	1.06
Green turtle	1.87	0.16	0.07	0.01	0	0	3.78	1.97	1.44

[a] Listed as Endangered under the ESA.

Table 42. 12 m monopile, 6000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	1.12	0.02	0.02	0.02	0.02	0.02	3.57	1.77	1.31
Leatherback turtle[a]	1.27	0.17	0.02	0.02	0.02	0.02	3.24	1.35	1.12
Loggerhead turtle	0.63	<0.01	<0.01	0.01	0.01	0.01	3.05	1.20	0.85
Green turtle	2.24	0.15	0.03	<0.01	<0.01	<0.01	3.65	1.83	1.49

[a] Listed as Endangered under the ESA.

Table 43. 13 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.60	0	0	<0.01	<0.01	<0.01	2.83	1.19	0.69
Leatherback turtle[a]	0.58	0	0	0	0	0	2.78	0.69	0.51
Loggerhead turtle	0.29	<0.01	0	0	0	0	2.54	0.62	0.55
Green turtle	1.11	<0.01	<0.01	0	0	0	3.27	1.15	0.98

[a] Listed as Endangered under the ESA.

Table 44. 13 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.68	0.02	0	<0.01	<0.01	<0.01	2.87	1.12	0.87
Leatherback turtle[a]	0.56	0.02	0	0	0	0	2.77	0.98	0.51
Loggerhead turtle	0.37	<0.01	0	0	0	0	2.53	0.65	0.44
Green turtle	1.59	0.04	<0.01	0	0	0	3.20	1.23	0.96

[a] Listed as Endangered under the ESA.

Table 45. 4 m pin pile, 3500 kJ hammer, four pin piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury						Behavior		
	L_E			L_{pk}			L_p		
	Attenuation (dB)						Attenuation (dB)		
	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle[a]	0.68	0.04	0	0	0	0	2.34	0.47	0.33
Leatherback turtle[a]	0.71	0.03	0	0	0	0	2.17	0.45	0.33
Loggerhead turtle	0.44	0	0	0	0	0	2.15	0.44	0.27
Green turtle	1.52	0.03	0.02	0	0	0	2.76	0.58	0.38

[a] Listed as Endangered under the ESA.

4.5. Acoustic Impacts to Fish

Applying the thresholds for potential injury (see Section 2.5) with 10 dB attenuation, the range to PK sound levels associated with 4 m jacket foundation piles, 12 m monopile foundation piles, and 13 m monopile foundations are 108 m, 157 m, and 127 m, respectively. Ranges from the piling source to regulatory-defined thresholds for SEL are 10 km for 4 m jacket foundation piles, 12 km for 12 m monopiles, and 12 km for 13 m monopiles all with 10 dB attenuation. These estimates do not account for any aversion that might occur as a result of the use of sound attenuation technologies (e.g., bubble curtains). Popper et al. 2014 does not define quantitative acoustic thresholds for behavioral response in fish. GARFO (2020) uses a 150 dB SPL threshold for all fish. When this criterion is used, distances to potential behavioral disturbance for fish are over 8 km from the 4 m jacket foundation piles, 14 km from the 12 m monopiles, and 12 km from the 13 m monopiles, respectively.

5. Discussion

Sounds fields produced during impact pile driving of monopile and jacket foundation piles for the maximum envelope of New England Wind, including Phases 1 and 2, were found by modeling the vibration of the pile when struck with a hammer, determining a far-field representation of the pile as a sound source, and then propagating the sound from the apparent source into the environment. The sound fields were then sampled by simulating animal movement within the sound fields and determining if simulated marine mammal and sea turtle animats (simulated animals) receive sound levels exceeding regulatory thresholds. The mean number of individuals of each species likely to receive sound levels exceeding the thresholds was determined by scaling the animat results using the real-world density of each species. For those animats that received sound levels exceeding threshold criteria, the closest point of approach to the source was found and the distance accounting for 95% of exceedances was reported as the exposure range, $ER_{95\%}$. The species-specific $ER_{95\%}$ (see tables in Section 4.4) were determined with different broadband attenuation levels (0, 6, 10, and 12 dB) to account for the use of noise reduction systems, such as bubble curtains. $ER_{95\%}$ can be used for mitigation purposes, like establishing monitoring or exclusion areas. Fish were considered as static receivers, so exposure ranges were not calculated. Instead, the acoustic distance to their regulatory thresholds were determined and reported with the different broadband attenuation levels (see tables in Section 4.5).

5.1. Exposure Estimates for Marine Mammals and Sea Turtles

The potential risk of exposure for marine mammals and sea turtles was estimated from the sound levels received by each animat over the course of the JASMINE simulation, comparing those levels with the relevant regulatory thresholds, scaling by the mean monthly densities for each species (Roberts et al. 2016a, 2016b, 2017, 2018, 2021), and then summing over the construction period to get the total number of individual animals that may experience sound levels exceeding regulatory thresholds. The thresholds for injurious exposures are based on cumulative SEL and maximum PK pressure level (NMFS 2018). Thresholds for behavioral disruption are based on maximum SPL (NOAA 2005, Wood et al. 2012, Finneran et al. 2017). Mean exposures above injury and behavior thresholds for Construction Schedules A and B assuming 10 dB of broadband attenuation are summarized in Table 46 (marine mammals) and Table 47 (sea turtles).

Table 46. Summary of impact pile driving exposures above injury and behavioral threshold for marine mammals for Construction Schedules A and B (all years summed), assuming 10 dB of broadband attenuation.

Species	Construction Schedule A				Construction Schedule B			
	L_E	L_{pk}	L_p [a]	L_p [b]	L_E	L_{pk}	L_p [a]	L_p [b]
Low-frequency cetaceans								
Fin whale[c]	21.51	0.04	33.58	66.20	37.72	0.09	41.87	78.58
Minke whale	9.71	0.03	26.79	207.05	20.59	0.03	50.89	300.67
Humpback whale	13.69	0.05	16.46	31.83	20.47	0.02	19.53	34.17
North Atlantic right whale[c]	3.09	<0.01	7.01	11.99	3.92	<0.01	6.92	9.34
Sei whale[c]	0.53	<0.01	1.29	20.13	1.14	<0.01	1.88	24.66
Mid-frequency cetaceans								
Atlantic white-sided dolphin	0.21	1.56	1334.89	1021.70	0.87	1.17	2385.18	1638.66
Atlantic spotted dolphin	0	0	3.92	4.18	0	0	4.31	5.24
Short-beaked common dolphin	1.28	5.09	6999.42	4697.60	2.52	5.16	9012.55	5737.60
Bottlenose dolphin	0.15	0.62	387.83	246.92	0.31	0.41	526.97	315.02
Risso's dolphin	0.02	0.03	6.23	5.65	0.03	0.02	8.98	7.52
Long-finned pilot whale	0.06	0.15	165.24	126.66	0.18	0.14	260.80	181.87
Short-finned pilot whale	<0.01	0.24	121.26	94.85	0.01	0.14	194.21	135.57
Sperm whale[c]	<0.01	<0.01	2.64	2.52	<0.01	<0.01	4.60	4.04
High-frequency cetaceans								
Harbor porpoise	97.62	5.91	258.58	5509.56	173.78	8.82	400.40	5868.55
Pinnipeds in water								
Gray seal	1.07	<0.01	32.11	60.51	1.55	<0.01	21.91	41.14
Harbor seal	1.95	0.18	75.85	123.09	3.85	0.10	77.88	99.42
Harp seal	0.94	0	37.64	67.95	1.42	0	36.14	52.37

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 47. Summary of impact pile driving exposures above injury and behavioral threshold for sea turtles for Construction Schedules A and B (all years summed), assuming 10 dB of broadband attenuation.

Species	Construction Schedule A			Construction Schedule B		
	L_E	L_{pk}	L_p	L_E	L_{pk}	L_p
Kemp's ridley turtle[a]	<0.01	<0.01	0.25	0.01	<0.01	0.35
Leatherback turtle[a]	0.23	0.23	8.57	0.18	0.17	10.09
Loggerhead turtle	0.04	0.08	4.57	0	0.09	5.24
Green turtle	0.01	<0.01	0.32	0.02	<0.01	0.42

[a] Listed as Endangered under the ESA.

The endangered NARW is predicted to experience fewer than four injurious exposures during the combined installation of Phases 1 and 2. This corresponds to approximately 1% of the total species abundance (exposure estimates as a percent of abundance for all species are provided in Section 4.3.4). While NARW are migrating south during most of the proposed activity periods, they are also feeding. Rather than implementing a migrating behavioral state, we modeled foraging behaviors that result in more conservative exposure estimates as the animats have longer dwell times for feeding compared to the migratory assumption. The number of exposures above SEL injury threshold for all low-frequency cetaceans, assuming 10 dB attenuation, varies from approximately 1 to 38 individuals. Predicted injury-level acoustic exposures for mid-frequency cetacean species are low. Even the species with the highest number of predicted exposures, the common dolphin, has fewer than three exposures above the SEL threshold for injury, and fewer than six exposures above the PK threshold for injury (<0.01% of the population). Harbor porpoise, the only high frequency cetacean in the acoustic analysis, is predicted to experience up to 174 exposures above the SEL injury threshold, but this still only represents less than 0.2% of the population. For NARW, fewer than 10 animals are predicted to experience sound levels exceeding behavioral thresholds, which corresponds to 2.6% of the total population. Due to their relatively high local monthly densities, common dolphins have the highest predicted number of exposures above behavioral thresholds at approximately 9000 animals (approximately 5.2% of the population).

Even within a hearing group, the exposure modeling results vary substantially between species due to differences in estimated local species density, modeled monthly construction schedule, and modeled swimming and diving behavior. Injury exposure estimates for sei whales and NARWs are lower than for other low-frequency species (Table 46). The proposed schedules were developed considering a variety of factors including NARW temporal restrictions and anticipated weather days. The NARW restrictions are expected to preclude foundation installation in the periods with the greatest presence of NARW. Therefore, construction is modeled to occur only when NARW are expected not to be present, or present in only very low numbers. Furthermore, the construction schedule aligns with the predicted weather conditions resulting in greater construction activity over the summer months when NARW densities are at their lowest. Fewer weather delays and longer daylight will allow greater construction productivity. In some cases, particularly for low frequency cetaceans, the simulations predicted similar exposure estimates and ranges for injury and behavior criteria (Tables 46 and 47). This stems from the different threshold metrics that are used when assessing injury (SEL) and behavioral (SPL) thresholds. Behavioral criteria are based on the loudest single sound pressure level experienced by an animat and are similar across different species within a particular hearing group. In contrast, injury exposures for most of the species considered in this assessment are dominated by the cumulative sound exposure metric, which is more sensitive to the way animats move through and “sample” the sound field and also to the total number of strikes and hammer energy levels (see Tables 3 and 4). JASMINE species definitions are based on the most recent available literature on behavioral parameters such as speed, dive depth, dive reversals, surface intervals, and directionality.

Fewer than one sea turtle is predicted to be exposed to sound levels exceeding injury threshold. Up to 11 exposures above behavior threshold are predicted to occur.

5.2. Exposure Ranges for Marine Mammals and Sea Turtles

Tables 48 and 49, respectively, summarize the minimum and maximum exposure ranges across all foundation types and pile installation schedules (e.g., piles per day) for marine mammal and sea turtle injury and behavioral disruption. For the dual-criteria injury threshold the maximum of SEL or PK is reported, and, it is noted, that because different metrics and evaluation periods are used for injury and behavior the range to injury threshold may exceed the range to behavioral threshold. For example, the received level may be below the behavioral criteria threshold for a single strike but when the energy for many strikes is aggregated, the injury threshold may be exceeded.

The maximum $ER_{95\%}$ NARW exposure range across all foundation types to injury thresholds for any source with 10 dB attenuation is 3.16 km. The maximum $ER_{95\%}$ exposure range to injury thresholds for all low frequency cetaceans is approximately 4 km. For harbor porpoise, the exposure range to injury thresholds is up to 2.3 km. The maximum NARW exposure range for potential behavioral disruption is 5.6 km. The harbor porpoise has the largest $ER_{95\%}$ to behavioral threshold by a substantial margin, at approximately 86 km to the 50% threshold level as defined by (Wood et al. 2012). Harbor porpoises are designated as a sensitive species under these criteria, and the 50% threshold level for sensitive species is 120 dB SPL.

The maximum exposure range for sea turtle injury for any foundation type is 170 m. Sea turtle maximum exposure range for behavioral disruption is approximately 2 km.

Table 48. Summary of the predicted minimum and maximum marine mammal exposure ranges to injury and behavioral thresholds from impact pile driving assuming 10 dB of broadband attenuation.

Species	$max(L_E, L_{pk})$		L_p [a]		L_p [b]	
	Min	Max	Min	Max	Min	Max
Low-frequency cetaceans						
Fin whale[c]	2.37	4.07	3.56	6.19	3.58	6.21
Minke whale	1.50	2.59	3.34	5.66	19.07	29.19
Humpback whale	2.76	4.62	3.56	5.95	3.57	5.93
North Atlantic right whale[c]	1.84	3.16	3.34	5.60	3.38	5.65
Sei whale[c]	1.66	3.08	3.39	5.79	19.61	32.38
Mid-frequency cetaceans						
Atlantic white-sided dolphin	0	0.02	3.27	5.40	2.33	3.31
Atlantic spotted dolphin	0	0	3.26	5.87	2.27	3.13
Short-beaked common dolphin	0	0.02	3.34	5.68	2.41	3.36
Bottlenose dolphin	0	0.01	2.87	4.93	1.90	3.02
Risso's dolphin	<0.01	0.02	3.38	5.89	2.42	3.46
Long-finned pilot whale	0	0.02	3.30	5.55	2.32	3.37
Short-finned pilot whale	0	0.02	3.37	5.62	2.38	3.30
Sperm whale[c]	0	0.02	3.36	5.84	2.35	3.47
High-frequency cetaceans						
Harbor porpoise	1.50	2.30	3.38	5.76	53.14	86.45
Pinnipeds in water						
Gray seal	0.51	1.31	3.49	6.06	3.30	4.38
Harbor seal	0.16	0.63	3.44	6.03	3.08	4.15
Harp seal	0.09	0.41	3.49	5.97	3.21	4.23

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table 49. Summary of the predicted minimum and maximum sea turtle exposure ranges to injury and behavioral thresholds from impact pile driving assuming 10 dB of broadband attenuation.

Species	max(L_E, L_{pk})		L_p	
	Min	Max	Min	Max
Kemp's ridley turtle[a]	<0.01	0.07	0.47	1.77
Leatherback turtle[a]	0	0.17	0.45	1.39
Loggerhead turtle	0	0.02	0.44	1.20
Green turtle	<0.01	0.16	0.58	1.97

[a] Listed as Endangered under the ESA.

On average, there is a very slight increase in exposure range from 12 m to 13 m diameter monopiles at 5000 kJ, for both injury and behavior, but it is not as substantial as the increase from 1–2 piles per day or the increase from 5000 kJ to 6000 kJ max hammer energy. For both injury and behavior, the 2 pile per day cases were slightly longer than 1 per day for most species and foundation types.

5.3. Acoustic Ranges for Fish

Using exposure guidelines defined by Popper et al. (2014), acoustic results indicate that ranges to potential injury for fish with swim bladders not involved in hearing are small. Maximum range to the threshold defining potential injury across all foundation types is 2 km with 10 dB attenuation level. GARFO (2020) defines a broad behavioral criterion for all fish, which corresponds to a maximum range to threshold of 14 km.

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Appendix A. Glossary

Unless otherwise stated in an entry, these definitions are consistent with ISO 80000-3 (2017).

1/3-octave

One third of an octave. *Note*: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band

Frequency band whose bandwidth is one one-third octave. *Note*: The bandwidth of a one-third octave-band increases with increasing centre frequency.

absorption

The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.

acoustic noise

Sound that interferes with an acoustic process.

agent-based modelling

A simulation of autonomous agents acting in an environment used to assess the agents' experience of the environment and/or their effect on the environment. Also see **animal movement modelling**.

ambient sound

Sound that would be present in the absence of a specified activity, usually a composite of sound from many sources near and far, e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

animal movement modelling

Simulation of animal movement based on behavioural rules for the purpose of predicting an animal's experience of an environment.

attenuation

The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

auditory frequency weighting

The process of applying an auditory frequency weighting function. In human audiometry, C-weighting is the most commonly used function, an example for marine mammals are the auditory frequency weighting functions published by Southall et al. (2007).

auditory frequency weighting function

Frequency weighting function describing a compensatory approach accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity. Example hearing groups are low-, mid-, and high-frequency cetaceans, phocid and otariid pinnipeds.

azimuth

A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation, it is also called bearing.

bandwidth

The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI S1.13-2005 (R2010)).

broadband level

The total level measured over a specified frequency range.

cetacean

Any animal in the order Cetacea. These are aquatic species and include whales, dolphins, and porpoises.

compressional wave

A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

decade

Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 80000-3:2006).

decidecade

One tenth of a decade (ISO 2017). Note: An alternative name for decidecade (symbol ddec) is “one-tenth decade”. A decidecade is approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct) and for this reason is sometimes referred to as a “one-third octave”.

decidecade band

Frequency band whose bandwidth is one decidecade. *Note*: The bandwidth of a decidecade band increases with increasing center frequency.

decibel (dB)

Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale. Unit: dB.

frequency

The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: f. 1 Hz is equal to 1 cycle per second.

frequency weighting

The process of applying a frequency weighting function.

frequency-weighting function

The squared magnitude of the sound pressure transfer function. For sound of a given frequency, the frequency weighting function is the ratio of output power to input power of a specified filter, sometimes expressed in decibels. Examples include the following:

- *Auditory frequency weighting function*: compensatory frequency weighting function accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.
- *System frequency weighting function*: frequency weighting function describing the sensitivity of an acoustic acquisition system, typically consisting of a hydrophone, one or more amplifiers, and an analogue to digital converter.

geoacoustic

Relating to the acoustic properties of the seabed.

hearing group

Category of animal species when classified according to their hearing sensitivity and to the susceptibility to sound. Examples for marine mammals include very low-frequency (VLF) cetaceans, low-frequency (LF) cetaceans, mid-frequency (MF) cetaceans, high-frequency (HF) cetaceans, very high-frequency (VHF) cetaceans, otariid pinnipeds in water (OPW), phocid pinnipeds in water (PPW), sirenians (SI), other marine carnivores in air (OCA), and other marine carnivores in water (OCW) (NMFS 2018, Southall et al. 2019). See **auditory frequency weighting functions**, which are often applied to these groups. Examples for fish include species for which the swim bladder is involved in hearing, species for which the swim bladder is not involved in hearing, and species without a swim bladder (Popper et al. 2014).

hertz (Hz)

A unit of frequency defined as one cycle per second.

impulsive sound

Qualitative term meaning sounds that are typically transient, brief (less than 1 second), broadband, with rapid rise time and rapid decay. They can occur in repetition or as a single event. Examples of impulsive sound sources include explosives, seismic airguns, and impact pile drivers.

level

A measure of a quantity expressed as the logarithm of the ratio of the quantity to a specified reference value of that quantity. Examples include sound pressure level, sound exposure level, and peak sound pressure level. For example, a value of sound exposure level with reference to 1 μPa^2 s can be written in the form x dB re 1 μPa^2 s.

low-frequency (LF) cetacean

See **hearing group**.

level

A measure of a quantity expressed as the logarithm of the ratio of the quantity to a specified reference value of that quantity. Examples include sound pressure level, sound exposure level, and peak sound pressure level. For example, a value of sound exposure level with reference to 1 μPa^2 s can be written in the form *x* dB re 1 μPa^2 s.

low-frequency (LF) cetacean

See **hearing group**.

octave

The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

parabolic equation method

A computationally efficient solution to the acoustic wave equation that is used to model propagation loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of propagation loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak sound pressure level (zero-to-peak sound pressure level)

The level ($L_{p,pk}$ or L_{pk}) of the squared maximum magnitude of the sound pressure (p_{pk}^2). Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 μPa^2.

$$L_{p,\mathrm{pk}} := 10\log_{10}\left(p_{\mathrm{pk}}^2/p_0^2\right)\,\mathrm{dB} \;= 20\log_{10}\left(p_{\mathrm{pk}}/p_0\right)\,\mathrm{dB}$$

The frequency band and time window should be specified. Abbreviation: PK or Lpk.

permanent threshold shift (PTS)

An irreversible loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

point source

A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

pressure, acoustic

The deviation from the ambient pressure caused by a sound wave. Also called sound pressure.
Unit: pascal (Pa).

pressure, hydrostatic

The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

propagation loss (PL)

Difference between a source level (SL) and the level at a specified location, PL(x) = SL − L(x). Also see **transmission loss**.

received level

The level measured (or that would be measured) at a defined location. The type of level should be specified.

reference values

standard underwater references values used for calculating sound **levels**, e.g., the reference value for expressing sound pressure level in decibels is 1 µPa.

Quantity	Reference value
Sound pressure	1 µPa
Sound exposure	1 μPa^2 s
Sound particle displacement	1 pm
Sound particle velocity	1 nm/s
Sound particle acceleration	1 $\mu m/s^2$

rms

abbreviation for root-mean-square.

shear wave

A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called a secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

sound

A time-varying disturbance in the pressure, stress, or material displacement of a medium propagated by local compression and expansion of the medium.

sound exposure

Time integral of squared sound pressure over a stated time interval. The time interval can be a specified time duration (e.g., 24 hours) or from start to end of a specified event (e.g., a pile strike, an airgun pulse, a construction operation). Unit: Pa^2 s.

sound exposure level

The level (L_E) of the sound exposure (E). Unit: decibel (dB). Reference value (E_0) for sound in water: 1 μPa^2 s.

$$L_E := 10\log_{10}(E/E_0)\ \text{dB} \ = 20\log_{10}\left(E^{1/2}/E_0^{1/2}\right)\ \text{dB}$$

The frequency band and integration time should be specified. Abbreviation: SEL.

sound field

Region containing sound waves.

sound pressure

The contribution to total pressure caused by the action of sound.

sound pressure level (rms sound pressure level)

The level ($L_{p,\mathrm{rms}}$) of the time-mean-square sound pressure (p_{rms}^2). Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 µPa^2.

$$L_{p,\mathrm{rms}} := 10 \log_{10}(p_{\mathrm{rms}}^2 / p_0^2)\ \mathrm{dB}\ = 20 \log_{10}(p_{\mathrm{rms}} / p_0)\ \mathrm{dB}$$

The frequency band and averaging time should be specified. Abbreviation: SPL or Lrms.

sound speed profile

The speed of sound in the water column as a function of depth below the water surface.

source level (SL)

A property of a sound source obtained by adding to the sound pressure level measured in the far field the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 µPa^{2}m^2.

temporary threshold shift (TTS)

Reversible loss of hearing sensitivity. TTS can be caused by noise exposure.

transmission loss (TL)

The difference between a specified level at one location and that at a different location, TL(x1,x2) = L(x1) − L(x2). Also see **propagation loss**.

Appendix B. Summary of Acoustic Assessment Assumptions

The amount of sound generated during pile installation varies with the energy required to drive the piles to the desired depth, which depends on the sediment resistance encountered. Sediment types with greater resistance require pile drivers that deliver higher energy strikes. Maximum sound levels from pile installation usually occur during the last stage of driving (Betke 2008). The representative make and model of impact hammers, and the hammering energy schedule were provided by the Proponent.

Two different foundation types are being considered for New England Wind – foundations using 4 piles used to secure a jacket structure (see Figure 5) and monopile foundations consisting of single piles (monopiles, see Figure 3). For both jacket and monopile foundation models, the piles are assumed to be vertical and driven to a penetration depth of 50 m and 40 m, respectively. While pile penetrations across the SWDA will vary, these values were chosen as maximum penetration depths. The estimated number of strikes required to install piles to completion were obtained from the Proponent in consultation with potential hammer suppliers. All acoustic evaluation was performed assuming that only one pile is driven at a time. Sound from the piling barge was not included in the model.

Additional modeling assumptions for the jacket foundation piles are as follows:

- 4 m diameter steel cylindrical pilings with a nominal wall thickness of 100 mm
- Impact pile driver hammer energy: 3500 kJ
- Helmet weight: 1830 kN
- Ram weight: 1719 kN
- Four piles installed per day

Additional modeling assumptions for the monopiles are as follows:

- One 12 m and one 13 m diameter steel cylindrical piling with a nominal wall thickness of 200 mm
- Impact pile driver hammer energy: Two estimated hammer energies (5000 and 6000 kJ) for the 12 m diameter pile and one hammer energy (5000 kJ) for the 13 m diameter pile modeled using a scaling factor of 2.556 dB per energy doubling
- Helmet weight: 2351 kN
- Ram weight: 2726 kN
- One or two piles installed per day

B.1. Detailed Modeling Technical Inputs

Table B-1. Details of model inputs, assumptions, and methods.

Parameter	Description
Jacket pile driving source model	
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; Hammer forcing functions computed using GRLWEAP
Impact hammer energy	3500 kJ
Ram weight	1719 kN
Helmet weight	1830 kN
Expected penetration	50 m
Modeled seabed penetration	10.5 m @ 525 kJ, 23 m @ 1000 kJ, 33 m @ 1750 kJ, 43 m @ 2500 kJ, and 48 m @ 3500 kJ
Pile length	100 m
Pile diameter	4 m
Pile wall thickness	100 mm
L_E accumulation	Per-pulse sound exposures assumed to be equal for a given hammer energy, summed over expected number of strikes
Monopile pile driving source model	
12 m Monopile 5000 kJ	
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; Hammer forcing functions computed using GRLWEAP
Impact hammer energy	5000 kJ
Ram weight	2726 kN
Helmet weight	2351 kN
Expected penetration	40 m
Modeled seabed penetration	8 m @ 1000 kJ, 18 m @ 2000 kJ, 26 m @ 3000 kJ, 34 m @ 4000 kJ, and 38 m @ 5000 kJ
Pile length	95 m
Pile diameter	12 m
Pile wall thickness	200 mm
L_E accumulation	Per-pulse sound exposures assumed to be equal for a given hammer energy, summed over expected number of strikes
12 m Monopile 6000 kJ	
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; Hammer forcing functions computed using GRLWEAP
Impact hammer energy	6000 kJ
Ram weight	2726 kN
Helmet weight	2351 kN
Expected penetration	40 m
Modeled seabed penetration	8 m @ 1000 kJ, 18 m @ 2000 kJ, 26 m @ 3000 kJ, 34 m @ 4500 kJ, and 38 m @ 6000 kJ
Pile length	95 m
Pile diameter	12 m
Pile wall thickness	200 mm
L_E accumulation	Per-pulse sound exposures assumed to be equal for a given hammer energy, summed over expected number of strikes

13 m Monopile 5000 kJ	
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; Hammer forcing functions computed using GRLWEAP
Impact hammer energy	5000 kJ
Ram weight	2726 kN
Helmet weight	2351 kN
Expected penetration	40 m
Modeled seabed penetration	8 m @ 1000 kJ, 18 m @ 2000 kJ, 26 m @ 3000 kJ, 34 m @ 4000 kJ, and 38 m @ 5000 kJ
Pile length	95 m
Pile diameter	13 m
Pile wall thickness	200 mm
L_E accumulation	Per-pulse sound exposures assumed to be equal for a given hammer energy, summed over expected number of strikes
Environmental parameters for all pile types	
Sound speed profile	GDEM data averaged over region
Bathymetry	SRTM data combined with bathymetry data provided by client
Geoacoustics	Elastic seabed properties based on client-supplied description of surficial sediment samples
Quake (shaft and toe)	2.54 mm (shaft) and 3.333 mm (toe)
Shaft damping	0.164 s/m
Toe damping	0.49 s/m
Shaft resistance	34%, 53%, 63%, 69%, 83% (for each energy level – Jackets) 28%, 30%, 40%, 46%, 66% (for each energy level – Monopiles)
Propagation model for all pile types	
Modeling method	Parabolic-equation propagation model with 2.5° azimuthal resolution; FWRAM full-waveform parabolic equation propagation model for 4 radials
Source representation	Vertical line array
Frequency range	10–25,000 Hz
Synthetic trace length	400 ms
Maximum modeled range	100 km

Appendix C. Underwater Acoustics Metrics

This section provides a detailed description of the acoustic metrics relevant to the modeling study and the modeling methodology.

C.1. Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017).

The zero-to-peak sound pressure, or peak sound pressure (PK or L_{pk}; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $\mathrm{p(t)}$:

$$L_{pk} = 10\log_{10}\frac{\max|\mathrm{p}^2(\mathrm{t})|}{\mathrm{p}_0^2} = 20\log_{10}\frac{\max|\mathrm{p(t)}|}{\mathrm{p}_0} \quad \text{(C-1)}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The sound pressure level (SPL or L_p; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{\mathrm{T}}\int_{\mathrm{T}} \mathrm{g(t)}\,\mathrm{p}^2(\mathrm{t})\,\mathrm{dt} \Big/ \mathrm{p}_0^2\right)\mathrm{dB} \quad \text{(C-2)}$$

where $\mathrm{g(t)}$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $\mathrm{g(t)}$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,fast}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $\mathrm{g(t)}$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,boxcar\ 125ms}$. Another approach, historically used to evaluate SPL of impulsive signals underwater, defines $\mathrm{g(t)}$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 µPa^2·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right)\ \mathrm{dB} \tag{C-3}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,\mathrm{N}} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right)\ \mathrm{dB} \tag{C-4}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related numerically by the following expression, which depends only on the duration of the time window T:

$$L_p = L_E - 10\log_{10}(T) \tag{C-5}$$

$$L_{p90} = L_E - 10\log_{10}(T_{90}) - 0.458 \tag{C-6}$$

where the 0.458 dB factor accounts for the 10% of pulse SEL missing from the SPL(T_{90}) integration time window.

Energy equivalent SPL (L_{eq}; dB re 1 µPa) denotes the SPL of a stationary (constant amplitude) sound that generates the same SEL as the signal being examined, $p(t)$, over the same time period, T:

$$L_{eq} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)\,dt \Big/ p_0^2\right) \tag{C-7}$$

The equations for SPL and the energy-equivalent SPL are numerically identical. Conceptually, the difference between the two metrics is that the SPL is typically computed over short periods (typically of one second or less) and tracks the fluctuations of a non-steady acoustic signal, whereas the L_{eq} reflects the average SPL of an acoustic signal over time periods typically of one minute to several hours.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LF,24h}$; see Appendix A) or auditory-weighted SPL ($L_{p,ht}$). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

C.2. Decidecade Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analyzing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into 1/3-octave-bands, which are one tenth of a decade (approximately one-third of an octave) wide. Each decade represents a factor 10 in sound frequency. Each octave represents a factor 2 in sound frequency. The center frequency of the i^{th} 1/3-octave-band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{\frac{i}{10}} \tag{C-8}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith band are defined as:

$$f_{lo,i} = 10^{\frac{-1}{20}} f_c(i) \quad \text{and} \quad f_{hi,i} = 10^{\frac{1}{20}} f_c(i)\,. \tag{C-9}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure C-1). The acoustic modeling spans from band 10 (f_c (10) = 10 Hz) to band 44 ($f_c(44)$ = 25 kHz).

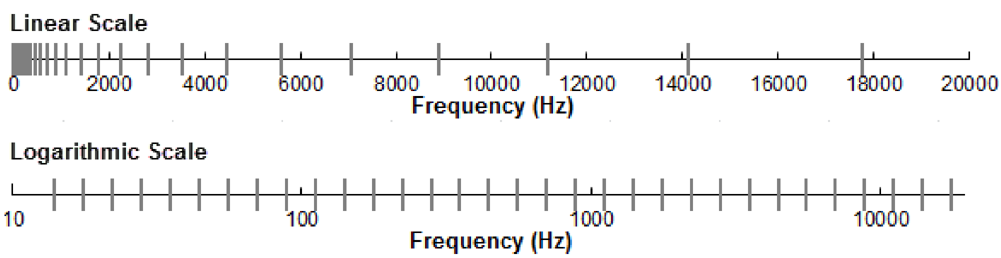

Figure C-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{lo,i}$ and $f_{hi,i}$:

$$L_{p,i} = 10 \log_{10} \int_{f_{lo,i}}^{f_{hi,i}} S(f)\, df\,. \tag{C-10}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband Lp} = 10 \log_{10} \sum_i 10^{\frac{L_{p,i}}{10}}\,. \tag{C-11}$$

Figure C-2 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient noise signal. Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the spectral levels, especially at higher frequencies. Acoustic modeling of decidecade bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

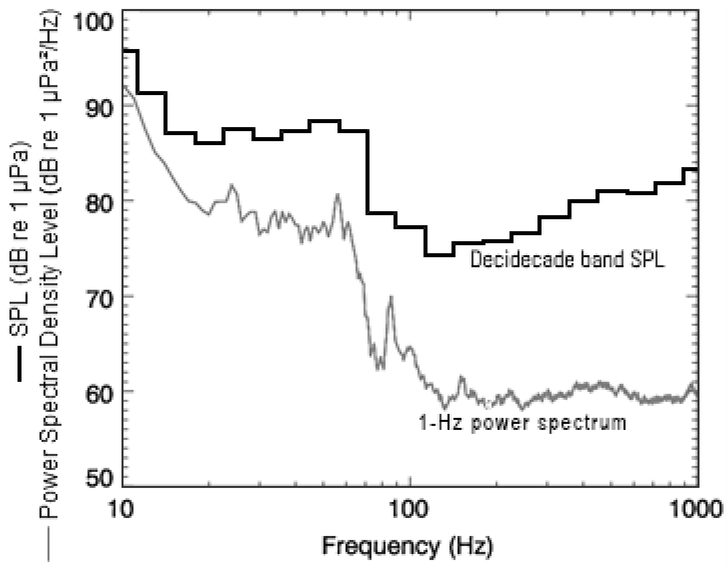

Figure C-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient sound shown on a logarithmic frequency scale. Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the power spectrum.

Appendix D. Auditory (Frequency) Weighting Functions

The potential for noise to affect animals of a certain species depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

D.1. Frequency Weighting Functions - Technical Guidance (NMFS 2018)

In 2015, a US Navy technical report by Finneran (2015) recommended new auditory weighting functions.

The auditory weighting functions for marine mammals are applied in a similar way as A-weighting for noise level assessments for humans. The new frequency-weighting functions are expressed as:

$$G(f) = K + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}. \quad \text{(D-1)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively), phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses acoustic impacts on marine mammals (NMFS 2018). The updates did not affect the content related to either the definitions of M-weighting functions or the threshold values. Table D-1 lists the frequency-weighting parameters for each hearing group; Figure D-1 shows the resulting frequency-weighting curves.

In 2017, the Criteria and Thresholds for US Navy Acoustic and Explosive Effects Analysis (Finneran et al. 2017) updated the auditory weighting functions to include sea turtles. The sea turtle weighting curve uses the same equation used for marine mammal auditory weighting functions (Equation D-1). Parameters are provided in Table D-1.

Table D-1. Parameters for the auditory weighting functions recommended by NMFS (2018).

Hearing group	a	b	f_{lo} (Hz)	f_{hi} (kHz)	K* (dB)
Low-frequency cetaceans	1.0	2	200	19,000	0.13
Mid-frequency cetaceans	1.6	2	8800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds in water	1.0	2	1900	30,000	0.75
Otariid pinnipeds in water	2.0	2	940	25,000	0.64
Sea turtles	1.4	2	77	440	2.35

* In NMFS (2018), this variable is labelled C.

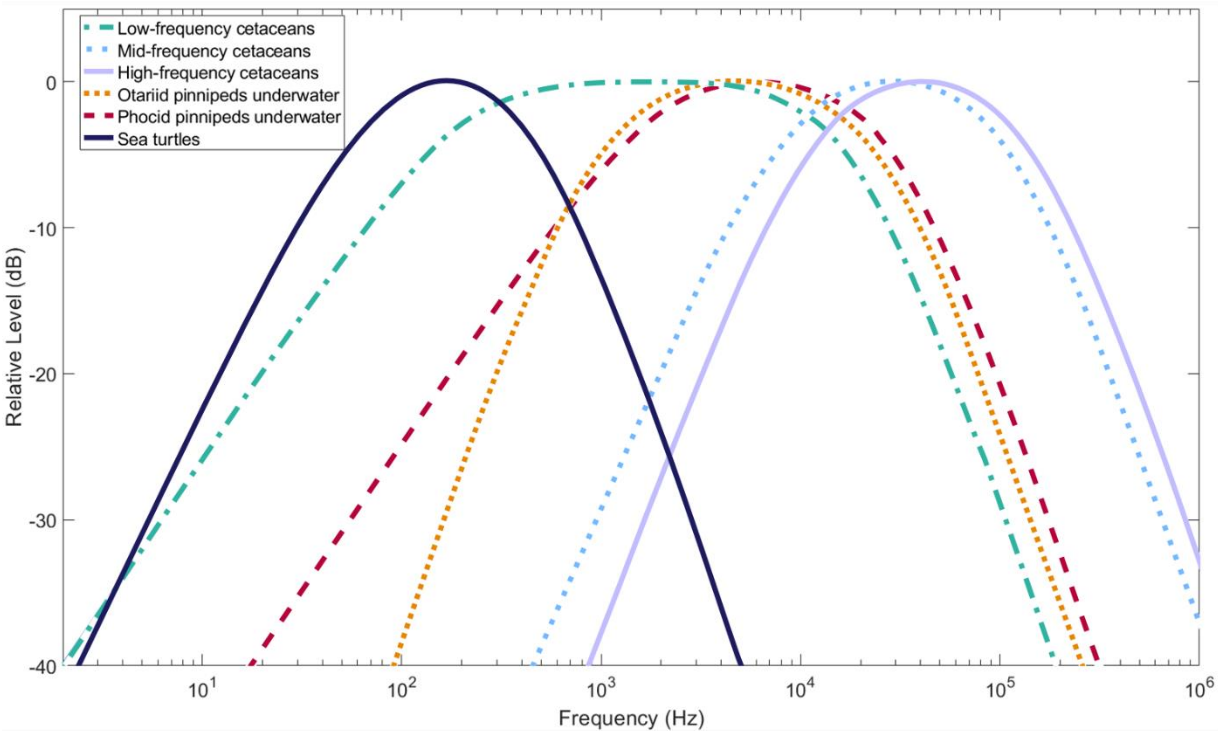

Figure D-1. Auditory weighting functions for functional marine mammal hearing groups included in NMFS (2018).

D.2. Southall et al. (2007) Frequency Weighting Functions

Auditory weighting functions for marine mammals—called M-weighting functions—were proposed by Southall et al. (2007). These M-weighting functions are applied in a similar way as A-weighting for noise level assessments for humans. Functions were defined for five hearing groups of marine mammals:

- Low-frequency (LF) cetaceans—mysticetes (baleen whales)
- Mid-frequency (MF) cetaceans—some odontocetes (toothed whales)
- High-frequency (HF) cetaceans—odontocetes specialized for using high-frequencies
- Pinnipeds in water (PW)—seals, sea lions, and walrus
- Pinnipeds in air (not addressed here)

The M-weighting functions have unity gain (0 dB) through the passband and their high- and low-frequency roll-offs are approximately –12 dB per octave. The amplitude response in the frequency domain of each M-weighting function is defined by:

$$G(f) = -20\log_{10}\left[\left(1+\frac{a^2}{f^2}\right)\left(1+\frac{f^2}{b^2}\right)\right] \quad \text{(D-2)}$$

where $G(f)$ is the weighting function amplitude (in dB) at the frequency f (in Hz), and a and b are the estimated lower and upper hearing limits, respectively, which control the roll-off and passband of the weighting function. The parameters a and b are defined uniquely for each hearing group (Table D-2). shows the auditory weighting functions.

Table D-2. Parameters for the auditory weighting functions recommended by Southall et al. (2007).

Functional hearing group	*a* (Hz)	*b* (Hz)
Low-frequency cetaceans	7	22,000
Mid-frequency cetaceans	150	160,000
High-frequency cetaceans	200	180,000
Pinnipeds in water	75	75,000

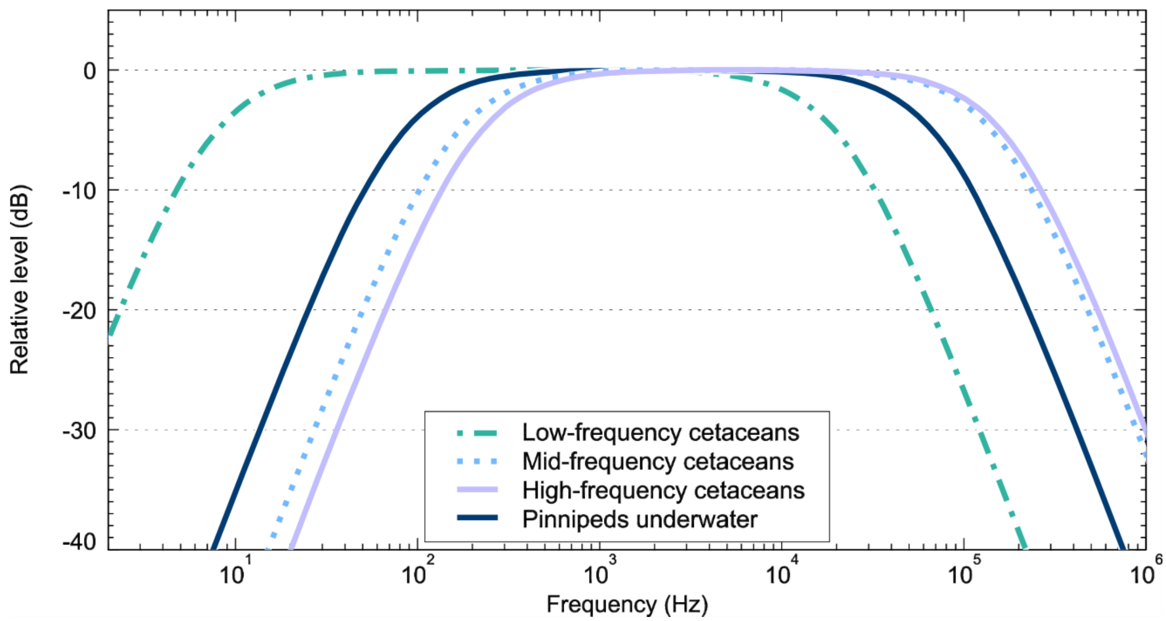

Figure D-2. Auditory weighting functions for the functional marine mammal hearing groups as recommended by Southall et al. (2007).

Appendix E. Pile Driving Source Model (PDSM)

A physical model of pile vibration and near-field sound radiation is used to calculate source levels of piles. The physical model employed in this study computes the underwater vibration and sound radiation of a pile by solving the theoretical equations of motion for axial and radial vibrations of a cylindrical shell. These equations of motion are solved subject to boundary conditions, which describe the forcing function of the hammer at the top of the pile and the soil resistance at the base of the pile (Figure E-1). Damping of the pile vibration due to radiation loading is computed for Mach waves emanating from the pile wall. The equations of motion are discretised using the finite difference (FD) method and are solved on a discrete time and depth mesh.

To model the sound emissions from the piles, the force of the pile driving hammers also had to be modeled. The force at the top of each pile was computed using the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010), which includes a large database of simulated hammers—both impact and vibratory—based on the manufacturer's specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

The sound radiating from the pile itself is simulated using a vertical array of discrete point sources. The point sources are centered on the pile axis. Their amplitudes are derived using an inverse technique, such that their collective particle velocity, calculated using a near-field wave-number integration model, matches the particle velocity in the water at the pile wall. The sound field propagating away from the vertical source array is then calculated using a time-domain acoustic propagation model (see Appendix F.3). MacGillivray (2014) describes the theory behind the physical model in more detail.

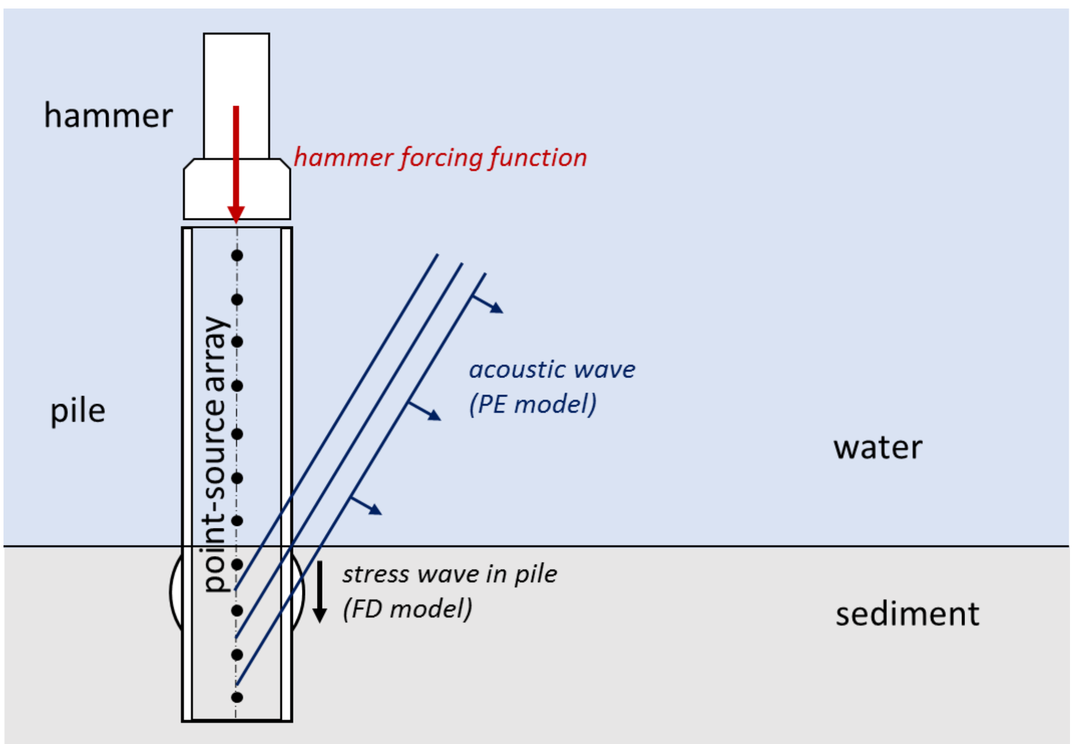

Figure E-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical array of point sources is used with the parabolic equation (PE) model to compute the acoustic waves that the pile wall radiates.

Appendix F. Sound Propagation Modeling

F.1. Environmental Parameters

F.1.1. Bathymetry

A bathymetry grid for the acoustic propagation model was compiled based on data provided by the Proponent and Shuttle Radar Topography Mission (SRTM) referred to as SRTM-TOPO15+ (Becker et al. 2009).

F.1.2. Geoacoustics

In shallow water environments where there is increased interaction with the seafloor, the properties of the substrate have a large influence over the sound propagation. Compositional data of the surficial sediments were provided by the Proponent. The dominant soil type is expected to be sand. Table F-1 shows the sediment layer geoacoustic property profile based on the sediment type and generic porosity-depth profile using a sediment grain-shearing model (Buckingham 2005).

Table F-1. Estimated geoacoustic properties used for modeling, as a function of depth, in meters below the seabed. Within an indicated depth range, the parameter varies linearly within the stated range.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5	Sand	2.086–2.093	1761–1767	0.88–0.879	300	3.65
5–10		2.093–2.099	1767–1774	0.879–0.877		
10–15		2.099–2.106	1774–1780	0.877–0.876		
15–65		2.106–2.172	1780–1842	0.876–0.861		
65–115		2.172–2.235	1842–1901	0.861–0.843		
115–240		2.235–2.382	1901–2034	0.843–0.79		
240–365		2.382–2.513	2034–2150	0.79–0.73		
365–615		2.513–2.719	2150–2342	0.73–0.616		
615–865		2.719–2.845	2342–2500	0.616–0.541		
>865		2.845	2500	0.541		

F.1.3. Sound Speed Profile

The speed of sound in sea-water is a function of temperature, salinity and pressure (depth) (Coppens 1981). Sound speed profiles were obtained from the U.S. Navy's Generalized Digital Environmental Model (GDEM; NAVO 2003). Considering the greater area around the proposed construction area and deep waters, we see that the shape of the sound speed profiles does not change substantially from month to month, from May to December. Water depths in the SWDA are less than 100 m; sound speed profiles for the shallow water are provided in (Figure F-1). An average profile, obtained by calculating the mean of all profiles shown in Figure F-1 was assumed representative of the area for modeling purposes.

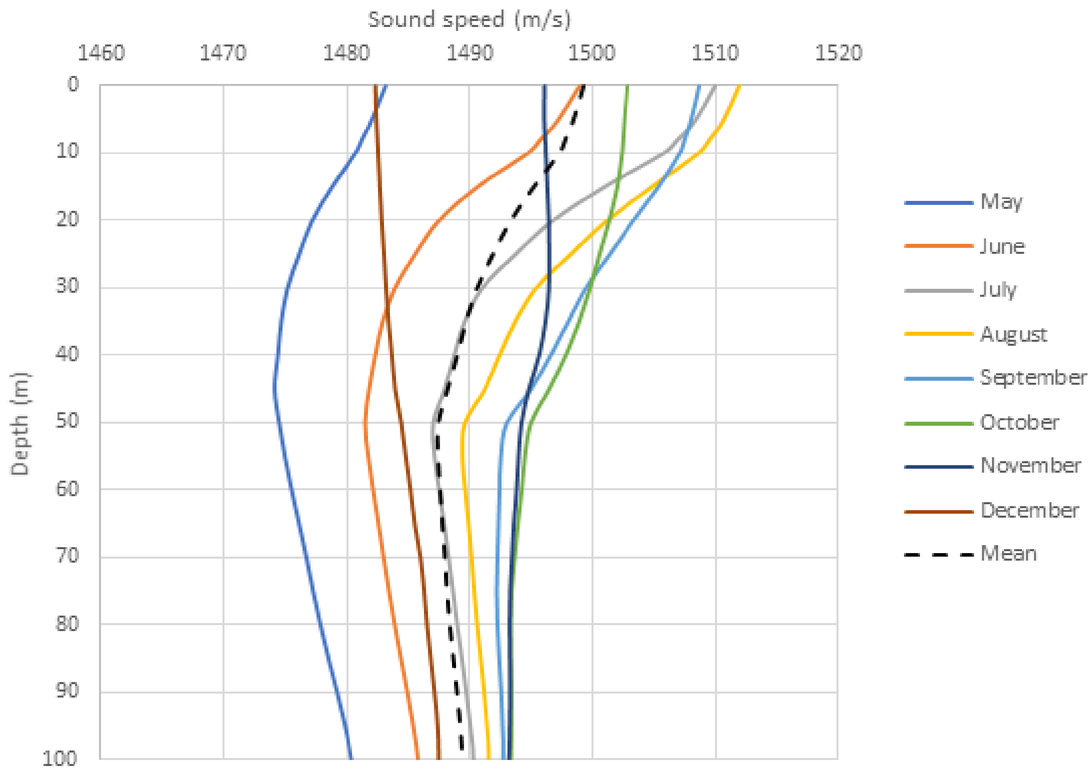

Figure F-1. Sound speed profiles up to 100 m depth for the months of May through December for Southern Wind Development Area (SWDA), and the mean profile used in the modeling and obtained by taking the average of all profiles.

F.2. Propagation Loss

The propagation of sound through the environment can be modeled by predicting the acoustic propagation loss—a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which propagation loss occurs. Propagation loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Propagation loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

If the acoustic source level (SL), expressed in dB re 1 μPa²m²s, and propagation loss (PL), in units of dB, at a given frequency are known, then the received level (RL) at a receiver location can be calculated in dB re 1 μPa²s by:

$$\mathrm{RL} = \mathrm{SL} - \mathrm{PL} \tag{F-1}$$

F.3. Sound Propagation with MONM

Propagation loss (i.e., sound propagation) can be predicted with JASCO's Marine Operations Noise Model (MONM). MONM computes received sound energy, the sound exposure level (L_E), for directional sources. MONM uses a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the US Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM's predictions have been validated against experimental data from several underwater acoustic measurement programs conducted by JASCO (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b). MONM accounts for the additional reflection loss at the seabed due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates site-specific environmental properties, such as bathymetry, underwater sound speed as a function of depth, and a geoacoustic profile the seafloor.

MONM treats frequency dependence by computing acoustic propagation loss at the center frequencies of 1/3-octave-bands. At each center frequency, the propagation loss is modeled as a function of depth and range from the source. Composite broadband received SEL are then computed by summing the received 1/3-octave-band levels across the modeled frequency range.

For computational efficiency, MONM and similar models such as PE-RAM, do not track temporal aspects of the propagating signal (as opposed to models that can output time-domain pressure signals, see Appendix F.4). It is the total sound energy propagation loss that is calculated. For our purposes, that is equivalent to propagating the L_E acoustic metric. For continuous, steady-state signals SPL is readily obtained from the SEL.

Acoustic fields in three dimensions are generated by modeling propagation loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D (Figure F-2). These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ planes.

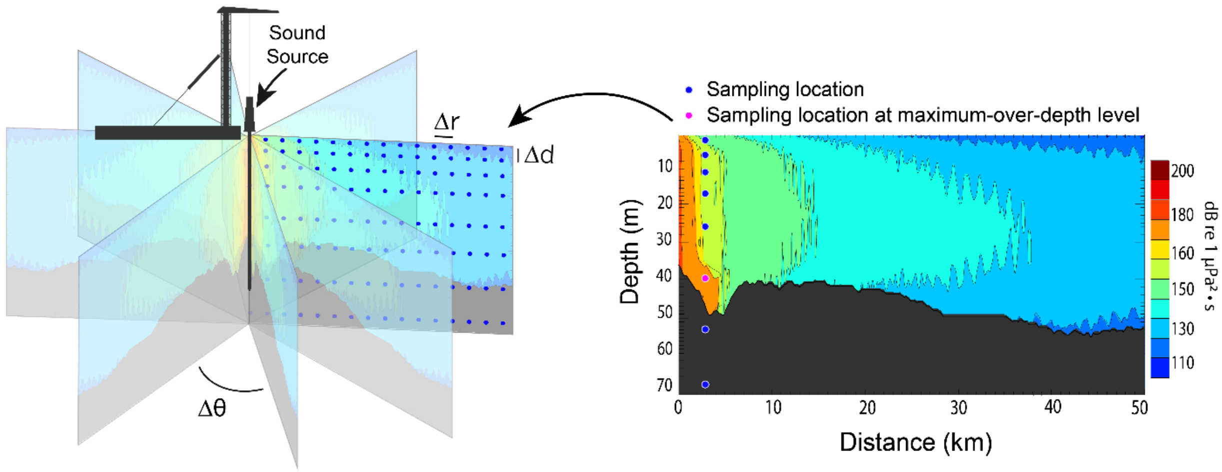

Figure F-2. Modeled three-dimensional sound field (N×2-D method) and maximum-over-depth modeling approach. Sampling locations are shown as blue dots on both figures. On the right panel, the pink dot represents the sampling location where the sound level is maximum over the water column. This maximum-over-depth level is used in calculating distances to sound level thresholds for some marine animals.

F.4. Sound Propagation with FWRAM

For impulsive sounds from impact pile driving, time-domain representations of the pressure waves generated in the water are required for calculating SPL and peak pressure level. Furthermore, the pile must be represented as a distributed source to accurately characterize vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seabed geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Synthetic pressure waveforms were modeled over the frequency range 10–2048 Hz, inside a 1 s window (e.g., Figure F-3). The synthetic pressure waveforms were post-processed, after applying a travel time correction, to calculate standard SPL and SEL metrics versus range and depth from the source.

Besides providing direct calculations of the peak pressure level and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

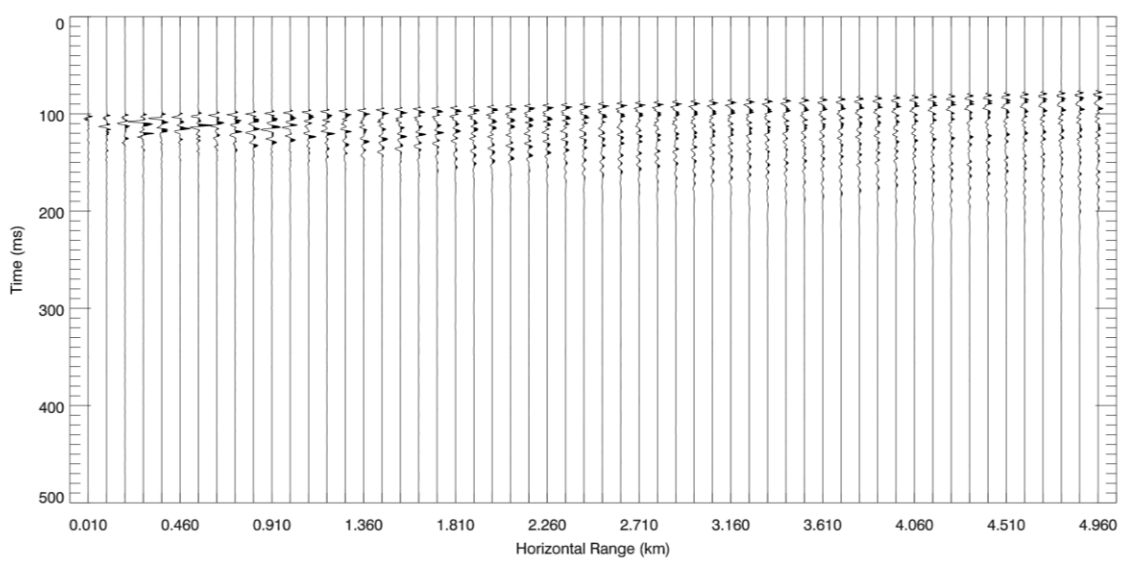

Figure F-3. Example of synthetic pressure waveforms computed by FWRAM at multiple range offsets. Receiver depth is 35 m and the amplitudes of the pressure traces have been normalised for display purposes.

F.5. Estimating Acoustic Range to Threshold Levels

A maximum-over depth approach is used to determine acoustic ranges to the defined thresholds (ranges to isopleths). That is, at each horizontal sampling range, the maximum received level that occurs within the water column is used as the value at that range. The ranges to a threshold typically differ along different radii and may not be continuous because sound levels may drop below threshold at some ranges and then exceed threshold at farther ranges. Figure F-4 shows an example of an area with sound levels above threshold and two methods of reporting the injury or behavioral disruption range: (1) R_{max}, the maximum range at which the sound level was encountered in the modeled maximum-over-depth sound field, and (2) $R_{95\%}$, the maximum range at which the sound level was encountered after the 5% farthest such points were excluded. $R_{95\%}$ is used because, regardless of the shape of the maximum-over-depth footprint, the predicted range encompasses at least 95% of the horizontal area that would be exposed to sound at or above the specified level. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the heterogeneity of the acoustic environment. $R_{95\%}$ excludes ends of protruding areas or small isolated acoustic foci not representative of the nominal ensonification zone.

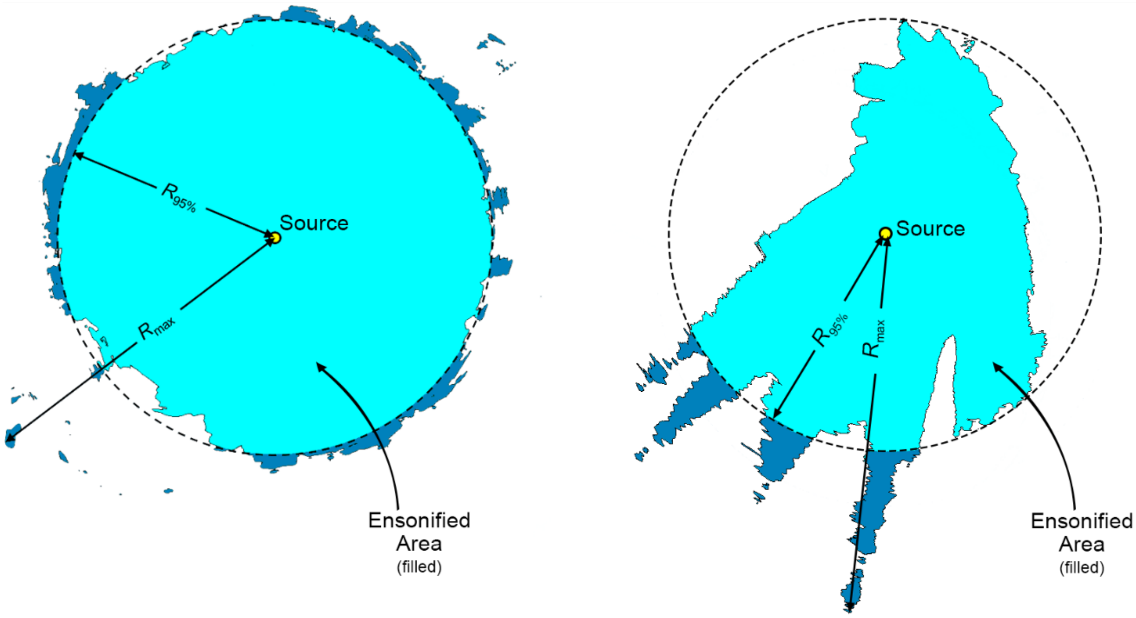

Figure F-4. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

F.6. Model Validation Information

Predictions from JASCO's propagation models (MONM and FWRAM) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Arctic, Canadian and southern United States waters, Greenland, Russia and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modeling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).

Appendix G. Ranges to Regulatory Thresholds

The following subsections contain tables of ranges to injury and behavior thresholds described in Sections 2.4 and 2.5. Results are presented for pile driving operations assuming a 0, 6, 10, and 12 dB broadband attenuation achieved using noise attenuation systems.

G.1. Ranges to Acoustic Thresholds for a 12 m (5000 kJ hammer energy) Monopile Foundation with Attenuation

G.1.1. Marine Mammals

G.1.1.1. 0 dB Attenuation

Table G-1. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	33	54	61	79
	L_E	183	17437			
Mid-frequency (MF) cetaceans	L_{pk}	230	4	6	7	9
	L_E	185	644			
High-frequency (HF) cetaceans	L_{pk}	202	580	600	660	720
	L_E	155	11686			
Phocid seals in water (PW)	L_{pk}	218	38	59	68	94
	L_E	185	5024			

L_{pk}= unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-2. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 0 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	7107	8570	9303	10867
Low-frequency (LF) cetaceans	120	100018	103606	104936	107079
	140	30590	34419	35996	38930
	160	7084	8545	9268	10835
	180	1397	1727	2074	2524
Mid-frequency (MF) cetaceans	120	97114	100118	101308	103633
	140	25335	28567	29859	32248
	160	4150	4919	5188	6181
	180	412	581	707	978
High-frequency (HF) cetaceans	120	94970	98888	99797	49856
	140	23379	26463	27590	12051
	160	3982	4173	4262	2141
	180	322	424	490	63
Phocid seals in water (PW)	120	99221	102402	103888	61308
	140	28602	32270	33810	17073
	160	5275	6838	7308	3422
	180	769	1131	1181	224

L_p = sound pressure level (dB re 1 µPa).

G.1.1.2. 6 dB Attenuation

Table G-3. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	7	12	17	36
	L_E	183	10485			
Mid-frequency (MF) cetaceans	L_{pk}	230	3	4	4	4
	L_E	185	161			
High-frequency (HF) cetaceans	L_{pk}	202	173	250	360	400
	L_E	155	7344			
Phocid seals in water (PW)	L_{pk}	218	9	15	22	42
	L_E	185	2120			

L_{pk}= unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-4. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 6 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	4168	4745	5213	6350
Low-frequency (LF) cetaceans	120	81789	92729	93752	95823
	140	21462	24103	25253	27613
	160	4162	4714	5187	6325
	180	552	727	896	1160
Mid-frequency (MF) cetaceans	120	65272	80474	87533	92223
	140	16420	19051	20128	21985
	160	3186	3476	3545	3907
	180	122	197	241	322
High-frequency (HF) cetaceans	120	59894	70724	76783	88004
	140	14720	17182	18141	19847
	160	2988	3219	3281	3462
	180	100	122	134	224
Phocid seals in water (PW)	120	74839	91110	92854	94358
	140	19465	22260	23399	25451
	160	3721	4053	4153	4630
	180	279	394	440	608

L_p = sound pressure level (dB re 1 μPa).

G.1.1.3. 10 dB Attenuation

Table G-5. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at R95% (in meters) at which the auditory injury threshold may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	4	6	8	11
	L_E	183	7036			
Mid-frequency (MF) cetaceans	L_{pk}	230	2	3	3	3
	L_E	185	89			
High-frequency (HF) cetaceans	L_{pk}	202	78	105	177	230
	L_E	155	5126			
Phocid seals in water (PW)	L_{pk}	218	5	7	9	14
	L_E	185	1121			

L_{pk}= unweighted peak sound pressure level (dB re 1 μPa); L_E = frequency-weighted sound exposure level (dB re 1 μPa^2·s).

Table G-6. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 10 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	3614	3909	4048	4244
Low-frequency (LF) cetaceans	120	56755	65673	69563	79400
	140	16157	18657	19805	22062
	160	3604	3899	4038	4235
	180	269	354	424	600
Mid-frequency (MF) cetaceans	120	47947	55053	57995	63370
	140	11562	13818	14728	16283
	160	2110	2884	2999	3188
	180	63	85	102	128
High-frequency (HF) cetaceans	120	44415	50855	53387	57960
	140	9989	12127	12971	14500
	160	1949	2128	2308	2947
	180	45	63	72	100
Phocid seals in water (PW)	120	53702	61954	65493	72473
	140	14374	16655	17670	19783
	160	3088	3371	3479	3716
	180	108	184	224	310

L_p = sound pressure level (dB re 1 µPa).

G.1.1.4. 12 dB Attenuation

Table G-7. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	4	5	6	8
	L_E	183	5549			
Mid-frequency (MF) cetaceans	L_{pk}	230	2	3	3	3
	L_E	185	63			
High-frequency (HF) cetaceans	L_{pk}	202	64	83	108	191
	L_E	155	4159			
Phocid seals in water (PW)	L_{pk}	218	4	6	7	9
	L_E	185	1075			

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-8. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 12 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	3289	3565	3672	4026
Low-frequency (LF) cetaceans	120	49514	56384	59512	65410
	140	14005	16172	17179	19408
	160	3278	3557	3661	4015
	180	184	244	303	424
Mid-frequency (MF) cetaceans	120	41928	47595	49994	54089
	140	9476	11472	12270	13886
	160	1669	2108	2235	2896
	180	45	63	72	100
High-frequency (HF) cetaceans	120	39144	44122	46104	49856
	140	8098	9920	10653	12051
	160	1164	1727	2072	2141
	180	28	45	57	63
Phocid seals in water (PW)	120	46788	53336	56069	61308
	140	12109	14321	15246	17073
	160	2462	3101	3188	3422
	180	82	108	128	224

L_p = sound pressure level (dB re 1 µPa).

G.1.2. Fish and Sea Turtles

Table G-9. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	4	5	5	7
	L_E	204	2860			
	L_p	175	2664	3105	3236	3486
Fish without swim bladder	L_{pk}	213	72	91	162	210
	L_E	216	439			
Fish with swim bladder not involved in hearing	L_{pk}	207	193	270	380	540
	L_E	203	3170			
Fish with swim bladder involved in hearing	L_{pk}	207	193	270	380	540
	L_E	203	3170			
Fish greater than or equal to 2 g	L_{pk}	206	290	360	410	580
	L_E	187	15184			
	L_p	150	16181	18684	19836	22085
Fish less than 2 g	L_{pk}	206	290	360	410	580
	L_E	183	20182			
	L_p	150	16181	18684	19836	22085

L_{pk}= unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-10. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	2	3	3	4
	L_E	204	1181			
	L_p	175	1199	1515	1760	2310
Fish without swim bladder	L_{pk}	213	33	54	61	79
	L_E	216	134			
Fish with swim bladder not involved in hearing	L_{pk}	207	72	91	162	210
	L_E	203	1407			
Fish with swim bladder involved in hearing	L_{pk}	207	72	91	162	210
	L_E	203	1407			
Fish greater than or equal to 2 g	L_{pk}	206	78	105	177	230
	L_E	187	9357			
	L_p	150	10137	12018	12864	14724
Fish less than 2 g	L_{pk}	206	78	105	177	230
	L_E	183	13033			
	L_p	150	10137	12018	12864	14724

L_{pk}= unweighted peak sound pressure (dB re 1 µPa); L_E= unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-11. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	2	3	3	3
	L_E	204	612			
	L_p	175	632	896	1002	1365
Fish without swim bladder	L_{pk}	213	12	18	36	47
	L_E	216	63			
Fish with swim bladder not involved in hearing	L_{pk}	207	48	64	75	105
	L_E	203	762			
Fish with swim bladder involved in hearing	L_{pk}	207	48	64	75	105
	L_E	203	762			
Fish greater than or equal to 2 g	L_{pk}	206	55	71	84	157
	L_E	187	6356			
	L_p	150	7107	8570	9303	10867
Fish less than 2 g	L_{pk}	206	55	71	84	157
	L_E	183	9357			
	L_p	150	7107	8570	9303	10867

L_{pk}= unweighted peak sound pressure (dB re 1 µPa); L_E= unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-12. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	0	2	2	3
	L_E	204	439			
	L_p	175	474	600	747	984
Fish without swim bladder	L_{pk}	213	7	12	17	36
	L_E	216	45			
Fish with swim bladder not involved in hearing	L_{pk}	207	33	54	61	79
	L_E	203	539			
Fish with swim bladder involved in hearing	L_{pk}	207	33	54	61	79
	L_E	203	539			
Fish greater than or equal to 2 g	L_{pk}	206	38	59	68	94
	L_E	187	5101			
	L_p	150	5866	7128	7825	9200
Fish less than 2 g	L_{pk}	206	38	59	68	94
	L_E	183	7786			
	L_p	150	5866	7128	7825	9200

L_{pk}= unweighted peak sound pressure (dB re 1 µPa); L_E= unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

G.2. Ranges to Acoustic Thresholds for a 12 m Monopile Foundation (6000 kJ hammer energy) with Attenuation

G.2.1. Marine Mammals

G.2.1.1. 0 dB Attenuation

Table G-13. Modeled 6000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Low-frequency (LF) cetaceans	L_{pk}	219	24	42	58	73	79
	L_E	183	20770				
Mid-frequency (MF) cetaceans	L_{pk}	230	4	5	6	8	9
	L_E	185	1101				
High-frequency (HF) cetaceans	L_{pk}	202	560	500	600	700	720
	L_E	155	13769				
Phocid seals in water (PW)	L_{pk}	218	33	52	62	80	94
	L_E	185	6320				

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-14. Modeled 6000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 0 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)				
		1000	2000	3000	4500	6000
Flat	160	8822	10377	11307	12850	14103
Low-frequency (LF) cetaceans	120	105561	109742	110505	111108	113100
	140	36173	40504	42168	44575	48731
	160	8790	10357	11284	12825	14073
	180	1893	2181	2552	3075	3200
Mid-frequency (MF) cetaceans	120	102063	107005	108098	109136	111332
	140	30375	34803	36111	37480	41011
	160	5203	6706	7121	8078	9225
	180	671	1071	1128	1222	1660
High-frequency (HF) cetaceans	120	100350	105306	106556	107459	110217
	140	28130	32311	33559	34779	38153
	160	4289	5660	6106	6827	7944
	180	495	710	955	1089	1159
Phocid seals in water (PW)	120	104585	109099	109920	110581	112595
	140	34160	38497	39997	41851	45879
	160	7115	8784	9518	10784	12081
	180	1149	1469	1720	2154	2468

L_p = sound pressure level (dB re 1 µPa).

G.2.1.2. 6 dB Attenuation

Table G-15. Modeled 6000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Low-frequency (LF) cetaceans	L_{pk}	219	6	9	15	23	36
	L_E	183	12996				
Mid-frequency (MF) cetaceans	L_{pk}	230	2	4	3	4	4
	L_E	185	301				
High-frequency (HF) cetaceans	L_{pk}	202	165	210	320	400	400
	L_E	155	8902				
Phocid seals in water (PW)	L_{pk}	218	8	12	18	36	42
	L_E	185	3111				

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-16. Modeled 6000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 6 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)				
		1000	2000	3000	4500	6000
Flat	160	4880	5868	6539	7801	8568
Low-frequency (LF) cetaceans	120	94059	98540	99378	100220	102986
	140	25171	28217	29505	31547	34284
	160	4851	5839	6505	7761	8543
	180	767	961	1157	1500	1723
Mid-frequency (MF) cetaceans	120	89683	94685	95980	97226	99667
	140	20443	23604	24543	25646	28125
	160	3647	4005	4102	4190	4832
	180	228	341	394	475	585
High-frequency (HF) cetaceans	120	80881	93129	94038	95059	98350
	140	18535	21693	22617	23592	25961
	160	3341	3703	3889	4022	4160
	180	141	242	291	356	422
Phocid seals in water (PW)	120	93335	97452	98557	99363	101797
	140	23505	26540	27682	29211	31965
	160	4113	4403	5050	5982	6834
	180	405	566	707	948	1137

L_p = sound pressure level (dB re 1 µPa).

G.2.1.3. 10 dB Attenuation

Table G-17. Modeled 6000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Low-frequency (LF) cetaceans	L_{pk}	219	4	5	7	9	11
	L_E	183	8924				
Mid-frequency (MF) cetaceans	L_{pk}	230	2	3	3	3	3
	L_E	185	113				
High-frequency (HF) cetaceans	L_{pk}	202	71	90	165	220	230
	L_E	155	6414				
Phocid seals in water (PW)	L_{pk}	218	4	6	8	11	14
	L_E	185	2037				

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-18. Modeled 6000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at R95% (in meters) at which the auditory behavioral threshold may be reached with 10 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)				
		1000	2000	3000	4500	6000
Flat	160	3959	4152	4274	5174	5827
Low-frequency (LF) cetaceans	120	71035	89658	91821	93196	95626
	140	19501	22213	23381	25039	27061
	160	3952	4148	4263	5153	5795
	180	382	484	600	797	967
Mid-frequency (MF) cetaceans	120	59542	71277	76488	82586	92113
	140	14912	17560	18444	19554	21751
	160	3025	3259	3334	3569	3821
	180	102	128	161	228	301
High-frequency (HF) cetaceans	120	54757	65205	68398	71931	87785
	140	13260	15833	16662	17563	19687
	160	2363	3117	3161	3268	3429
	180	72	108	117	134	206
Phocid seals in water (PW)	120	67054	84920	89560	91753	94246
	140	17670	20451	21530	23077	25047
	160	3479	3777	3949	4149	4257
	180	200	291	342	440	561

L_p = sound pressure level (dB re 1 µPa).

G.2.1.4. 12 dB Attenuation

Table G-19. Modeled 6000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Low-frequency (LF) cetaceans	L_{pk}	219	4	5	5	7	8
	L_E	183	7140				
Mid-frequency (MF) cetaceans	L_{pk}	230	0	2	2	3	3
	L_E	185	89				
High-frequency (HF) cetaceans	L_{pk}	202	59	75	99	186	191
	L_E	155	5272				
Phocid seals in water (PW)	L_{pk}	218	4	5	6	8	9
	L_E	185	1128				

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-20. Modeled 6000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 12 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 12 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)				
		1000	2000	3000	4500	6000
Flat	160	3648	3893	4065	4242	4702
Low-frequency (LF) cetaceans	120	60482	71224	76550	83762	92189
	140	16826	19382	20580	22381	24105
	160	3639	3884	4054	4235	4671
	180	272	342	422	595	728
Mid-frequency (MF) cetaceans	120	51097	59975	62847	65721	76870
	140	12444	14927	15737	16773	18787
	160	2206	3017	3122	3252	3389
	180	72	100	108	128	201
High-frequency (HF) cetaceans	120	47209	55193	57675	60222	68471
	140	10879	13338	14088	14947	16833
	160	2079	2371	2845	3052	3180
	180	60	72	85	108	126
Phocid seals in water (PW)	120	57114	67333	70837	76130	90012
	140	15169	17595	18641	20223	22183
	160	3152	3408	3524	3890	4048
	180	117	189	240	322	400

L_p = sound pressure level (dB re 1 μPa).

G.2.2. Fish and Sea Turtles

Table G-21. Modeled 6000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Sea turtles	L_{pk}	232	3	5	5	6	7
	L_E	204	3620				
	L_p	175	3149	3372	3530	3892	4025
Fish without swim bladder	L_{pk}	213	64	83	111	200	210
	L_E	216	611				
Fish with swim bladder not involved in hearing	L_{pk}	207	174	240	360	420	540
	L_E	203	4111				
Fish with swim bladder involved in hearing	L_{pk}	207	174	240	360	420	540
	L_E	203	4111				
Fish greater than or equal to 2 g	L_{pk}	206	193	260	390	560	580
	L_E	187	17808				
	L_p	150	19525	22237	23403	25067	27084
Fish less than 2 g	L_{pk}	206	193	260	390	560	580
	L_E	183	23220				
	L_p	150	19525	22237	23403	25067	27084

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-22. Modeled 6000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 12 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Sea turtles	L_{pk}	232	2	3	3	3	4
	L_E	204	1690				
	L_p	175	1682	2058	2322	2873	3055
Fish without swim bladder	L_{pk}	213	24	42	58	73	79
	L_E	216	224				
Fish with swim bladder not involved in hearing	L_{pk}	207	64	83	111	200	210
	L_E	203	1921				
Fish with swim bladder involved in hearing	L_{pk}	207	64	83	111	200	210
	L_E	203	1921				
Fish greater than or equal to 2 g	L_{pk}	206	71	90	165	220	230
	L_E	187	11280				
	L_p	150	12394	14481	15462	17144	18740
Fish less than 2 g	L_{pk}	206	71	90	165	220	230
	L_E	183	15420				
	L_p	150	12394	14481	15462	17144	18740

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-23. Modeled 6000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 12 m monopile foundation pile. Numbers represent the distance at R95% (in meters) at which the auditory behavioral and injury threshold may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Sea turtles	L_{pk}	232	0	2	2	3	3
	L_E	204	930				
	L_p	175	943	1145	1374	1738	2068
Fish without swim bladder	L_{pk}	213	9	14	23	42	47
	L_E	216	89				
Fish with swim bladder not involved in hearing	L_{pk}	207	38	57	69	87	105
	L_E	203	1104				
Fish with swim bladder involved in hearing	L_{pk}	207	38	57	69	87	105
	L_E	203	1104				
Fish greater than or equal to 2 g	L_{pk}	206	42	62	77	104	157
	L_E	187	7912				
	L_p	150	8822	10377	11307	12850	14103
Fish less than 2 g	L_{pk}	206	42	62	77	104	157
	L_E	183	11280				
	L_p	150	8822	10377	11307	12850	14103

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-24. Modeled 6000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one and two, 12 m monopile foundation piles. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			1000	2000	3000	4500	6000
Sea turtles	L_{pk}	232	0	2	2	2	3
	L_E	204	611				
	L_p	175	628	800	1009	1354	1513
Fish without swim bladder	L_{pk}	213	6	9	15	23	36
	L_E	216	63				
Fish with swim bladder not involved in hearing	L_{pk}	207	24	42	58	73	79
	L_E	203	764				
Fish with swim bladder involved in hearing	L_{pk}	207	24	42	58	73	79
	L_E	203	764				
Fish greater than or equal to 2 g	L_{pk}	206	33	52	62	80	94
	L_E	187	6440				
	L_p	150	7257	8700	9520	10998	12041
Fish less than 2 g	L_{pk}	206	33	52	62	80	94
	L_E	183	9491				
	L_p	150	7257	8700	9520	10998	12041

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

G.3. Ranges to Acoustic Thresholds for a 13 m Monopile Foundation (5000 kJ hammer energy) with Attenuation

G.3.1. Marine Mammals

G.3.1.1. 0 dB Attenuation

Table G-25. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 13 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	23	49	73	93
	L_E	183	19473			
Mid-frequency (MF) cetaceans	L_{pk}	230	6	7	8	13
	L_E	185	480			
High-frequency (HF) cetaceans	L_{pk}	202	440	580	740	860
	L_E	155	11896			
Phocid seals in water (PW)	L_{pk}	218	35	52	80	104
	L_E	185	4936			

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-26. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 13 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 0 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	7662	8853	10623	12815
Low-frequency (LF) cetaceans	120	114664	117832	117798	117503
	140	37226	46966	50956	62209
	160	7616	8822	10577	12759
	180	1300	1484	2014	2629
Mid-frequency (MF) cetaceans	120	112881	117597	117748	117739
	140	25821	34960	36461	43539
	160	3795	4631	5002	6552
	180	272	482	541	856
High-frequency (HF) cetaceans	120	112245	115457	115749	117874
	140	22907	30975	31941	38761
	160	3500	4111	4188	5249
	180	184	342	397	582
Phocid seals in water (PW)	120	113891	117913	117884	117574
	140	32357	42142	44640	54066
	160	5020	6664	7841	9754
	180	566	859	1119	1601

L_p = sound pressure level (dB re 1 µPa).

G.3.1.2. 6 dB Attenuation

Table G-27. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 13 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	8	12	17	27
	L_E	183	11235			
Mid-frequency (MF) cetaceans	L_{pk}	230	4	5	5	6
	L_E	185	144			
High-frequency (HF) cetaceans	L_{pk}	202	124	230	400	540
	L_E	155	7316			
Phocid seals in water (PW)	L_{pk}	218	9	14	20	42
	L_E	185	2348			

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-28. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 13 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 6 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	4208	4638	5762	7223
Low-frequency (LF) cetaceans	120	102724	112786	112980	114670
	140	23979	28956	31902	37447
	160	4200	4610	5724	7188
	180	439	526	752	1118
Mid-frequency (MF) cetaceans	120	95813	109050	109459	112880
	140	15488	21001	21983	25980
	160	2722	3160	3331	3740
	180	100	156	184	286
High-frequency (HF) cetaceans	120	87953	106277	106714	112250
	140	13349	18454	19113	22986
	160	2362	2980	3068	3408
	180	82	128	141	190
Phocid seals in water (PW)	120	100892	111958	112297	113902
	140	20143	25442	27545	32647
	160	3478	3822	4166	4909
	180	201	297	393	558

L_p = sound pressure level (dB re 1 µPa).

G.3.1.3. 10 dB Attenuation

Table G-29. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 13 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	6	8	10	14
	L_E	183	7213			
Mid-frequency (MF) cetaceans	L_{pk}	230	3	4	4	5
	L_E	185	89			
High-frequency (HF) cetaceans	L_{pk}	202	87	112	200	290
	L_E	155	4955			
Phocid seals in water (PW)	L_{pk}	218	6	8	11	16
	L_E	185	1246			

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-30. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 13 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 10 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	3490	3530	4124	4636
Low-frequency (LF) cetaceans	120	86552	101685	102516	109312
	140	17864	21303	23733	27756
	160	3481	3518	4116	4605
	180	228	267	372	540
Mid-frequency (MF) cetaceans	120	65844	94129	95222	103308
	140	10413	14571	15434	18615
	160	1548	2449	2622	3112
	180	40	89	100	144
High-frequency (HF) cetaceans	120	56202	86067	87170	100049
	140	8515	12543	13273	16111
	160	1259	1939	2301	2707
	180	28	63	80	117
Phocid seals in water (PW)	120	82575	99994	100649	107353
	140	14528	18355	20041	23797
	160	2805	3083	3289	3760
	180	100	144	179	297

L_p = sound pressure level (dB re 1 µPa).

G.3.1.4. 12 dB Attenuation

Table G-31. Modeled 5000 kJ monopile foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one, 13 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)			
			1000	2000	3000	5000
Low-frequency (LF) cetaceans	L_{pk}	219	5	7	7	10
	L_E	183	5716			
Mid-frequency (MF) cetaceans	L_{pk}	230	3	4	4	5
	L_E	185	82			
High-frequency (HF) cetaceans	L_{pk}	202	71	90	119	240
	L_E	155	3917			
Phocid seals in water (PW)	L_{pk}	218	6	7	8	13
	L_E	185	656			

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s).

Table G-32. Modeled 5000 kJ monopile foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one, 13 m monopile foundation piles. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 12 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)			
		1000	2000	3000	5000
Flat	160	3220	3219	3545	4129
Low-frequency (LF) cetaceans	120	79048	95173	96905	102864
	140	15368	18186	20464	23899
	160	3210	3212	3532	4121
	180	152	184	272	385
Mid-frequency (MF) cetaceans	120	52233	81393	82836	95879
	140	8311	11928	12730	15571
	160	1209	1816	2143	2693
	180	28	63	72	108
High-frequency (HF) cetaceans	120	46019	70674	73201	88050
	140	6738	10094	10747	13392
	160	835	1360	1553	2369
	180	20	28	40	85
Phocid seals in water (PW)	120	66833	90285	92215	100982
	140	12057	15422	17040	20273
	160	2195	2664	3052	3347
	180	80	100	134	200

L_p = sound pressure level (dB re 1 µPa).

G.3.2. Fish and Sea Turtles

Table G-33. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 13 m monopile foundation pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ) 1 Pile Per Day			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	5	6	7	8
	L_E	204	2987			
	L_p	175	2646	2789	3158	3441
Fish without swim bladder	L_{pk}	213	78	97	132	260
	L_E	216	412			
Fish with swim bladder not involved in hearing	L_{pk}	207	196	240	420	580
	L_E	203	3465			
Fish with swim bladder involved in hearing	L_{pk}	207	196	240	420	580
	L_E	203	3465			
Fish greater than or equal to 2 g	L_{pk}	206	260	380	520	620
	L_E	187	17892			
	L_p	175	17914	21346	23773	27802
Fish less than 2 g	L_{pk}	206	260	380	520	620
	L_E	183	24456			
	L_p	175	17914	21346	23773	27802

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-34. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 13 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ) 1 Pile Per Day			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	4	5	5	5
	L_E	204	1230			
	L_p	175	1105	1323	1734	2394
Fish without swim bladder	L_{pk}	213	23	49	73	93
	L_E	216	144			
Fish with swim bladder not involved in hearing	L_{pk}	207	78	97	132	260
	L_E	203	1372			
Fish with swim bladder involved in hearing	L_{pk}	207	78	97	132	260
	L_E	203	1372			
Fish greater than or equal to 2 g	L_{pk}	206	87	112	200	290
	L_E	187	10629			
	L_p	175	11071	13029	15020	17683
Fish less than 2 g	L_{pk}	206	87	112	200	290
	L_E	183	15264			
	L_p	175	11071	13029	15020	17683

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-35. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 13 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ) 1 Pile Per Day			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	3	4	4	5
	L_E	204	560			
	L_p	175	526	641	944	1341
Fish without swim bladder	L_{pk}	213	10	16	24	52
	L_E	216	80			
Fish with swim bladder not involved in hearing	L_{pk}	207	40	70	87	114
	L_E	203	690			
Fish with swim bladder involved in hearing	L_{pk}	207	40	70	87	114
	L_E	203	690			
Fish greater than or equal to 2 g	L_{pk}	206	44	76	97	127
	L_E	187	7084			
	L_p	175	7662	8853	10623	12815
Fish less than 2 g	L_{pk}	206	44	76	97	127
	L_E	183	10629			
	L_p	175	7662	8853	10623	12815

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table G-36. Modeled 5000 kJ monopile foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one, 13 m monopile foundation pile. Numbers represent the mean distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury threshold may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ) 1 Pile Per Day			
			1000	2000	3000	5000
Sea turtles	L_{pk}	232	3	4	4	4
	L_E	204	412			
	L_p	175	379	451	641	1000
Fish without swim bladder	L_{pk}	213	8	12	17	27
	L_E	216	45			
Fish with swim bladder not involved in hearing	L_{pk}	207	23	49	73	93
	L_E	203	464			
Fish with swim bladder involved in hearing	L_{pk}	207	23	49	73	93
	L_E	203	464			
Fish greater than or equal to 2 g	L_{pk}	206	35	52	80	104
	L_E	187	5581			
	L_p	175	6277	7225	8778	10708
Fish less than 2 g	L_{pk}	206	35	52	80	104
	L_E	183	8739			
	L_p	175	6277	7225	8778	10708

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa).

G.4. Ranges to Acoustic Thresholds for a 4 m Jacket Foundation (3500 kJ hammer energy) with Attenuations

G.4.1. Marine Mammals

G.4.1.1. 0 dB Attenuation

Table G-37. Modeled 3500 kJ jacket foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Low-frequency (LF) cetaceans	L_{pk}	219	4	8	33
	L_E	183	18049 (29350)		
Mid-frequency (MF) cetaceans	L_{pk}	230	-	-	2
	L_E	185	481 (1577)		
High-frequency (HF) cetaceans	L_{pk}	202	153	340	580
	L_E	155	11908 (17577)		
Phocid seals in water (PW)	L_{pk}	218	5	10	87
	L_E	185	5738 (10051)		

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Table G-38. Modeled 3500 kJ jacket foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one 4 m pin pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 0 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)		
		525	1000	3500
Flat	160	3945	4533	8424
Low-frequency (LF) cetaceans	120	99542	100667	110415
	140	21478	27067	40384
	160	3938	4501	8396
	180	321	505	1485
Mid-frequency (MF) cetaceans	120	96499	99973	108194
	140	15671	20683	32588
	160	2942	3550	4696
	180	122	171	504
High-frequency (HF) cetaceans	120	91173	99842	107076
	140	13901	18555	29780
	160	2463	3433	4213
	180	89	144	361
Phocid seals in water (PW)	120	99207	100150	109770
	140	19104	24650	37403
	160	3536	3968	6718
	180	170	321	935

L_p = sound pressure level (dB re 1 µPa).

G.4.1.2. 6 dB Attenuation

Table G-39. Modeled 3500 kJ jacket foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Low-frequency (LF) cetaceans	L_{pk}	219	0	2	5
	L_E	183	10461 (18083)		
Mid-frequency (MF) cetaceans	L_{pk}	230	-	-	-
	L_E	185	146 (482)		
High-frequency (HF) cetaceans	L_{pk}	202	111	131	380
	L_E	155	7326 (11922)		
Phocid seals in water (PW)	L_{pk}	218	0	2	7
	L_E	185	2377 (5743)		

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Table G-40. Modeled 3500 kJ jacket foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one 4 m pin pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 6 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)		
		525	1000	3500
Flat	160	2946	3451	4485
Low-frequency (LF) cetaceans	120	62281	91985	100219
	140	13403	17200	26576
	160	2930	3444	4446
	180	117	171	519
Mid-frequency (MF) cetaceans	120	49797	70696	99892
	140	8880	12051	20077
	160	1253	2236	3479
	180	28	85	161
High-frequency (HF) cetaceans	120	45142	62436	99740
	140	7616	10570	17988
	160	1183	1649	3091
	180	28	45	141
Phocid seals in water (PW)	120	57474	86190	100035
	140	11407	15058	24124
	160	2200	2962	3928
	180	82	122	306

L_p = sound pressure level (dB re 1 µPa).

G.4.1.3. 10 dB Attenuation

Table G-41. Modeled 3500 kJ jacket foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Low-frequency (LF) cetaceans	L_{pk}	219	-	0	2
	L_E	183	6885 (12677)		
Mid-frequency (MF) cetaceans	L_{pk}	230	-	-	-
	L_E	185	89 (268)		
High-frequency (HF) cetaceans	L_{pk}	202	37	103	139
	L_E	155	5726 (8847)		
Phocid seals in water (PW)	L_{pk}	218	-	0	2
	L_E	185	1234 (3510)		

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Table G-42. Modeled 3500 kJ jacket foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one 4 m pin pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 10 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)		
		525	1000	3500
Flat	160	1797	2502	3642
Low-frequency (LF) cetaceans	120	44164	57519	98346
	140	9332	12372	19704
	160	1794	2496	3638
	180	45	89	268
Mid-frequency (MF) cetaceans	120	35506	46528	89400
	140	5366	8069	14195
	160	608	1215	2502
	180	0	28	89
High-frequency (HF) cetaceans	120	32496	42263	79019
	140	4672	6906	12362
	160	467	879	2302
	180	0	20	85
Phocid seals in water (PW)	120	40891	53398	96910
	140	7457	10449	17460
	160	1194	1800	3224
	180	28	45	146

L_p = sound pressure level (dB re 1 µPa).

G.4.1.4. 12 dB Attenuation

Table G-43. Modeled 3500 kJ jacket foundation ranges for auditory injury thresholds for marine mammals (NMFS 2018) for one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory injury threshold may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Low-frequency (LF) cetaceans	L_{pk}	219	-	-	0
	L_E	183	5248 (10482)		
Mid-frequency (MF) cetaceans	L_{pk}	230	-	-	-
	L_E	185	80 (146)		
High-frequency (HF) cetaceans	L_{pk}	202	15	75	123
	L_E	155	4651 (7339)		
Phocid seals in water (PW)	L_{pk}	218	-	-	2
	L_E	185	1174 (2377)		

L_{pk} = unweighted peak sound pressure level (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Table G-44. Modeled 3500 kJ jacket foundation ranges for auditory behavioral disturbance thresholds for marine mammals (Wood et al. 2012, NOAA 2005) for one 4 m pin pile. Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral threshold may be reached with 12 dB attenuation.

Faunal group	L_p Threshold (dB)	Hammer energy (kJ)		
		525	1000	3500
Flat	160	1242	2183	3414
Low-frequency (LF) cetaceans	120	37870	48370	89065
	140	7569	10372	16912
	160	1238	2178	3408
	180	28	63	171
Mid-frequency (MF) cetaceans	120	30593	39218	67285
	140	4580	6248	11695
	160	425	747	2193
	180	0	20	82
High-frequency (HF) cetaceans	120	27860	35727	59400
	140	4061	5317	10278
	160	322	597	1582
	180	0	0	40
Phocid seals in water (PW)	120	35109	45055	82122
	140	5915	8470	14735
	160	740	1244	2910
	180	20	28	117

L_p = sound pressure level (dB re 1 µPa).

G.4.2. Fish and Sea Turtles

Table G-45. Modeled 3500 kJ jacket foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury thresholds may be reached with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Sea turtles	L_{pk}	232	-	-	0
	L_E	204	2426 (5224)		
	L_p	175	752	1231	2819
Fish without swim bladder	L_{pk}	213	23	92	131
	L_E	216	306 (945)		
Fish with swim bladder not involved in hearing	L_{pk}	207	117	138	410
	L_E	203	2723 (5858)		
Fish with swim bladder involved in hearing	L_{pk}	207	117	138	410
	L_E	203	2723 (5858)		
Fish greater than or equal to 2 g	L_{pk}	206	125	145	440
	L_E	187	15463 (24399)		
	L_p	150	9365	12406	19734
Fish less than 2 g	L_{pk}	206	125	145	440
	L_E	183	21005 (32006)		
	L_p	150	9365	12406	19734

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Table G-46. Modeled 3500 kJ jacket foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury thresholds may be reached with 6 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Sea turtles	L_{pk}	232	-	-	0
	L_E	204	943 (2433)		
	L_p	175	269	422	1232
Fish without swim bladder	L_{pk}	213	4	8	33
	L_E	216	108 (310)		
Fish with swim bladder not involved in hearing	L_{pk}	207	23	92	131
	L_E	203	1189 (2736)		
Fish with swim bladder involved in hearing	L_{pk}	207	23	92	131
	L_E	203	1189 (2736)		
Fish greater than or equal to 2 g	L_{pk}	206	37	103	139
	L_E	187	9046 (15490)		
	L_p	150	5011	7006	12171
Fish less than 2 g	L_{pk}	206	37	103	139
	L_E	183	13128 (21040)		
	L_p	150	5011	7006	12171

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Table G-47. Modeled 3500 kJ jacket foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury thresholds may be reached with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Sea turtles	L_{pk}	232	-	-	0
	L_E	204	422 (1230)		
	L_p	175	134	213	626
Fish without swim bladder	L_{pk}	213	2	3	8
	L_E	216	45 (144)		
Fish with swim bladder not involved in hearing	L_{pk}	207	7	13	100
	L_E	203	511 (1493)		
Fish with swim bladder involved in hearing	L_{pk}	207	7	13	100
	L_E	203	511 (1493)		
Fish greater than or equal to 2 g	L_{pk}	206	9	17	108
	L_E	187	5843 (11027)		
	L_p	150	3945	4533	8424
Fish less than 2 g	L_{pk}	206	9	17	108
	L_E	183	9046 (15490)		
	L_p	150	3945	4533	8424

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Table G-48. Modeled 3500 kJ jacket foundation ranges to auditory injury and behavioral thresholds for sea turtles and fish using one (and four) 4 m pin pile(s). Numbers represent the distance at $R_{95\%}$ (in meters) at which the auditory behavioral and injury thresholds may be reached with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)		
			525	1000	3500
Sea turtles	L_{pk}	232	-	-	0
	L_E	204	306 (945)		
	L_p	175	89	146	425
Fish without swim bladder	L_{pk}	213	0	2	5
	L_E	216	28 (108)		
Fish with swim bladder not involved in hearing	L_{pk}	207	4	8	33
	L_E	203	358 (1190)		
Fish with swim bladder involved in hearing	L_{pk}	207	4	8	33
	L_E	203	358 (1190)		
Fish greater than or equal to 2 g	L_{pk}	206	5	10	87
	L_E	187	4571 (9068)		
	L_p	150	3624	4056	6950
Fish less than 2 g	L_{pk}	206	5	10	87
	L_E	183	7315 (13150)		
	L_p	150	3624	4056	6950

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa^2·s); L_p = unweighted sound pressure level (dB re 1 µPa). Dashes indicate that thresholds were not reached. L_E values in parentheses are for four pin piles.

Appendix H. Animal Movement and Exposure Modeling

To assess the risk of impacts from anthropogenic sound exposure, an estimate of the received sound levels for individuals of each species known to occur in the Project area during the assessed activities is required. Both sound sources and animals move. 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 locations of the Project sound sources are known, and acoustic modeling can be used to predict the individual and aggregate 3-D sound fields of the sources. 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 (animats) 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 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 et al. 1999, Frankel et al. 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 (Appendix H-2). 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 (Ellison et al. 2016).

H.1. 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.

H.1.1. Exposure Integration Time

The interval over which acoustic exposure (L_E) should be integrated and maximal exposure (SPL) determined is not well defined. Both Southall et al. (2007) and the NMFS (2018) 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 (e.g., marine mammal tag data) (Houser 2006). For this study, one-week simulations (i.e., 7 days) were modeled.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that might be present in the Project area during sound-producing activities 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 70 km (43.5 mi) from the Offshore Development Area (see figures in Appendix H.2). In the simulation, every animat that reaches and leaves a border of the simulation area is replaced by another animat entering at an opposite border—e.g., an animat departing at the northern border of the simulation area is replaced by an animat entering the simulation area at 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 H.2). 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.

H.1.2. Aversion

Animals may avoid loud sounds by moving away from the source, and the risk assessment framework (Southall et al. 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 greater deflections associated with higher received levels (Tables H-1 and H-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 H-1 and H-2). During this time, travel parameters are recalculated periodically as with normal behaviors. At the end of the aversion interval, the animat model parameters are changed (see Tables H-1 and H-2), depending on the current level of exposure and the animat either begins another aversion interval or transitions to a non-aversive behavior; while if aversion begins immediately, transition to a regular behavior occurs at the end of the next surface interval, consistent with regular behavior transitions.

Table H-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 (L_p, dB re 1 µPa)	Change in course (°)	Duration of aversion (s)
10%	140	10	300
50%	160	20	60
90%	180	30	30

Table H-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 (L_p, dB re 1 µPa)	Change in course (°)	Duration of aversion(s)
50%	120	20	60
90%	140	30	30

H.1.3. 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 greater than 1000 m (Aoki et al. 2007), and the simulation location contained a relatively high portion of shallow water areas. For each species, 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. To evaluate potential Level A or B harassment, threshold exceedance was determined in 24 h 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 3, the local density estimates were obtained from the habitat-based models of Roberts et al. (2016a, 2016b, 2017, 2018, 2021).

H.2. Animal Movement Modeling Supplemental Results

This section contains supplemental exposure modeling results assuming 0, 6, 10, and 12 dB broadband attenuation. Tables H-3 to H-6 describe the number of days of piling per month for each year of Construction Schedules A and B.

For each year of Construction Schedules A and B for both marine mammals and turtles, exposure estimates are provided in Appendices H.2.1 and H.2.2, and potential impacts relative to species' abundance are provided in Appendix H.2.3. Exposure ranges for modeled foundation types not included in Construction Schedules A and B are provided in Appendix H.2.4.

Table H-3. Construction Schedule A, Year 1: The number of potential piling days per month under the maximum envelope used to estimate the total number of marine mammal and sea turtle acoustic exposures for New England Wind.

Construction month	12 m Monopile, 5000 kJ		12 m Monopile, 6000 kJ		13 m Monopile, 5000 kJ		4 m Pin Pile, 3500 kJ
	1 pile/day	2 piles/day	1 pile/day	2 piles/day	1 pile/day	2 piles/day	4 pin piles/day
May	4	0	0	0	0	0	0
June	2	5	0	0	0	0	0
July	0	9	0	0	0	0	0
August	0	9	0	0	0	0	0
September	0	1	0	0	1	6	2
October	0	0	0	0	0	6	0
November	0	0	0	0	0	3	0
December	0	0	0	0	4	0	0
Total # Days	**6**	**24**	**0**	**0**	**5**	**15**	**2**

Table H-4. Construction Schedule A, Year 2: The number of potential piling days per month under the maximum envelope used to estimate the total number of marine mammal and sea turtle acoustic exposures for New England Wind.

Construction month	12 m Monopile, 5000 kJ		12 m Monopile, 6000 kJ		13 m Monopile, 5000 kJ		4 m Pin Pile, 3500 kJ
	1 pile/day	2 piles/day	1 pile/day	2 piles/day	1 pile/day	2 piles/day	4 pin piles/day
May	0	0	4	0	0	0	0
June	0	0	0	3	0	0	0
July	0	0	0	4	0	0	0
August	0	0	0	0	0	0	8
September	0	0	0	0	0	0	7
October	0	0	0	0	0	0	6
November	0	0	0	0	0	0	2
December	0	0	0	0	0	0	1
Total # Days	**0**	**0**	**4**	**7**	**0**	**0**	**24**

Table H-5. Construction Schedule B, Year 1: The number of potential piling days per month under the maximum envelope used to estimate the total number of marine mammal and sea turtle acoustic exposures for New England Wind.

Construction month	12 m Monopile, 5000 kJ		4 m Pin Pile, 3500 kJ
	1 pile/day	2 piles/day	4 pin piles/day
May	4	0	0
June	6	4	0
July	0	7	0
August	1	5	1
September	0	3	1
October	1	1	1
November	2	0	0
December	1	0	0
Total	**15**	**20**	**3**

Table H-6. Construction Schedule B, Year 2: The number of potential piling days per month under the maximum envelope used to estimate the total number of marine mammal and sea turtle acoustic exposures for New England Wind.

Construction month	12 m Monopile, 5000 kJ		4 m Pin Pile, 3500 kJ
	1 pile/day	2 piles/day	4 pin piles/day
May	0	0	1
June	0	0	9
July	0	0	14
August	0	0	14
September	0	0	8
October	0	0	4
November	0	0	2
December	0	0	1
Total	**0**	**0**	**53**

Table H-7. Construction Schedule B, Year 3: The number of potential piling days per month under the maximum envelope used to estimate the total number of marine mammal and sea turtle acoustic exposures for New England Wind.

Construction month	12 m Monopile, 5000 kJ		4 m Pin Pile, 3500 kJ
	1 pile/day	2 piles/day	4 pin piles/day
May	0	0	1
June	0	0	4
July	0	0	5
August	0	0	5
September	0	0	5
October	0	0	1
November	0	0	1
December	0	0	0
Total	**0**	**0**	**22**

H.2.1. Marine Mammal Exposure Estimates

Table H-8. Construction Schedule A, All Years Summed: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Summed construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	146.36	49.61	21.51	13.94	0.14	0.04	0.04	0.02	147.36	57.06	33.58	28.56	205.54	103.84	66.20	53.73
Minke whale	49.59	20.24	9.71	6.32	0.06	0.04	0.03	0.03	74.94	37.66	26.79	23.90	422.12	281.60	207.05	175.39
Humpback whale	81.08	29.12	13.69	9.09	0.13	0.05	0.05	0.05	68.89	26.90	16.46	14.11	97.99	49.67	31.83	25.69
North Atlantic right whale[c]	18.08	6.56	3.09	2.16	0.02	<0.01	<0.01	<0.01	26.02	10.89	7.01	5.98	36.32	18.67	11.99	9.72
Sei whale[c]	3.60	1.20	0.53	0.36	0.01	<0.01	<0.01	<0.01	5.44	2.17	1.29	1.09	42.29	27.66	20.13	16.86
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0.62	0.21	0.21	0.21	1.56	1.56	1.56	1.56	3610.99	1830.24	1334.89	1189.53	2722.32	1532.12	1021.70	814.92
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	14.74	5.28	3.92	3.38	17.04	7.47	4.18	3.03
Short-beaked common dolphin	4.05	2.55	1.28	0	6.96	5.77	5.09	5.09	16247.71	9083.36	6999.42	6371.06	11666.25	6902.20	4697.60	3805.18
Bottlenose dolphin	1.13	0.44	0.15	0	0.62	0.62	0.62	0.62	825.16	505.51	387.83	331.24	690.84	387.84	246.92	194.13
Risso's dolphin	0.04	0.02	0.02	<0.01	0.04	0.03	0.03	0.03	19.27	8.75	6.23	5.59	16.53	8.82	5.65	4.45
Long-finned pilot whale	0.06	0.06	0.06	0	0.15	0.15	0.15	0.15	447.66	227.09	165.24	147.76	324.89	187.96	126.66	100.70
Short-finned pilot whale	0.05	0.03	<0.01	<0.01	0.24	0.24	0.24	0.24	337.97	168.12	121.26	108.08	251.74	143.39	94.85	74.60
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	8.93	3.91	2.64	2.34	7.71	4.04	2.52	1.92
High-frequency cetacean																
Harbor porpoise	359.73	173.92	97.62	67.84	34.26	14.77	5.91	3.87	758.01	367.08	258.58	227.94	11092.63	7737.44	5509.56	4618.70
Pinnipeds in water																
Gray seal	10.12	3.00	1.07	0.54	<0.01	<0.01	<0.01	<0.01	170.45	62.85	32.11	24.86	199.28	97.57	60.51	47.44
Harbor seal	29.00	7.21	1.95	0.91	0.28	0.19	0.18	0.18	321.18	126.64	75.85	61.00	402.88	198.97	123.09	96.25
Harp seal	12.51	2.99	0.94	0.36	0.10	0.04	0	0	187.66	70.59	37.64	30.42	225.05	109.18	67.95	53.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-9. Construction Schedule A, Year 1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	71.33	24.05	10.27	6.37	0.06	0.01	0.01	0.01	84.00	32.66	18.93	16.66	115.42	58.85	37.56	30.76
Minke whale	24.01	9.37	4.39	2.87	0.03	0.03	0.02	0.02	37.99	18.67	13.53	12.26	225.15	149.56	107.81	91.13
Humpback whale	39.42	13.57	6.41	4.24	0.08	0.04	0.04	0.04	39.08	15.07	8.99	7.76	55.78	28.23	18.05	14.62
North Atlantic right whale[c]	8.49	2.95	1.35	0.96	0.01	<0.01	<0.01	<0.01	12.83	5.30	3.52	3.04	18.90	9.56	6.12	4.94
Sei whale[c]	1.77	0.58	0.24	0.17	<0.01	<0.01	<0.01	<0.01	2.60	1.05	0.65	0.59	21.63	14.24	10.04	8.27
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0.04	0.01	0.01	0.01	1.08	1.08	1.08	1.08	1883.99	920.68	670.96	605.30	1414.29	790.26	520.33	407.55
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	7.88	3.14	2.34	2.04	8.69	3.83	2.16	1.59
Short-beaked common dolphin	0.33	0.22	0.11	0	5.98	4.79	4.23	4.23	8037.76	4211.55	3142.22	2861.28	5868.59	3333.92	2238.25	1783.86
Bottlenose dolphin	0.23	0.04	0.01	0	0.53	0.53	0.53	0.53	415.04	236.95	175.42	151.05	353.16	187.22	117.19	91.48
Risso's dolphin	0.02	0.01	0.01	<0.01	0.03	0.03	0.02	0.02	10.74	4.75	3.20	2.86	9.13	4.80	3.05	2.37
Long-finned pilot whale	<0.01	<0.01	<0.01	0	0.11	0.11	0.11	0.11	233.51	113.63	80.31	72.04	170.34	97.08	64.28	50.21
Short-finned pilot whale	<0.01	<0.01	<0.01	0	0.19	0.19	0.19	0.19	177.62	82.55	57.73	52.07	131.70	74.05	48.08	37.18
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	4.82	2.05	1.36	1.22	4.06	2.15	1.32	0.98
High-frequency cetacean																
Harbor porpoise	167.25	78.29	43.98	30.77	17.20	7.00	2.82	1.77	371.46	175.46	126.74	113.19	5977.20	4002.28	2806.21	2338.16
Pinnipeds in water																
Gray seal	4.43	1.28	0.39	0.18	<0.01	<0.01	<0.01	<0.01	71.26	25.97	13.53	12.11	84.23	42.13	26.45	20.32
Harbor seal	12.22	2.65	0.67	0.18	0.10	0.10	0.10	0.10	131.20	54.14	34.04	29.25	170.31	84.84	52.58	40.76
Harp seal	5.10	1.23	0.40	0.15	0.05	0	0	0	77.02	28.89	16.61	14.32	92.02	46.03	29.07	22.64

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-10. Construction Schedule A, Year 2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	75.03	25.56	11.24	7.57	0.08	0.02	0.02	<0.01	63.36	24.40	14.65	11.90	90.12	44.99	28.64	22.97
Minke whale	25.58	10.87	5.32	3.44	0.02	0.02	0.01	0.01	36.96	18.98	13.26	11.64	196.97	132.03	99.24	84.26
Humpback whale	41.66	15.54	7.28	4.85	0.05	<0.01	<0.01	<0.01	29.81	11.83	7.47	6.35	42.22	21.44	13.79	11.07
North Atlantic right whale[c]	9.60	3.61	1.74	1.21	<0.01	<0.01	<0.01	<0.01	13.19	5.59	3.49	2.93	17.42	9.11	5.87	4.78
Sei whale[c]	1.83	0.62	0.29	0.19	<0.01	<0.01	<0.01	<0.01	2.85	1.12	0.63	0.50	20.66	13.42	10.08	8.59
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0.58	0.19	0.19	0.19	0.48	0.48	0.48	0.48	1727.00	909.56	663.93	584.23	1308.03	741.86	501.36	407.37
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	6.87	2.14	1.58	1.34	8.35	3.64	2.02	1.45
Short-beaked common dolphin	3.73	2.33	1.17	0	0.98	0.98	0.87	0.87	8209.95	4871.81	3857.21	3509.78	5797.67	3568.28	2459.35	2021.32
Bottlenose dolphin	0.90	0.40	0.13	0	0.09	0.09	0.09	0.09	410.12	268.55	212.42	180.18	337.68	200.62	129.74	102.65
Risso's dolphin	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	8.53	4.01	3.03	2.73	7.40	4.02	2.60	2.08
Long-finned pilot whale	0.06	0.06	0.06	0	0.04	0.04	0.04	0.04	214.15	113.46	84.93	75.72	154.55	90.88	62.38	50.49
Short-finned pilot whale	0.04	0.03	<0.01	<0.01	0.05	0.05	0.05	0.05	160.35	85.57	63.54	56.01	120.04	69.34	46.77	37.42
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	4.11	1.86	1.28	1.12	3.65	1.90	1.20	0.94
High-frequency cetacean																
Harbor porpoise	192.48	95.63	53.65	37.07	17.06	7.78	3.08	2.10	386.54	191.62	131.84	114.75	5115.43	3735.16	2703.36	2280.54
Pinnipeds in water																
Gray seal	5.69	1.72	0.68	0.36	<0.01	<0.01	<0.01	<0.01	99.20	36.88	18.57	12.75	115.05	55.44	34.06	27.12
Harbor seal	16.78	4.56	1.28	0.73	0.18	0.10	0.09	0.09	189.97	72.51	41.80	31.75	232.57	114.14	70.51	55.50
Harp seal	7.40	1.77	0.54	0.21	0.05	0.04	0	0	110.64	41.70	21.03	16.09	133.03	63.15	38.88	30.52

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-11. Construction Schedule B, All Years Summed: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Summed construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	251.74	86.42	37.72	25.35	0.31	0.09	0.09	0.02	160.68	60.16	41.87	37.77	236.43	119.99	78.58	64.38
Minke whale	97.69	42.60	20.59	13.10	0.10	0.05	0.03	0.03	115.38	64.81	50.89	46.74	617.91	404.75	300.67	253.54
Humpback whale	117.67	43.84	20.47	13.67	0.15	0.02	0.02	0.02	69.43	27.97	19.53	17.64	101.72	52.39	34.17	27.70
North Atlantic right whale[c]	19.76	7.84	3.92	2.77	0.02	<0.01	<0.01	<0.01	19.26	9.33	6.92	6.23	25.98	13.89	9.34	7.75
Sei whale[c]	6.78	2.44	1.14	0.83	0.02	<0.01	<0.01	<0.01	6.12	2.64	1.88	1.73	54.33	33.99	24.66	20.41
Mid-frequency cetaceans																
Atlantic white-sided dolphin	2.60	0.87	0.87	0.87	1.17	1.17	1.17	1.17	5332.04	2997.62	2385.18	2160.55	4060.10	2411.65	1638.66	1327.44
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	17.42	5.61	4.31	3.75	21.26	9.38	5.24	3.76
Short-beaked common dolphin	7.55	5.04	2.52	0	5.72	5.72	5.16	5.16	19012.51	11256.30	9012.55	8248.25	13432.98	8331.08	5737.60	4697.05
Bottlenose dolphin	2.02	0.93	0.31	0	0.41	0.41	0.41	0.41	998.97	662.07	526.97	447.68	830.86	490.39	315.02	248.12
Risso's dolphin	0.05	0.03	0.03	<0.01	0.03	0.02	0.02	0.01	23.89	11.46	8.98	8.23	20.92	11.60	7.52	5.97
Long-finned pilot whale	0.18	0.18	0.18	0	0.14	0.14	0.14	0.14	601.70	329.84	260.80	237.32	432.84	265.11	181.87	146.36
Short-finned pilot whale	0.08	0.08	0.01	0	0.14	0.14	0.14	0.14	447.99	248.08	194.21	175.55	334.52	201.46	135.57	107.62
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	13.09	6.10	4.60	4.19	11.90	6.40	4.04	3.13
High-frequency cetacean																
Harbor porpoise	611.86	313.95	173.78	117.38	56.46	27.69	8.82	6.32	932.60	512.43	400.40	363.83	12817.69	8579.47	5868.55	4939.12
Pinnipeds in water																
Gray seal	13.69	4.19	1.55	0.92	<0.01	<0.01	<0.01	<0.01	103.73	36.68	21.91	19.94	131.69	66.08	41.14	31.52
Harbor seal	48.24	12.61	3.85	1.64	0.77	0.19	0.10	0.10	236.43	108.01	77.88	67.72	300.72	155.21	99.42	78.24
Harp seal	20.33	5.56	1.42	0.52	0.19	0	0	0	129.91	52.91	36.14	32.17	159.01	81.27	52.37	41.11

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-12. Construction Schedule B, Year 1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	50.70	17.13	7.37	4.60	0.06	0.03	0.03	0.02	58.72	22.85	13.84	12.25	78.01	41.09	26.64	21.86
Minke whale	19.94	7.58	3.66	2.38	0.04	0.03	0.03	0.03	31.66	15.58	11.40	10.32	188.28	123.16	87.70	73.94
Humpback whale	25.35	8.73	3.95	2.61	0.04	0.02	0.02	0.02	23.68	9.46	5.76	5.08	32.30	17.11	11.07	8.96
North Atlantic right whale[c]	5.61	1.93	0.90	0.68	<0.01	<0.01	<0.01	<0.01	8.00	3.46	2.35	2.07	11.17	5.90	3.84	3.12
Sei whale[c]	1.56	0.51	0.21	0.14	<0.01	<0.01	<0.01	<0.01	2.39	0.97	0.61	0.55	20.03	13.17	9.14	7.47
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0.07	0.02	0.02	0.02	1.17	1.17	1.17	1.17	1380.78	684.50	510.25	461.74	1061.81	603.29	400.45	312.54
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	4.18	1.63	1.18	1.04	4.65	2.12	1.22	0.91
Short-beaked common dolphin	0.44	0.30	0.15	0	5.72	5.72	5.16	5.16	4153.76	2264.72	1765.71	1617.76	3036.60	1815.32	1241.81	998.24
Bottlenose dolphin	0.26	0.05	0.02	0	0.41	0.41	0.41	0.41	227.97	135.57	103.85	89.27	201.32	108.64	67.85	52.49
Risso's dolphin	0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.01	6.14	2.85	2.02	1.82	5.28	2.89	1.86	1.44
Long-finned pilot whale	<0.01	<0.01	<0.01	0	0.14	0.14	0.14	0.14	150.78	74.84	55.12	49.74	111.29	65.60	43.69	34.13
Short-finned pilot whale	0.02	0.02	0.01	0	0.14	0.14	0.14	0.14	113.55	53.98	39.10	35.43	85.78	49.65	32.51	25.13
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	3.42	1.47	1.00	0.90	2.95	1.57	0.97	0.72
High-frequency cetacean																
Harbor porpoise	126.36	59.59	33.97	24.01	13.25	5.66	2.21	1.41	266.79	128.94	94.70	84.39	4271.24	2709.18	1853.85	1564.77
Pinnipeds in water																
Gray seal	3.99	1.20	0.39	0.19	<0.01	<0.01	<0.01	<0.01	63.06	22.80	11.85	10.79	73.66	37.47	23.56	18.07
Harbor seal	11.07	2.38	0.58	0.17	0.11	0.11	0.10	0.10	115.58	48.00	30.64	26.45	150.06	75.38	46.76	36.35
Harp seal	4.44	1.07	0.40	0.15	0.05	0	0	0	67.30	25.29	14.90	12.82	79.55	40.66	25.79	20.11

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-13. Construction Schedule B, Year 2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	141.85	48.89	21.41	14.65	0.18	0.04	0.04	0	71.94	26.33	19.78	18.01	111.77	55.67	36.64	30.01
Minke whale	53.95	24.30	11.75	7.44	0.04	0.01	0	0	58.09	34.16	27.40	25.27	298.11	195.39	147.78	124.62
Humpback whale	63.57	24.18	11.38	7.62	0.07	0	0	0	31.51	12.75	9.48	8.65	47.80	24.30	15.91	12.90
North Atlantic right whale[c]	9.33	3.89	1.99	1.38	0.01	<0.01	0	0	7.42	3.87	3.01	2.74	9.77	5.27	3.63	3.05
Sei whale[c]	3.51	1.30	0.63	0.46	<0.01	<0.01	0	0	2.51	1.12	0.86	0.79	23.05	13.99	10.43	8.70
Mid-frequency cetaceans																
Atlantic white-sided dolphin	1.78	0.59	0.59	0.59	0	0	0	0	2786.78	1631.42	1322.37	1198.16	2114.66	1275.42	873.30	715.80
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	9.32	2.80	2.20	1.91	11.69	5.11	2.83	2.01
Short-beaked common dolphin	5.02	3.35	1.67	0	0	0	0	0	10498.71	6353.16	5120.38	4684.89	7345.74	4603.82	3176.58	2613.45
Bottlenose dolphin	1.24	0.62	0.21	0	0	0	0	0	542.17	370.23	297.54	252.04	442.69	268.45	173.81	137.57
Risso's dolphin	0.03	0.02	0.02	<0.01	<0.01	0	0	0	12.60	6.12	4.94	4.55	11.10	6.18	4.01	3.21
Long-finned pilot whale	0.12	0.12	0.12	0	0	0	0	0	318.65	180.20	145.35	132.56	227.23	140.99	97.65	79.31
Short-finned pilot whale	0.05	0.05	0	0	0	0	0	0	236.34	137.17	109.61	99.02	175.78	107.28	72.83	58.29
Sperm whale[c]	<0.01	<0.01	<0.01	0	0	0	0	0	7.02	3.36	2.62	2.39	6.50	3.51	2.23	1.75
High-frequency cetacean																
Harbor porpoise	331.45	173.65	95.44	63.74	29.50	15.04	4.51	3.35	454.54	261.80	208.70	190.77	5834.57	4007.58	2740.79	2303.63
Pinnipeds in water																
Gray seal	5.93	1.83	0.71	0.45	0	0	0	0	24.89	8.50	6.16	5.60	35.51	17.51	10.76	8.23
Harbor seal	22.75	6.26	2.00	0.90	0.40	0.05	0	0	73.96	36.73	28.91	25.25	92.20	48.85	32.22	25.64
Harp seal	9.72	2.74	0.62	0.22	0.09	0	0	0	38.32	16.91	13.00	11.84	48.63	24.85	16.27	12.86

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-14. Construction Schedule B, Year 3: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	59.19	20.40	8.94	6.11	0.07	0.02	0.02	0	30.02	10.98	8.25	7.51	46.64	23.23	15.29	12.52
Minke whale	23.80	10.72	5.19	3.28	0.02	<0.01	0	0	25.63	15.07	12.09	11.15	131.52	86.20	65.19	54.98
Humpback whale	28.74	10.94	5.15	3.44	0.03	0	0	0	14.25	5.76	4.29	3.91	21.62	10.99	7.20	5.83
North Atlantic right whale[c]	4.82	2.01	1.03	0.71	<0.01	<0.01	0	0	3.84	2.00	1.56	1.42	5.05	2.72	1.88	1.58
Sei whale[c]	1.71	0.64	0.31	0.22	<0.01	<0.01	0	0	1.22	0.55	0.42	0.39	11.25	6.82	5.09	4.24
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0.75	0.25	0.25	0.25	0	0	0	0	1164.47	681.70	552.56	500.66	883.62	532.94	364.91	299.10
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	3.92	1.18	0.93	0.80	4.91	2.15	1.19	0.84
Short-beaked common dolphin	2.09	1.39	0.70	0	0	0	0	0	4360.04	2638.43	2126.46	1945.60	3050.64	1911.94	1319.21	1085.35
Bottlenose dolphin	0.52	0.26	0.09	0	0	0	0	0	228.83	156.26	125.58	106.38	186.84	113.30	73.36	58.06
Risso's dolphin	0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	5.15	2.50	2.02	1.86	4.54	2.53	1.64	1.31
Long-finned pilot whale	0.05	0.05	0.05	0	0	0	0	0	132.27	74.80	60.33	55.02	94.32	58.52	40.53	32.92
Short-finned pilot whale	0.02	0.02	0	0	0	0	0	0	98.10	56.94	45.50	41.10	72.96	44.53	30.23	24.20
Sperm whale[c]	<0.01	<0.01	<0.01	0	0	0	0	0	2.65	1.27	0.99	0.90	2.45	1.32	0.84	0.66
High-frequency cetacean																
Harbor porpoise	154.05	80.71	44.36	29.63	13.71	6.99	2.10	1.56	211.27	121.68	97.00	88.67	2711.88	1862.70	1273.91	1070.72
Pinnipeds in water																
Gray seal	3.76	1.16	0.45	0.28	0	0	0	0	15.78	5.39	3.90	3.55	22.52	11.10	6.82	5.22
Harbor seal	14.42	3.97	1.27	0.57	0.25	0.03	0	0	46.89	23.29	18.33	16.01	58.46	30.97	20.43	16.25
Harp seal	6.17	1.74	0.40	0.14	0.06	0	0	0	24.29	10.72	8.24	7.51	30.83	15.76	10.31	8.15

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

H.2.2. Sea Turtle Exposure Estimates

This section includes sea turtle exposure estimates for Construction Schedules A and B, both combined and per year, and assuming 0, 6, 10, and 12 dB broadband attenuation.

Table H-15. Construction Schedule A, All Years Summed: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Summed construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.24	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.15	0.51	0.25	0.18
Leatherback turtle[a]	5.57	0.78	0.23	0.02	0.23	0.23	0.23	0.23	40.48	17.76	8.57	5.69
Loggerhead turtle	2.18	0.51	0.04	<0.01	0.08	0.08	0.08	0.08	22.56	9.62	4.57	3.23
Green turtle	0.49	0.09	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.26	0.62	0.32	0.20

[a] Listed as Endangered under the ESA.

Table H-16. Construction Schedule A, Year 1: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.10	0.02	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.61	0.24	0.12	0.09
Leatherback turtle[a]	2.62	0.52	0.14	0	0.18	0.18	0.18	0.18	21.59	9.21	4.98	3.20
Loggerhead turtle	1.07	0.28	0.03	0	0.07	0.07	0.07	0.07	11.23	4.89	2.36	1.64
Green turtle	0.23	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.70	0.34	0.17	0.11

[a] Listed as Endangered under the ESA.

Table H-17. Construction Schedule A, Year 2: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.14	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.54	0.26	0.12	0.09
Leatherback turtle[a]	2.95	0.26	0.09	0.02	0.05	0.05	0.05	0.05	18.88	8.55	3.59	2.50
Loggerhead turtle	1.11	0.22	0.01	<0.01	0.02	0.02	0.02	0.02	11.33	4.73	2.21	1.59
Green turtle	0.27	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.56	0.28	0.15	0.09

[a] Listed as Endangered under the ESA.

Table H-18. Construction Schedule B, All Years Summed: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.42	0.08	0.01	0	<0.01	<0.01	<0.01	<0.01	1.64	0.74	0.35	0.27
Leatherback turtle[a]	8.07	0.79	0.18	0	0.17	0.17	0.17	0.17	55.79	23.87	10.09	6.82
Loggerhead turtle	2.64	0.49	0	0	0.09	0.09	0.09	0.09	27.72	11.09	5.24	3.88
Green turtle	0.77	0.13	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	1.69	0.80	0.42	0.23

[a] Listed as Endangered under the ESA.

Table H-19. Construction Schedule B, Year 1: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.06	0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.41	0.16	0.08	0.06
Leatherback turtle[a]	1.55	0.32	0.07	0	0.17	0.17	0.17	0.17	13.65	5.47	2.88	1.93
Loggerhead turtle	0.58	0.14	0	0	0.09	0.09	0.09	0.09	6.36	2.48	1.25	0.99
Green turtle	0.14	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.48	0.22	0.11	0.07

[a] Listed as Endangered under the ESA.

Table H-20. Construction Schedule B, Year 2: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.25	0.05	<0.01	0	0	0	0	0	0.87	0.41	0.19	0.15
Leatherback turtle[a]	4.59	0.33	0.08	0	0	0	0	0	29.67	12.95	5.08	3.44
Loggerhead turtle	1.43	0.24	0	0	0	0	0	0	14.79	5.96	2.77	2.00
Green turtle	0.44	0.08	0.01	<0.01	0	0	0	0	0.86	0.41	0.22	0.11

[a] Listed as Endangered under the ESA.

Table H-21. Construction Schedule B, Year 3: The mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.11	0.02	<0.01	0	0	0	0	0	0.36	0.17	0.08	0.06
Leatherback turtle[a]	1.93	0.14	0.03	0	0	0	0	0	12.47	5.44	2.14	1.45
Loggerhead turtle	0.64	0.11	0	0	0	0	0	0	6.57	2.65	1.23	0.89
Green turtle	0.18	0.03	<0.01	<0.01	0	0	0	0	0.36	0.17	0.09	0.05

[a] Listed as Endangered under the ESA.

H.2.3. Potential Impacts Relative to Species' Abundance

Table H-22. Construction Schedule A, All Years Summed: Marine mammal exposures as a percent of abundance with sound attenuation. Summed construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	2.15	0.73	0.32	0.20	<0.01	<0.01	<0.01	<0.01	2.17	0.84	0.49	0.42	3.02	1.53	0.97	0.79
Minke whale	0.23	0.09	0.04	0.03	<0.01	<0.01	<0.01	<0.01	0.34	0.17	0.12	0.11	1.92	1.28	0.94	0.80
Humpback whale	5.81	2.09	0.98	0.65	<0.01	<0.01	<0.01	<0.01	4.94	1.93	1.18	1.01	7.02	3.56	2.28	1.84
North Atlantic right whale[c]	4.91	1.78	0.84	0.59	<0.01	<0.01	<0.01	<0.01	7.07	2.96	1.91	1.62	9.87	5.07	3.26	2.64
Sei whale[c]	0.06	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	0.03	0.02	0.02	0.67	0.44	0.32	0.27
Mid-frequency cetaceans																
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.87	1.96	1.43	1.28	2.92	1.64	1.10	0.87
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0.04	0.01	<0.01	<0.01	0.04	0.02	0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	9.39	5.25	4.05	3.68	6.74	3.99	2.72	2.20
Bottlenose dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	1.31	0.80	0.62	0.53	1.10	0.62	0.39	0.31
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.02	0.02	0.02	0.05	0.03	0.02	0.01
Long-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	1.14	0.58	0.42	0.38	0.83	0.48	0.32	0.26
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.17	0.58	0.42	0.37	0.87	0.50	0.33	0.26
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.21	0.09	0.06	0.05	0.18	0.09	0.06	0.04
High-frequency cetacean																
Harbor porpoise	0.38	0.18	0.10	0.07	0.04	0.02	<0.01	<0.01	0.79	0.38	0.27	0.24	11.61	8.10	5.77	4.83
Pinnipeds in water																
Gray seal	0.04	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.62	0.23	0.12	0.09	0.73	0.36	0.22	0.17
Harbor seal	0.05	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.52	0.21	0.12	0.10	0.66	0.32	0.20	0.16
Harp seal	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-23. Construction Schedule A, Year 1: Marine mammal exposures as a percent of abundance with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	1.05	0.35	0.15	0.09	<0.01	<0.01	<0.01	<0.01	1.23	0.48	0.28	0.24	1.70	0.87	0.55	0.45
Minke whale	0.11	0.04	0.02	0.01	<0.01	<0.01	<0.01	<0.01	0.17	0.09	0.06	0.06	1.02	0.68	0.49	0.41
Humpback whale	2.82	0.97	0.46	0.30	<0.01	<0.01	<0.01	<0.01	2.80	1.08	0.64	0.56	4.00	2.02	1.29	1.05
North Atlantic right whale[c]	2.31	0.80	0.37	0.26	<0.01	<0.01	<0.01	<0.01	3.49	1.44	0.96	0.83	5.14	2.60	1.66	1.34
Sei whale[c]	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.02	0.01	<0.01	0.34	0.23	0.16	0.13
Mid-frequency cetaceans																
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.02	0.99	0.72	0.65	1.52	0.85	0.56	0.44
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0.02	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	4.65	2.43	1.82	1.65	3.39	1.93	1.29	1.03
Bottlenose dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.66	0.38	0.28	0.24	0.56	0.30	0.19	0.15
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.01	<0.01	<0.01	0.03	0.01	<0.01	<0.01
Long-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.60	0.29	0.20	0.18	0.43	0.25	0.16	0.13
Short-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.61	0.29	0.20	0.18	0.46	0.26	0.17	0.13
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.11	0.05	0.03	0.03	0.09	0.05	0.03	0.02
High-frequency cetacean																
Harbor porpoise	0.18	0.08	0.05	0.03	0.02	<0.01	<0.01	<0.01	0.39	0.18	0.13	0.12	6.26	4.19	2.94	2.45
Pinnipeds in water																
Gray seal	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.26	0.10	0.05	0.04	0.31	0.15	0.10	0.07
Harbor seal	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.21	0.09	0.06	0.05	0.28	0.14	0.09	0.07
Harp seal	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-24. Construction Schedule A, Year 2: Marine mammal exposures as a percent of abundance with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	1.10	0.38	0.17	0.11	<0.01	<0.01	<0.01	<0.01	0.93	0.36	0.22	0.17	1.32	0.66	0.42	0.34
Minke whale	0.12	0.05	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.17	0.09	0.06	0.05	0.90	0.60	0.45	0.38
Humpback whale	2.98	1.11	0.52	0.35	<0.01	<0.01	<0.01	<0.01	2.14	0.85	0.54	0.46	3.02	1.54	0.99	0.79
North Atlantic right whale[c]	2.61	0.98	0.47	0.33	<0.01	<0.01	<0.01	<0.01	3.59	1.52	0.95	0.80	4.73	2.48	1.60	1.30
Sei whale[c]	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.02	0.01	<0.01	0.33	0.21	0.16	0.14
Mid-frequency cetaceans																
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.85	0.98	0.71	0.63	1.40	0.80	0.54	0.44
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0.02	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	4.75	2.82	2.23	2.03	3.35	2.06	1.42	1.17
Bottlenose dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.65	0.43	0.34	0.29	0.54	0.32	0.21	0.16
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	<0.01	<0.01	0.02	0.01	<0.01	<0.01
Long-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.55	0.29	0.22	0.19	0.39	0.23	0.16	0.13
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.55	0.30	0.22	0.19	0.42	0.24	0.16	0.13
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.09	0.04	0.03	0.03	0.08	0.04	0.03	0.02
High-frequency cetacean																
Harbor porpoise	0.20	0.10	0.06	0.04	0.02	<0.01	<0.01	<0.01	0.40	0.20	0.14	0.12	5.35	3.91	2.83	2.39
Pinnipeds in water																
Gray seal	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.36	0.14	0.07	0.05	0.42	0.20	0.12	0.10
Harbor seal	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.31	0.12	0.07	0.05	0.38	0.19	0.11	0.09
Harp seal	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-25. Construction Schedule B, All Years Summed: Marine mammal exposures as a percent of abundance with sound attenuation. Summed construction schedule assumptions are summarized in Section 1.2.7.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	3.70	1.27	0.55	0.37	<0.01	<0.01	<0.01	<0.01	2.36	0.88	0.62	0.56	3.48	1.76	1.16	0.95
Minke whale	0.44	0.19	0.09	0.06	<0.01	<0.01	<0.01	<0.01	0.53	0.30	0.23	0.21	2.81	1.84	1.37	1.15
Humpback whale	8.43	3.14	1.47	0.98	0.01	<0.01	<0.01	<0.01	4.97	2.00	1.40	1.26	7.29	3.75	2.45	1.98
North Atlantic right whale[c]	5.37	2.13	1.06	0.75	<0.01	<0.01	<0.01	<0.01	5.23	2.54	1.88	1.69	7.06	3.78	2.54	2.11
Sei whale[c]	0.11	0.04	0.02	0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.04	0.03	0.03	0.86	0.54	0.39	0.32
Mid-frequency cetaceans																
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	5.72	3.22	2.56	2.32	4.35	2.59	1.76	1.42
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0.04	0.01	0.01	<0.01	0.05	0.02	0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	10.99	6.51	5.21	4.77	7.77	4.82	3.32	2.72
Bottlenose dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	1.59	1.05	0.84	0.71	1.32	0.78	0.50	0.39
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.03	0.03	0.02	0.06	0.03	0.02	0.02
Long-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	1.53	0.84	0.67	0.61	1.10	0.68	0.46	0.37
Short-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	1.55	0.86	0.67	0.61	1.16	0.70	0.47	0.37
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.30	0.14	0.11	0.10	0.27	0.15	0.09	0.07
High-frequency cetacean																
Harbor porpoise	0.64	0.33	0.18	0.12	0.06	0.03	<0.01	<0.01	0.98	0.54	0.42	0.38	13.42	8.98	6.14	5.17
Pinnipeds in water																
Gray seal	0.05	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.38	0.13	0.08	0.07	0.48	0.24	0.15	0.12
Harbor seal	0.08	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.39	0.18	0.13	0.11	0.49	0.25	0.16	0.13
Harp seal	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-26. Construction Schedule B, Year 1: Marine mammal exposures as a percent of abundance with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	0.75	0.25	0.11	0.07	<0.01	<0.01	<0.01	<0.01	0.86	0.34	0.20	0.18	1.15	0.60	0.39	0.32
Minke whale	0.09	0.03	0.02	0.01	<0.01	<0.01	<0.01	<0.01	0.14	0.07	0.05	0.05	0.86	0.56	0.40	0.34
Humpback whale	1.82	0.63	0.28	0.19	<0.01	<0.01	<0.01	<0.01	1.70	0.68	0.41	0.36	2.31	1.23	0.79	0.64
North Atlantic right whale[c]	1.52	0.53	0.24	0.19	<0.01	<0.01	<0.01	<0.01	2.17	0.94	0.64	0.56	3.03	1.60	1.04	0.85
Sei whale[c]	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.02	<0.01	<0.01	0.32	0.21	0.15	0.12
Mid-frequency cetaceans																
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.48	0.73	0.55	0.50	1.14	0.65	0.43	0.34
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	2.40	1.31	1.02	0.94	1.76	1.05	0.72	0.58
Bottlenose dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.36	0.22	0.17	0.14	0.32	0.17	0.11	0.08
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Long-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.38	0.19	0.14	0.13	0.28	0.17	0.11	0.09
Short-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.39	0.19	0.14	0.12	0.30	0.17	0.11	0.09
Sperm whale[c]	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	0.08	0.03	0.02	0.02	0.07	0.04	0.02	0.02
High-frequency cetacean																
Harbor porpoise	0.13	0.06	0.04	0.03	0.01	<0.01	<0.01	<0.01	0.28	0.13	0.10	0.09	4.47	2.84	1.94	1.64
Pinnipeds in water																
Gray seal	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.23	0.08	0.04	0.04	0.27	0.14	0.09	0.07
Harbor seal	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	0.08	0.05	0.04	0.24	0.12	0.08	0.06
Harp seal	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-27. Construction Schedule B, Year 2: Marine mammal exposures as a percent of abundance with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	2.09	0.72	0.31	0.22	<0.01	<0.01	<0.01	0	1.06	0.39	0.29	0.26	1.64	0.82	0.54	0.44
Minke whale	0.25	0.11	0.05	0.03	<0.01	<0.01	0	0	0.26	0.16	0.12	0.12	1.36	0.89	0.67	0.57
Humpback whale	4.55	1.73	0.82	0.55	<0.01	0	0	0	2.26	0.91	0.68	0.62	3.42	1.74	1.14	0.92
North Atlantic right whale[c]	2.53	1.06	0.54	0.37	<0.01	<0.01	0	0	2.02	1.05	0.82	0.75	2.65	1.43	0.99	0.83
Sei whale[c]	0.06	0.02	<0.01	<0.01	<0.01	<0.01	0	0	0.04	0.02	0.01	0.01	0.37	0.22	0.17	0.14
Mid-frequency cetaceans																
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	0	0	0	0	2.99	1.75	1.42	1.29	2.27	1.37	0.94	0.77
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0.02	<0.01	<0.01	<0.01	0.03	0.01	<0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	6.07	3.67	2.96	2.71	4.25	2.66	1.84	1.51
Bottlenose dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	0.86	0.59	0.47	0.40	0.70	0.43	0.28	0.22
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	0.04	0.02	0.01	0.01	0.03	0.02	0.01	<0.01
Long-finned pilot whale	<0.01	<0.01	<0.01	0	0	0	0	0	0.81	0.46	0.37	0.34	0.58	0.36	0.25	0.20
Short-finned pilot whale	<0.01	<0.01	0	0	0	0	0	0	0.82	0.47	0.38	0.34	0.61	0.37	0.25	0.20
Sperm whale[c]	<0.01	<0.01	<0.01	0	0	0	0	0	0.16	0.08	0.06	0.05	0.15	0.08	0.05	0.04
High-frequency cetacean																
Harbor porpoise	0.35	0.18	0.10	0.07	0.03	0.02	<0.01	<0.01	0.48	0.27	0.22	0.20	6.11	4.19	2.87	2.41
Pinnipeds in water																
Gray seal	0.02	<0.01	<0.01	<0.01	0	0	0	0	0.09	0.03	0.02	0.02	0.13	0.06	0.04	0.03
Harbor seal	0.04	0.01	<0.01	<0.01	<0.01	<0.01	0	0	0.12	0.06	0.05	0.04	0.15	0.08	0.05	0.04
Harp seal	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-28. Construction Schedule B, Year 3: Marine mammal exposures as a percent of abundance with sound attenuation. Yearly construction schedule assumptions are summarized in Appendix H.2.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	0.87	0.30	0.13	0.09	<0.01	<0.01	<0.01	0	0.44	0.16	0.12	0.11	0.69	0.34	0.22	0.18
Minke whale	0.11	0.05	0.02	0.01	<0.01	<0.01	0	0	0.12	0.07	0.06	0.05	0.60	0.39	0.30	0.25
Humpback whale	2.06	0.78	0.37	0.25	<0.01	0	0	0	1.02	0.41	0.31	0.28	1.55	0.79	0.52	0.42
North Atlantic right whale[c]	1.31	0.55	0.28	0.19	<0.01	<0.01	0	0	1.04	0.54	0.42	0.39	1.37	0.74	0.51	0.43
Sei whale[c]	0.03	0.01	<0.01	<0.01	<0.01	<0.01	0	0	0.02	<0.01	<0.01	<0.01	0.18	0.11	0.08	0.07
Mid-frequency cetaceans																
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	0	0	0	0	1.25	0.73	0.59	0.54	0.95	0.57	0.39	0.32
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	2.52	1.53	1.23	1.12	1.76	1.11	0.76	0.63
Bottlenose dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	0.36	0.25	0.20	0.17	0.30	0.18	0.12	0.09
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Long-finned pilot whale	<0.01	<0.01	<0.01	0	0	0	0	0	0.34	0.19	0.15	0.14	0.24	0.15	0.10	0.08
Short-finned pilot whale	<0.01	<0.01	0	0	0	0	0	0	0.34	0.20	0.16	0.14	0.25	0.15	0.10	0.08
Sperm whale[c]	<0.01	<0.01	<0.01	0	0	0	0	0	0.06	0.03	0.02	0.02	0.06	0.03	0.02	0.02
High-frequency cetacean																
Harbor porpoise	0.16	0.08	0.05	0.03	0.01	<0.01	<0.01	<0.01	0.22	0.13	0.10	0.09	2.84	1.95	1.33	1.12
Pinnipeds in water																
Gray seal	0.01	<0.01	<0.01	<0.01	0	0	0	0	0.06	0.02	0.01	0.01	0.08	0.04	0.02	0.02
Harbor seal	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0.08	0.04	0.03	0.03	0.10	0.05	0.03	0.03
Harp seal	<0.01	<0.01	<0.01	<0.01	<0.01	0	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

H.2.4. Marine Mammal Exposure Ranges

Table H-29. 12 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	7.99	3.98	2.37	1.91	0.04	0.01	0.01	0.01	10.45	6.17	4.00	3.71	10.46	6.18	3.99	3.72
Minke whale	6.38	2.91	1.50	0.97	0.04	0.04	0.02	0.02	10.04	5.79	3.89	3.50	36.32	25.89	20.29	17.93
Humpback whale	9.08	4.68	2.76	2.12	0	0	0	0	10.45	6.09	3.99	3.74	10.47	6.03	3.99	3.74
North Atlantic right whale[c]	7.81	3.74	1.84	1.52	0	0	0	0	10.01	5.82	3.94	3.62	10.12	5.83	3.97	3.60
Sei whale[c]	7.20	3.36	1.95	1.26	<0.01	<0.01	<0.01	<0.01	10.21	5.84	3.88	3.67	38.10	26.74	21.02	18.41
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0.01	0.01	0.01	0.01	9.76	5.52	3.78	3.48	5.52	3.36	2.75	2.35
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	10.11	5.91	4.15	2.98	5.69	2.80	2.57	1.93
Short-beaked common dolphin	0	0	0	0	0.01	0.01	0.01	0.01	9.79	5.52	3.79	3.51	5.61	3.45	2.86	2.42
Bottlenose dolphin	0	0	0	0	0.01	0.01	0.01	0.01	9.35	4.97	3.40	2.97	5.03	2.96	2.34	1.74
Risso's dolphin	0.02	0.02	0	0	0.02	<0.01	<0.01	<0.01	10.20	5.98	3.85	3.62	6.07	3.47	2.94	2.65
Long-finned pilot whale	0	0	0	0	0.02	0.02	0.02	0.02	9.90	5.69	3.85	3.53	5.55	3.41	2.93	2.39
Short-finned pilot whale	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	9.91	5.61	3.83	3.56	5.56	3.46	2.86	2.39
Sperm whale[c]	0	0	0	0	0.02	0.02	0.02	0.02	10.18	5.76	3.90	3.72	5.71	3.64	2.96	2.32
High-frequency cetaceans																
Harbor porpoise	5.17	2.68	1.55	1.07	0.56	0.33	0.13	0.11	9.97	5.74	3.94	3.66	97.57	74.91	53.67	46.82
Pinnipeds in water																
Gray seal	2.23	0.89	0.51	0.42	0	0	0	0	10.73	6.31	4.13	3.95	8.67	4.54	3.56	3.28
Harbor seal	2.03	0.67	0.21	0.02	0.02	0.02	0.02	0.02	10.28	5.92	3.75	3.56	8.33	4.21	3.33	3.09
Harp seal	1.80	0.57	0.15	0.06	0.05	0	0	0	10.43	6.13	4.00	3.54	8.50	4.51	3.48	3.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-30. 12 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	9.66	5.05	2.79	2.19	0.02	0	0	0	10.31	6.00	3.98	3.80	10.37	6.00	4.00	3.82
Minke whale	7.29	3.32	1.67	1.29	0.07	0.02	0.02	0.02	9.67	5.43	3.80	3.55	36.30	25.68	20.44	17.74
Humpback whale	10.91	5.67	3.44	2.46	0.03	0.01	0.01	0.01	10.44	5.91	3.98	3.66	10.50	5.89	3.98	3.66
North Atlantic right whale[c]	8.81	4.03	2.34	1.69	0.04	<0.01	<0.01	<0.01	9.99	5.75	3.75	3.52	10.10	5.79	3.76	3.53
Sei whale[c]	8.50	4.09	2.04	1.50	0.03	0.03	0.02	0.02	10.17	5.82	3.85	3.54	38.42	26.84	20.94	18.42
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0.02	0.02	0.02	0.02	9.47	5.39	3.74	3.35	5.48	3.26	2.77	2.32
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	9.60	5.20	3.66	3.32	5.17	3.17	2.78	2.33
Short-beaked common dolphin	0	0	0	0	0.02	0.02	0.02	0.02	9.62	5.42	3.81	3.46	5.51	3.39	2.87	2.36
Bottlenose dolphin	<0.01	0	0	0	0.01	0.01	0.01	0.01	8.99	4.91	3.25	2.96	5.04	2.96	2.21	1.92
Risso's dolphin	0.02	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.01	10.01	5.77	3.80	3.55	5.82	3.46	2.85	2.49
Long-finned pilot whale	0	0	0	0	0.01	0.01	0.01	0.01	9.70	5.56	3.74	3.46	5.56	3.43	2.89	2.34
Short-finned pilot whale	0	0	0	0	0.02	0.02	0.02	0.02	9.71	5.59	3.78	3.48	5.58	3.41	2.85	2.31
Sperm whale[c]	0.29	0	0	0	<0.01	<0.01	<0.01	<0.01	9.75	5.75	3.79	3.55	5.54	3.43	2.82	2.39
High-frequency cetacean																
Harbor porpoise	5.50	2.92	1.60	1.28	0.56	0.25	0.15	0.09	9.91	5.44	3.86	3.63	97.41	74.49	53.14	46.68
Pinnipeds in water																
Gray seal	2.51	1.22	0.56	0.38	0.01	0.01	0.01	0.01	10.49	6.03	4.17	3.94	8.58	4.43	3.68	3.28
Harbor seal	2.43	0.74	0.21	0.16	<0.01	<0.01	<0.01	<0.01	10.20	6.04	3.81	3.63	8.32	4.35	3.45	3.14
Harp seal	2.20	0.65	0.31	0.09	0.06	0	0	0	10.40	5.99	4.01	3.60	8.36	4.35	3.54	3.12

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-31. 12 m monopile, 5000 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	12.12	6.39	3.63	2.72	0.03	0.02	0.02	0.02	10.32	5.89	3.94	3.62	10.40	5.90	3.95	3.63
Minke whale	8.07	3.78	1.92	1.42	0.05	0.02	0.02	0.02	9.56	5.42	3.78	3.52	36.15	25.69	20.12	17.60
Humpback whale	13.09	7.20	4.30	3.20	0.03	0.01	0.01	0.01	10.31	5.95	3.93	3.63	10.39	5.96	3.93	3.63
North Atlantic right whale[c]	10.09	5.02	2.64	2.01	0.03	0.02	0.02	0.02	9.68	5.71	3.78	3.52	9.88	5.73	3.80	3.53
Sei whale[c]	10.37	4.98	2.67	1.83	0.03	0.02	0.02	0.02	10.05	5.84	3.76	3.53	38.24	26.80	20.81	18.36
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0.02	0.02	0.02	0.02	9.44	5.33	3.78	3.40	5.52	3.32	2.80	2.36
Atlantic spotted dolphin	0	0	0	0	0.02	0.02	0.02	0.02	9.73	5.31	3.75	3.37	5.31	3.28	2.77	2.36
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	0.02	0.02	0.02	0.02	9.39	5.33	3.80	3.46	5.49	3.40	2.87	2.40
Bottlenose dolphin	0.20	0	0	0	0.01	0.01	0.01	0.01	8.38	4.26	3.09	2.88	4.25	2.88	2.16	1.91
Risso's dolphin	0.02	<0.01	<0.01	<0.01	0.01	0.01	0.01	<0.01	9.88	5.63	3.79	3.49	5.72	3.43	2.83	2.43
Long-finned pilot whale	0	0	0	0	0.02	0.02	0.02	0.02	9.48	5.46	3.73	3.46	5.44	3.40	2.82	2.18
Short-finned pilot whale	0	0	0	0	0.02	0.02	0.02	0.02	9.47	5.37	3.73	3.44	5.34	3.36	2.80	2.22
Sperm whale[c]	0.29	0	0	0	0.01	0.01	0.01	0.01	9.71	5.48	3.74	3.44	5.50	3.39	2.78	2.39
High-frequency cetacean																
Harbor porpoise	6.05	3.14	1.80	1.33	0.55	0.27	0.15	0.11	9.65	5.49	3.84	3.57	100.34	78.45	53.99	47.18
Pinnipeds in water																
Gray seal	3.11	1.38	0.63	0.43	0.01	0.01	0.01	0.01	10.61	6.01	4.14	3.84	8.52	4.48	3.60	3.21
Harbor seal	2.96	0.93	0.53	0.17	0.05	0.01	0.01	0.01	10.08	5.88	3.82	3.50	8.15	4.36	3.30	3.03
Harp seal	2.45	0.85	0.32	0.08	0.06	0.01	0.01	0.01	10.29	5.95	3.89	3.54	8.33	4.39	3.42	3.09

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-32. 12 m monopile, 6000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	10.14	5.24	3.31	2.45	0.04	0.01	0.01	0.01	15.62	9.16	6.19	4.63	15.63	9.16	6.21	4.66
Minke whale	8.15	4.11	2.40	1.68	0.02	0.02	0.02	0.02	14.49	8.53	5.66	4.27	60.34	37.31	28.63	25.77
Humpback whale	11.12	5.99	3.81	2.89	0.08	0	0	0	15.58	9.12	5.95	4.87	15.57	9.12	5.88	4.87
North Atlantic right whale[c]	9.84	5.03	2.93	2.03	0	0	0	0	14.50	8.44	5.46	4.51	14.58	8.56	5.48	4.52
Sei whale[c]	9.31	4.58	2.47	2.16	<0.01	<0.01	<0.01	<0.01	15.08	8.96	5.79	4.69	73.70	41.86	31.08	26.82
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0.01	0.01	0.01	0.01	14.21	8.33	5.35	4.34	8.81	4.19	3.31	2.93
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	15.29	8.91	5.87	4.57	8.91	4.57	3.13	3.04
Short-beaked common dolphin	0	0	0	0	0.01	0.01	0.01	0.01	14.53	8.44	5.68	4.39	9.04	4.30	3.36	2.97
Bottlenose dolphin	0.11	0	0	0	0.01	0.01	0.01	0.01	14.04	7.74	4.77	3.94	8.13	3.96	3.02	2.72
Risso's dolphin	0.02	0.02	0.02	0	0.02	<0.01	<0.01	<0.01	15.28	8.73	5.55	4.52	9.23	4.51	3.46	3.04
Long-finned pilot whale	0	0	0	0	0.02	0.02	0.02	0.02	14.61	8.43	5.55	4.44	8.81	4.17	3.37	3.00
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	14.46	8.57	5.57	4.55	8.97	4.40	3.30	3.03
Sperm whale[c]	0.01	0	0	0	0.02	0.02	0.02	0.02	15.19	8.64	5.73	4.59	8.98	4.33	3.47	3.00
High-frequency cetacean																
Harbor porpoise	6.53	3.68	2.26	1.69	0.60	0.28	0.21	0.18	14.64	8.49	5.76	4.45	105.70	95.50	84.55	80.55
Pinnipeds in water																
Gray seal	2.96	1.29	0.84	0.52	0	0	0	0	15.61	9.06	6.06	5.03	13.09	7.05	4.38	3.88
Harbor seal	2.86	1.08	0.43	0.22	0.02	0.02	0.02	0.02	15.39	8.67	6.01	4.48	12.58	6.72	4.09	3.70
Harp seal	2.39	1.07	0.25	0.09	0.05	0.05	0	0	15.38	9.10	5.93	4.89	12.83	6.91	4.22	3.89

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-33. 12 m monopile, 6000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	12.55	6.53	3.90	2.86	0.02	0	0	0	15.82	9.11	6.01	4.91	15.86	9.14	5.97	4.90
Minke whale	9.23	4.48	2.59	1.82	0.02	0.02	0.02	0.02	14.65	8.48	5.33	4.39	66.79	38.12	29.19	25.67
Humpback whale	13.59	7.46	4.62	3.60	0.03	0.01	0.01	0.01	15.78	9.14	5.92	4.72	15.81	9.19	5.93	4.72
North Atlantic right whale[c]	11.16	5.82	3.16	2.49	0.04	0.02	<0.01	<0.01	14.51	8.37	5.60	4.45	14.61	8.42	5.65	4.45
Sei whale[c]	11.07	5.47	3.08	2.25	0.02	0.02	0.02	0.02	15.40	8.90	5.79	4.79	76.41	44.02	32.38	27.74
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0.02	0.02	0.02	0.02	14.09	8.12	5.40	4.29	8.54	4.12	3.22	2.83
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	15.03	8.64	5.47	3.95	8.53	3.77	2.89	2.72
Short-beaked common dolphin	0.02	0	0	0	0.02	0.02	0.02	0.02	14.35	8.36	5.54	4.34	8.88	4.19	3.33	3.08
Bottlenose dolphin	0.19	0	0	0	0.01	0.01	0.01	0.01	14.12	7.85	4.93	3.77	8.39	3.69	2.92	2.57
Risso's dolphin	0.03	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.02	15.39	8.79	5.89	4.54	9.27	4.48	3.33	3.09
Long-finned pilot whale	0	0	0	0	0.01	0.01	0.01	0.01	14.65	8.53	5.50	4.43	8.80	4.20	3.26	2.95
Short-finned pilot whale	0.02	0	0	0	0.02	0.02	0.02	0.02	14.60	8.48	5.62	4.43	8.85	4.18	3.27	2.99
Sperm whale[c]	0.29	0	0	0	<0.01	<0.01	<0.01	<0.01	14.98	8.38	5.84	4.58	8.81	4.38	3.42	2.96
High-frequency cetacean																
Harbor porpoise	7.01	3.84	2.30	1.69	0.66	0.38	0.17	0.15	14.63	8.51	5.48	4.53	107.40	96.58	86.45	82.28
Pinnipeds in water																
Gray seal	3.29	1.54	1.01	0.56	0.01	0.01	0.01	0.01	15.83	9.33	6.05	4.92	13.02	7.06	4.31	4.07
Harbor seal	3.31	1.38	0.63	0.19	0.07	<0.01	<0.01	<0.01	15.37	8.77	6.03	4.78	12.97	6.97	4.15	3.63
Harp seal	3.07	1.14	0.41	0.20	0	0	0	0	15.69	8.94	5.97	4.86	12.86	7.03	4.23	3.83

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-34. 12 m monopile, 6000 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	15.60	8.48	5.19	3.84	0.03	0.02	0.02	0.02	15.71	9.14	5.95	4.82	15.82	9.19	5.95	4.80
Minke whale	10.39	5.19	2.85	1.97	0.02	0.02	0.02	0.02	14.34	8.33	5.41	4.37	70.45	37.95	29.15	25.62
Humpback whale	16.38	9.24	5.67	4.48	0.03	0.01	0.01	0.01	15.64	9.01	5.89	4.73	15.72	9.05	5.90	4.81
North Atlantic right whale[c]	13.06	6.90	3.80	2.83	0.06	0.02	0.02	0.02	14.22	8.19	5.59	4.40	14.38	8.33	5.61	4.43
Sei whale[c]	13.19	7.17	3.97	2.87	0.03	0.02	0.02	0.02	15.30	8.73	5.62	4.56	78.14	44.10	32.32	28.00
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0.02	0.02	0.02	0.02	14.21	8.19	5.37	4.28	8.63	4.19	3.23	2.92
Atlantic spotted dolphin	0	0	0	0	0.02	0.02	0.02	0.02	15.48	9.07	5.59	4.42	9.17	4.11	2.96	2.72
Short-beaked common dolphin	0.02	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.02	14.09	8.13	5.47	4.35	8.73	4.16	3.29	3.04
Bottlenose dolphin	0.18	0	0	0	0.01	0.01	0.01	0.01	13.32	7.37	4.26	3.55	7.88	3.51	2.85	2.50
Risso's dolphin	0.03	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02	15.06	8.75	5.64	4.59	9.21	4.45	3.33	3.00
Long-finned pilot whale	0	0	0	0	0.02	0.02	0.02	0.02	14.45	8.40	5.44	4.27	8.71	4.15	3.19	2.87
Short-finned pilot whale	0.02	0	0	0	0.02	0.02	0.02	0.02	14.49	8.26	5.35	4.27	8.71	4.12	3.22	2.98
Sperm whale[c]	0.28	0	0	0	0.01	0.01	0.01	0.01	14.85	8.50	5.55	4.38	8.78	4.24	3.35	2.97
High-frequency cetacean																
Harbor porpoise	7.49	4.04	2.47	1.86	0.65	0.39	0.20	0.15	14.46	8.36	5.54	4.46	111.64	100.40	91.07	87.37
Pinnipeds in water																
Gray seal	3.97	1.80	1.22	0.72	0.01	0.01	0.01	0.01	15.75	9.14	6.02	4.94	13.05	7.02	4.29	3.99
Harbor seal	4.42	1.62	0.67	0.59	0.07	0.01	0.01	0.01	15.12	8.78	5.75	4.63	12.70	6.65	4.15	3.52
Harp seal	3.70	1.24	0.52	0.35	0.05	0.02	0.02	0.02	15.44	8.84	5.86	4.73	12.72	6.92	4.24	3.62

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-35. 13 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	8.78	4.35	2.56	1.90	0.02	0	0	0	12.46	6.94	4.29	3.88	12.46	6.94	4.24	3.88
Minke whale	6.30	2.96	1.50	1.17	0	0	0	0	11.63	6.51	3.98	3.63	48.40	32.31	24.76	21.91
Humpback whale	9.40	4.80	2.87	2.27	0.03	<0.01	<0.01	<0.01	12.35	6.96	4.26	3.74	12.37	6.91	4.25	3.74
North Atlantic right whale[c]	8.05	3.85	2.26	1.54	0.03	<0.01	<0.01	<0.01	12.11	6.64	4.11	3.70	12.21	6.64	4.17	3.70
Sei whale[c]	7.73	3.56	1.66	1.25	0.03	<0.01	<0.01	<0.01	11.98	6.81	4.21	3.69	61.51	35.18	25.73	22.45
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0	0	0	0	11.47	6.22	3.95	3.58	5.68	3.18	2.55	2.27
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	11.50	6.04	4.01	3.76	5.34	3.30	2.64	2.59
Short-beaked common dolphin	0	0	0	0	<0.01	0	0	0	11.57	6.47	3.99	3.48	6.15	3.32	2.64	2.31
Bottlenose dolphin	0	0	0	0	0	0	0	0	10.98	6.02	3.53	3.01	5.73	2.97	2.30	1.97
Risso's dolphin	0.01	<0.01	<0.01	0	<0.01	0	0	0	12.15	6.74	4.26	3.77	6.28	3.17	2.62	2.39
Long-finned pilot whale	0	0	0	0	0	0	0	0	11.69	6.39	4.08	3.52	5.96	3.24	2.68	2.22
Short-finned pilot whale	0	0	0	0	<0.01	<0.01	<0.01	<0.01	11.82	6.48	4.10	3.53	6.04	3.35	2.68	2.40
Sperm whale[c]	0	0	0	0	0	0	0	0	11.88	6.70	4.15	3.64	6.17	3.42	2.61	2.36
High-frequency cetacean																
Harbor porpoise	5.13	2.50	1.51	1.07	0.59	0.25	0.23	0.19	11.79	6.58	4.00	3.63	106.34	97.07	85.66	79.37
Pinnipeds in water																
Gray seal	2.16	0.96	0.59	0.12	0	0	0	0	12.56	7.04	4.53	4.08	9.67	4.84	3.73	3.30
Harbor seal	1.94	0.67	0.16	0	0	0	0	0	12.21	6.95	4.25	3.73	9.48	4.56	3.31	3.17
Harp seal	1.85	0.65	0.09	0	0	0	0	0	12.31	7.03	4.30	3.75	9.48	4.89	3.40	3.07

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-36. 13 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	10.98	5.37	3.14	2.24	0.02	0	0	0	12.35	6.89	4.20	3.84	12.35	6.89	4.20	3.84
Minke whale	7.37	3.43	1.65	1.20	0	0	0	0	11.51	6.31	3.82	3.55	49.23	32.45	24.59	21.59
Humpback whale	11.59	5.76	3.66	2.79	0.05	<0.01	<0.01	<0.01	12.28	6.80	4.26	3.83	12.30	6.80	4.26	3.84
North Atlantic right whale[c]	9.52	4.53	2.53	1.79	0.02	<0.01	<0.01	<0.01	11.65	6.42	4.03	3.51	11.76	6.46	4.07	3.55
Sei whale[c]	9.48	4.50	2.31	1.62	0.03	<0.01	<0.01	<0.01	11.87	6.64	3.96	3.62	62.48	35.38	25.94	22.40
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	0	0	0	0	11.12	6.09	3.84	3.31	5.76	3.14	2.43	2.20
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	11.23	5.97	3.85	3.28	5.28	3.01	2.55	2.14
Short-beaked common dolphin	0	0	0	0	<0.01	0	0	0	11.28	6.23	3.95	3.43	5.96	3.27	2.65	2.31
Bottlenose dolphin	0	0	0	0	<0.01	<0.01	<0.01	<0.01	10.63	5.75	3.37	2.91	5.37	2.84	2.22	2.10
Risso's dolphin	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	11.90	6.48	4.03	3.64	6.24	3.38	2.64	2.42
Long-finned pilot whale	0	0	0	0	0	0	0	0	11.51	6.25	3.90	3.51	5.80	3.23	2.63	2.23
Short-finned pilot whale	0	0	0	0	<0.01	<0.01	<0.01	<0.01	11.58	6.32	3.95	3.50	5.95	3.36	2.64	2.31
Sperm whale[c]	0.30	0	0	0	<0.01	0	0	0	11.77	6.64	4.08	3.60	6.18	3.34	2.58	2.29
High-frequency cetacean																
Harbor porpoise	5.48	2.83	1.50	1.20	0.61	0.31	0.21	0.19	11.46	6.62	3.95	3.58	107.93	98.23	85.98	79.39
Pinnipeds in water																
Gray seal	2.55	1.28	0.57	0.32	0	0	0	0	12.49	7.04	4.52	4.12	9.67	4.82	3.67	3.29
Harbor seal	2.69	0.69	0.19	0.08	0	0	0	0	12.02	6.80	4.25	3.70	9.31	4.53	3.34	3.20
Harp seal	2.22	0.67	0.32	0.05	0.06	0	0	0	12.11	6.87	4.29	3.73	9.40	4.66	3.49	3.16

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-37. 13 m monopile, 5000 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	13.83	7.00	3.96	3.01	0.03	0.01	<0.01	<0.01	12.27	6.86	4.23	3.69	12.32	6.84	4.23	3.70
Minke whale	8.44	3.84	1.90	1.47	0.01	<0.01	<0.01	<0.01	11.29	6.25	3.85	3.49	49.86	32.38	24.53	21.38
Humpback whale	14.35	7.61	4.42	3.45	0.05	<0.01	<0.01	<0.01	12.17	6.84	4.24	3.74	12.24	6.86	4.22	3.74
North Atlantic right whale[c]	10.90	5.28	2.83	2.19	0.02	<0.01	<0.01	<0.01	11.56	6.23	3.98	3.47	11.67	6.30	4.02	3.51
Sei whale[c]	11.69	5.39	3.13	2.04	0.04	<0.01	<0.01	<0.01	11.86	6.71	4.04	3.53	62.70	35.35	26.00	22.37
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0	0	0	0	<0.01	<0.01	<0.01	<0.01	11.15	6.07	3.84	3.37	5.67	3.22	2.52	2.26
Atlantic spotted dolphin	0	0	0	0	<0.01	<0.01	0	0	11.40	6.09	4.07	3.46	5.48	3.20	2.53	2.20
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	<0.01	<0.01	<0.01	<0.01	10.99	5.95	3.92	3.45	5.76	3.22	2.62	2.28
Bottlenose dolphin	0	0	0	0	<0.01	<0.01	<0.01	<0.01	10.18	4.94	3.21	2.84	4.63	2.83	2.19	1.94
Risso's dolphin	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	11.79	6.49	4.00	3.54	6.18	3.37	2.62	2.34
Long-finned pilot whale	0	0	0	0	<0.01	<0.01	<0.01	<0.01	11.20	6.10	3.88	3.42	5.72	3.21	2.59	2.17
Short-finned pilot whale	0	0	0	0	<0.01	<0.01	<0.01	<0.01	11.41	6.30	3.89	3.45	5.77	3.22	2.59	2.31
Sperm whale[c]	0.30	0	0	0	<0.01	<0.01	0	0	11.78	6.50	3.93	3.52	5.94	3.22	2.72	2.33
High-frequency cetacean																
Harbor porpoise	6.04	3.11	1.75	1.27	0.61	0.30	0.19	0.17	11.33	6.42	3.95	3.51	112.74	102.05	89.43	83.15
Pinnipeds in water																
Gray seal	3.11	1.49	0.72	0.41	0.08	0	0	0	12.46	6.94	4.51	4.07	9.56	4.83	3.65	3.24
Harbor seal	3.10	0.93	0.51	0.15	0.06	<0.01	<0.01	<0.01	11.78	6.53	4.16	3.74	9.19	4.53	3.29	2.97
Harp seal	2.74	0.88	0.32	0.05	0.06	<0.01	<0.01	<0.01	12.04	6.87	4.25	3.54	9.36	4.69	3.41	3.07

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-38. 4 m pin pile, 3500 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species	Injury								Behavior							
	L_E				L_{pk}				L_p [a]				L_p [b]			
	Attenuation (dB)								Attenuation (dB)							
	0	6	10	12	0	6	10	12	0	6	10	12	0	6	10	12
Low-frequency cetaceans																
Fin whale[c]	13.29	6.84	4.07	3.14	0.02	<0.01	<0.01	0	8.47	4.44	3.56	3.29	8.49	4.46	3.58	3.30
Minke whale	7.87	3.32	1.83	1.26	0.01	<0.01	0	0	8.00	4.18	3.34	3.20	37.71	25.58	19.07	16.46
Humpback whale	13.83	7.50	4.49	3.25	0.02	0	0	0	8.44	4.47	3.56	3.28	8.44	4.47	3.57	3.28
North Atlantic right whale[c]	10.37	4.80	2.54	1.74	0.02	<0.01	0	0	8.15	4.26	3.34	3.16	8.23	4.27	3.38	3.19
Sei whale[c]	10.90	5.27	2.84	1.89	<0.01	<0.01	0	0	8.22	4.29	3.39	3.23	40.08	26.61	19.61	16.97
Mid-frequency cetaceans																
Atlantic white-sided dolphin	0.01	0.01	0.01	0.01	0	0	0	0	8.02	4.17	3.27	3.12	4.43	3.18	2.33	1.97
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	8.40	4.13	3.26	3.17	4.39	3.22	2.27	2.01
Short-beaked common dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	7.98	4.18	3.34	3.15	4.49	3.25	2.41	2.07
Bottlenose dolphin	0.08	0.01	0.01	0	0	0	0	0	6.44	3.45	2.87	2.59	3.79	2.76	1.90	1.50
Risso's dolphin	0.01	0.01	0.01	0.01	<0.01	0	0	0	8.27	4.33	3.38	3.16	4.59	3.24	2.42	2.06
Long-finned pilot whale	<0.01	<0.01	<0.01	0	0	0	0	0	7.96	4.16	3.30	3.10	4.49	3.17	2.32	1.91
Short-finned pilot whale	0.01	0.01	0	0	0	0	0	0	7.95	4.12	3.37	3.16	4.40	3.23	2.38	1.96
Sperm whale[c]	<0.01	<0.01	<0.01	0	0	0	0	0	8.17	4.34	3.36	3.11	4.61	3.20	2.35	1.89
High-frequency cetacean																
Harbor porpoise	5.90	3.10	1.77	1.29	0.53	0.26	0.10	0.10	8.15	4.32	3.38	3.21	96.13	93.76	65.51	54.74
Pinnipeds in water																
Gray seal	4.35	2.19	1.31	0.96	0	0	0	0	8.52	4.54	3.49	3.38	6.83	3.84	3.30	2.91
Harbor seal	3.33	1.06	0.32	0.12	0.06	<0.01	0	0	8.33	4.24	3.44	3.12	6.68	3.68	3.08	2.70
Harp seal	2.85	1.03	0.28	0.15	0.07	0	0	0	8.44	4.45	3.49	3.24	6.77	3.84	3.21	2.81

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

H.2.5. Sea Turtle Exposure Ranges

Table H-39. 12 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.72	0.07	0.02	0	0	0	0	0	2.91	1.85	0.82	0.69
Leatherback turtle[a]	0.98	0.04	0	0	<0.01	<0.01	<0.01	<0.01	2.76	1.49	0.78	0.44
Loggerhead turtle	0.12	0.02	0	0	0.02	0.02	0.02	0.02	2.65	1.17	0.75	0.38
Green turtle	1.03	0.32	0.02	0.02	0.01	0.01	0.01	0.01	3.19	2.06	1.03	0.77

[a] Listed as Endangered under the ESA.

Table H-40. 12 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.60	0.17	0.02	0	0.02	0.02	0.02	0.02	3.05	1.92	0.83	0.60
Leatherback turtle[a]	0.58	0.15	0.02	0	0.02	0.02	0.02	0.02	2.67	1.50	0.68	0.65
Loggerhead turtle	0.40	0.03	0	0	0.01	0.01	0.01	0.01	2.53	1.48	0.58	0.40
Green turtle	1.38	0.39	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.21	1.97	1.17	0.72

[a] Listed as Endangered under the ESA.

Table H-41. 12 m monopile, 5000 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.87	0.20	0.03	0.02	0.02	0.02	0.02	0.02	2.97	1.84	0.85	0.60
Leatherback turtle[a]	0.81	0.13	0.02	0	0.02	0.02	0.02	0.02	2.61	1.46	0.68	0.65
Loggerhead turtle	0.39	0.03	<0.01	0	0.02	0.02	0.02	0.02	2.47	1.44	0.69	0.46
Green turtle	1.82	0.50	0.02	0.02	<0.01	<0.01	<0.01	<0.01	3.16	1.97	1.30	0.74

[a] Listed as Endangered under the ESA.

Table H-42. 12 m monopile, 6000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.97	0.25	0.07	0.02	0	0	0	0	3.53	2.43	1.66	0.88
Leatherback turtle[a]	1.21	0.06	0.03	0	<0.01	<0.01	<0.01	<0.01	3.12	2.23	1.39	0.91
Loggerhead turtle	0.75	0.09	0.02	<0.01	0.02	0.02	0.02	0.02	3.42	2.49	1.13	1.06
Green turtle	1.87	0.53	0.16	0.07	0.01	0.01	0	0	3.78	2.65	1.97	1.44

[a] Listed as Endangered under the ESA.

Table H-43. 12 m monopile, 6000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	1.12	0.25	0.02	0.02	0.02	0.02	0.02	0.02	3.57	2.66	1.77	1.31
Leatherback turtle[a]	1.27	0.15	0.17	0.02	0.02	0.02	0.02	0.02	3.24	2.32	1.35	1.12
Loggerhead turtle	0.63	0.14	<0.01	<0.01	0.01	0.01	0.01	0.01	3.05	2.24	1.20	0.85
Green turtle	2.24	0.77	0.15	0.03	<0.01	<0.01	<0.01	<0.01	3.65	2.89	1.83	1.49

[a] Listed as Endangered under the ESA.

Table H-44. 12 m monopile, 6000 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	1.32	0.30	0.09	0.03	0.02	0.02	0.02	0.02	3.51	2.42	1.67	1.31
Leatherback turtle[a]	1.78	0.39	0.15	0.03	0.02	0.02	0.02	0.02	3.20	2.29	1.35	1.08
Loggerhead turtle	0.71	0.15	0.02	<0.01	0.02	0.02	0.02	0.02	3.04	1.98	1.34	0.84
Green turtle	2.71	0.88	0.22	0.03	<0.01	<0.01	<0.01	<0.01	3.56	2.79	1.97	1.52

[a] Listed as Endangered under the ESA.

Table H-45. 13 m monopile, 5000 kJ hammer, one pile per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.60	0.14	0	0	<0.01	<0.01	<0.01	<0.01	2.83	1.78	1.19	0.69
Leatherback turtle[a]	0.58	0.10	0	0	0	0	0	0	2.78	1.37	0.69	0.51
Loggerhead turtle	0.29	0.01	<0.01	0	0	0	0	0	2.54	1.58	0.62	0.55
Green turtle	1.11	0.29	<0.01	<0.01	0	0	0	0	3.27	2.34	1.15	0.98

[a] Listed as Endangered under the ESA.

Table H-46. 13 m monopile, 5000 kJ hammer, two piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.68	0.17	0.02	0	<0.01	<0.01	<0.01	<0.01	2.87	1.79	1.12	0.87
Leatherback turtle[a]	0.56	0.16	0.02	0	0	0	0	0	2.77	1.47	0.98	0.51
Loggerhead turtle	0.37	0.03	<0.01	0	0	0	0	0	2.53	1.66	0.65	0.44
Green turtle	1.59	0.38	0.04	<0.01	0	0	0	0	3.20	2.19	1.23	0.96

[a] Listed as Endangered under the ESA.

Table H-47. 13 m monopile, 5000 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.94	0.21	0.03	0.02	<0.01	<0.01	<0.01	<0.01	2.80	1.76	1.10	0.70
Leatherback turtle[a]	1.30	0.18	0.03	<0.01	<0.01	<0.01	0	0	2.75	1.47	0.90	0.61
Loggerhead turtle	0.40	0.03	<0.01	0	0	0	0	0	2.57	1.58	0.76	0.61
Green turtle	2.09	0.55	0.07	0.02	<0.01	<0.01	<0.01	<0.01	3.10	2.14	1.34	0.95

[a] Listed as Endangered under the ESA.

Table H-48. 4 m pin pile, 3500 kJ hammer, four piles per day: Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury								Behavior			
	L_E				L_{pk}				L_p			
	Attenuation (dB)								Attenuation (dB)			
	0	6	10	12	0	6	10	12	0	6	10	12
Kemp's ridley turtle[a]	0.68	0.14	0.04	0	0	0	0	0	2.34	1.09	0.47	0.33
Leatherback turtle[a]	0.71	0.07	0.03	0	0	0	0	0	2.17	0.98	0.45	0.33
Loggerhead turtle	0.44	0.02	0	0	0	0	0	0	2.15	0.85	0.44	0.27
Green turtle	1.52	0.27	0.03	0.02	0	0	0	0	2.76	1.32	0.58	0.38

[a] Listed as Endangered under the ESA.

H.3. Animat Seeding Areas

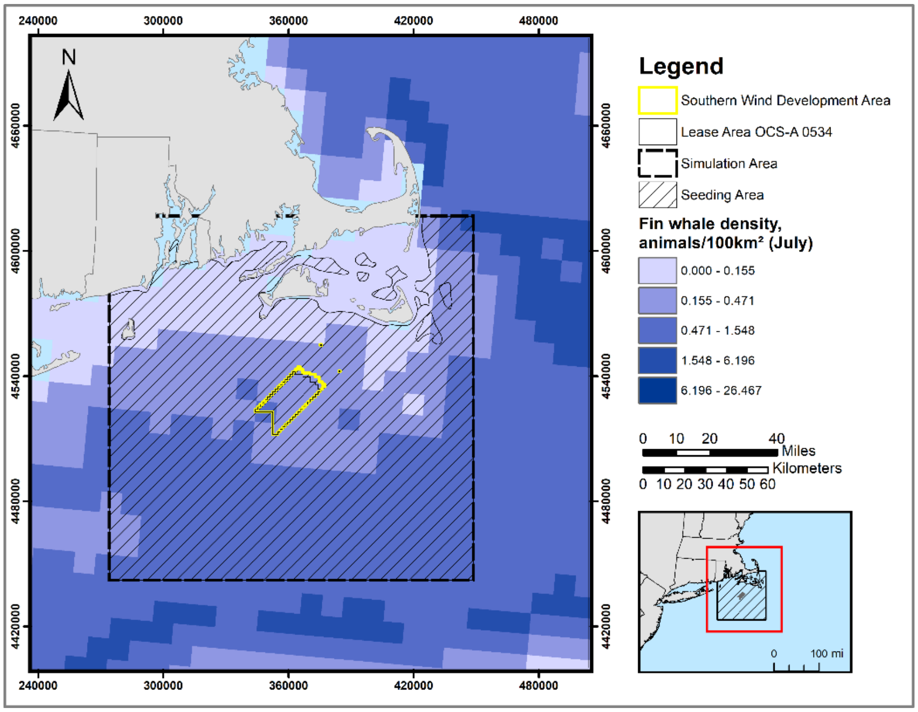

Figure H-1. Map of fin whale seeding area range for July, the month with the highest density.

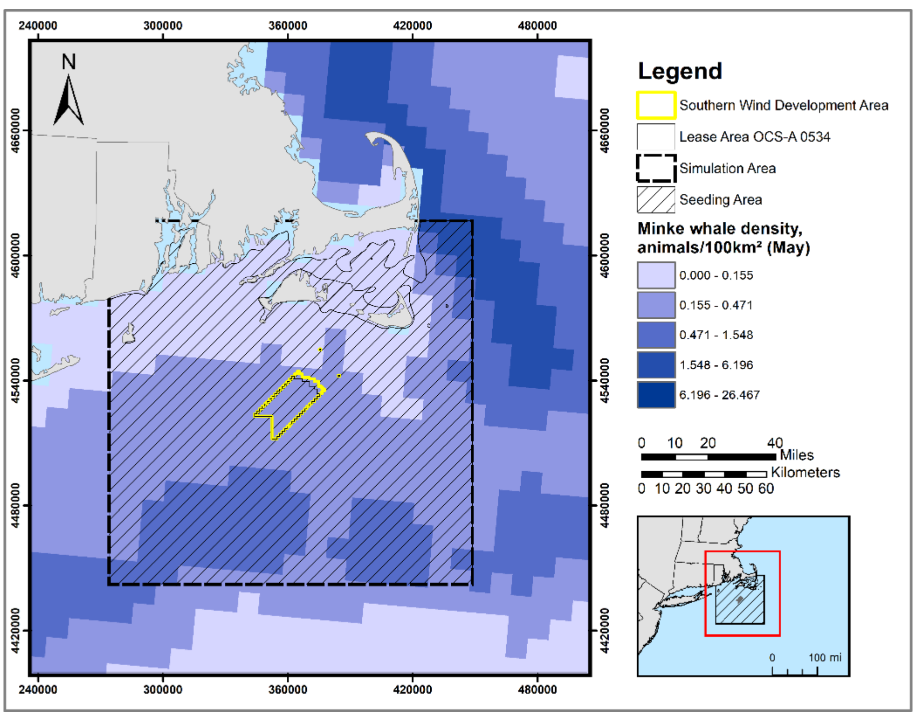

Figure H-2. Map of minke whale seeding area range for May, the month with the highest density.

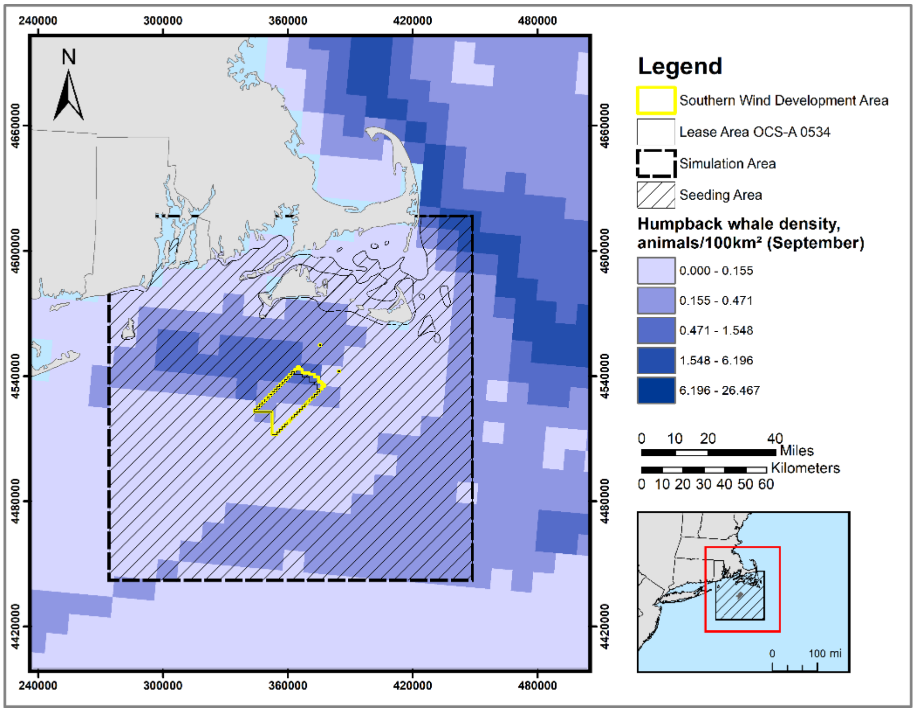

Figure H-3. Map of humpback whale seeding area range for September, the month with the highest density.

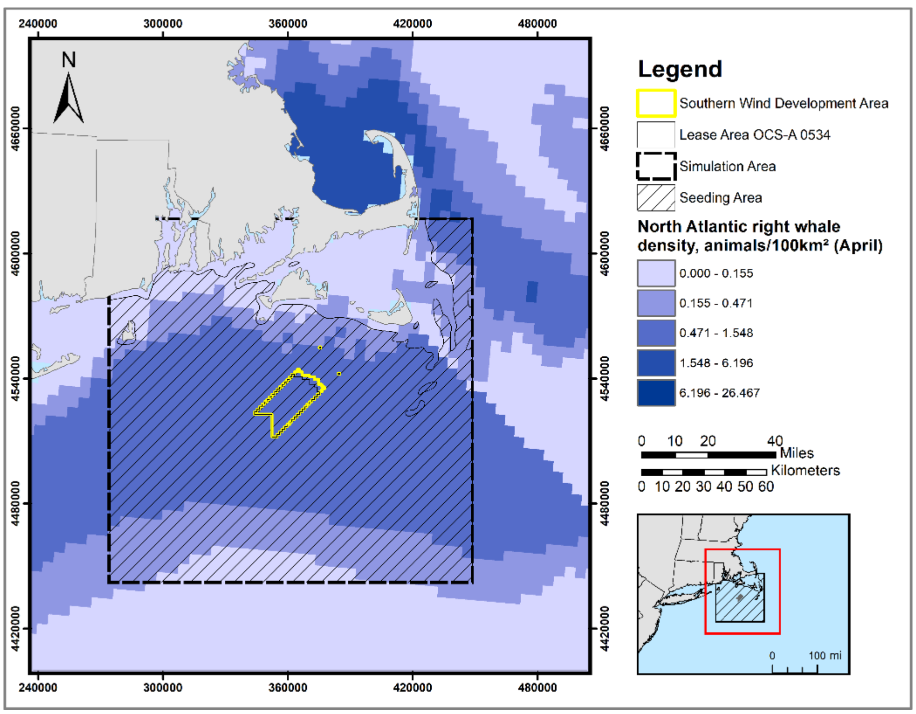

Figure H-4. Map of NARW seeding area range for April, the month with the highest density.

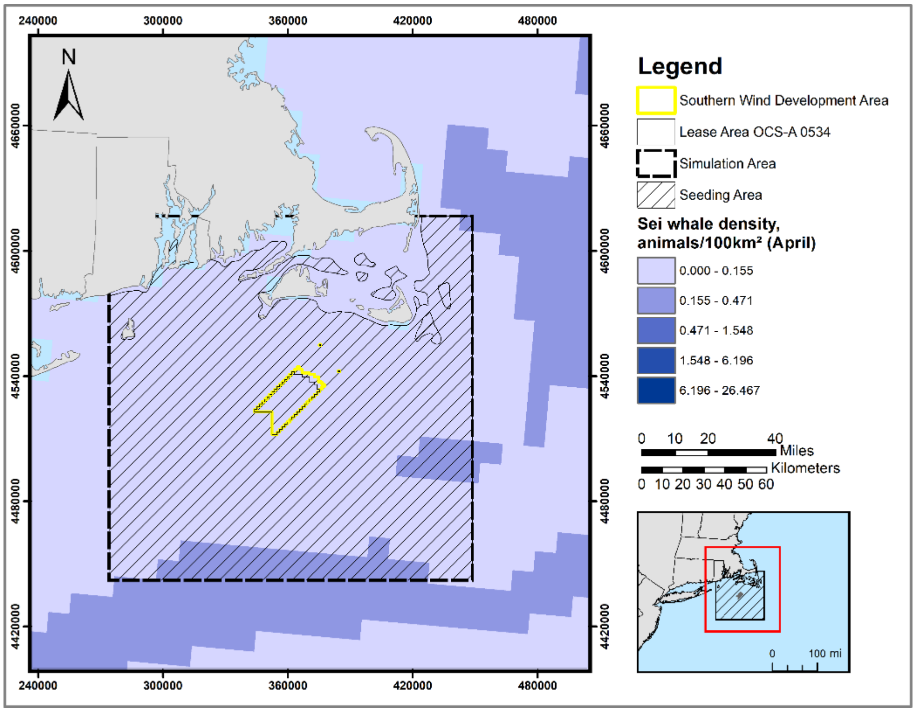

Figure H-5. Map of sei whale seeding area range for April, the month with the highest density.

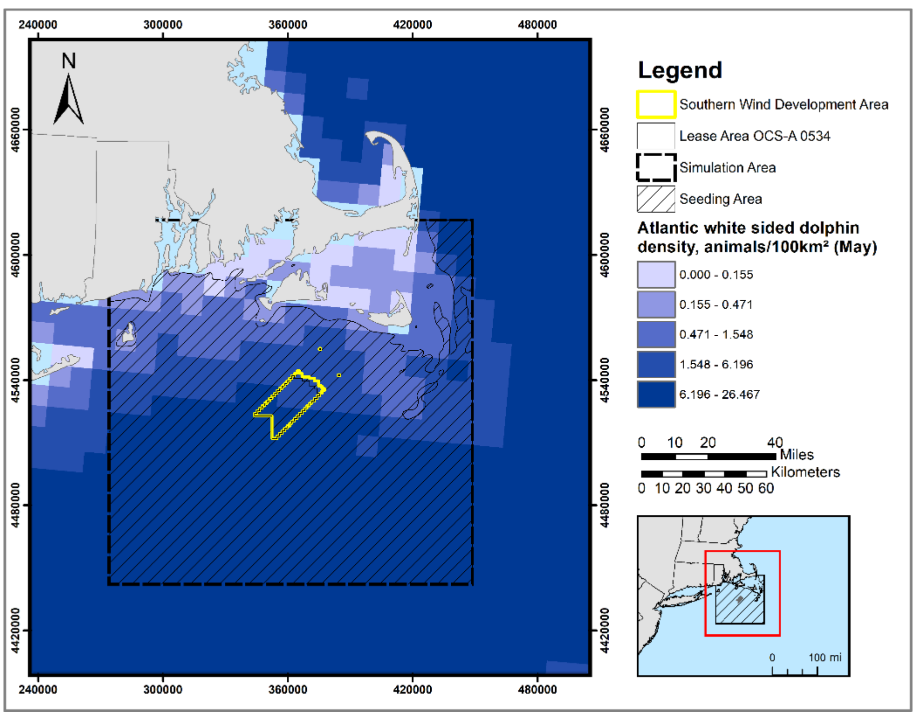

Figure H-6. Map of Atlantic white-sided dolphin seeding area range for May, the month with the highest density.

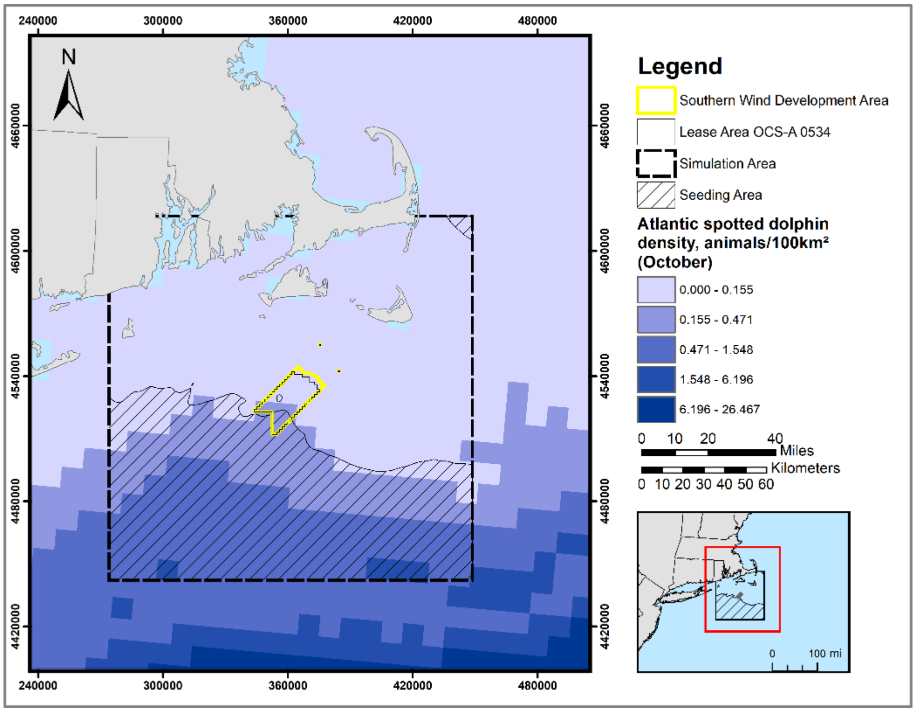

Figure H-7. Map of Atlantic spotted dolphin seeding area range for October, the month with the highest density.

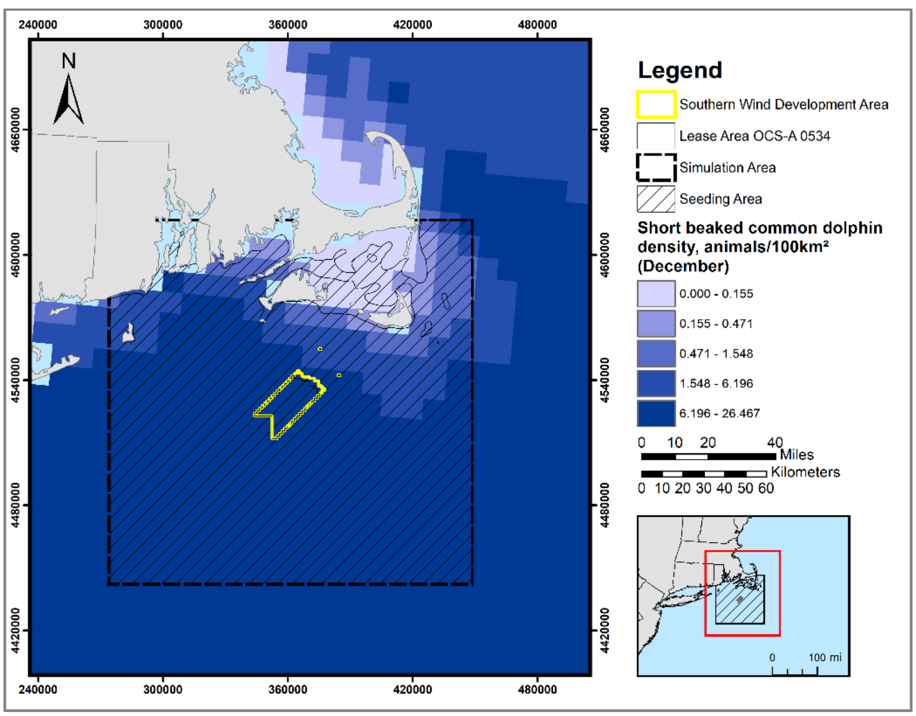

Figure H-8. Map of short-beaked common dolphin seeding area range for December, the month with the highest density.

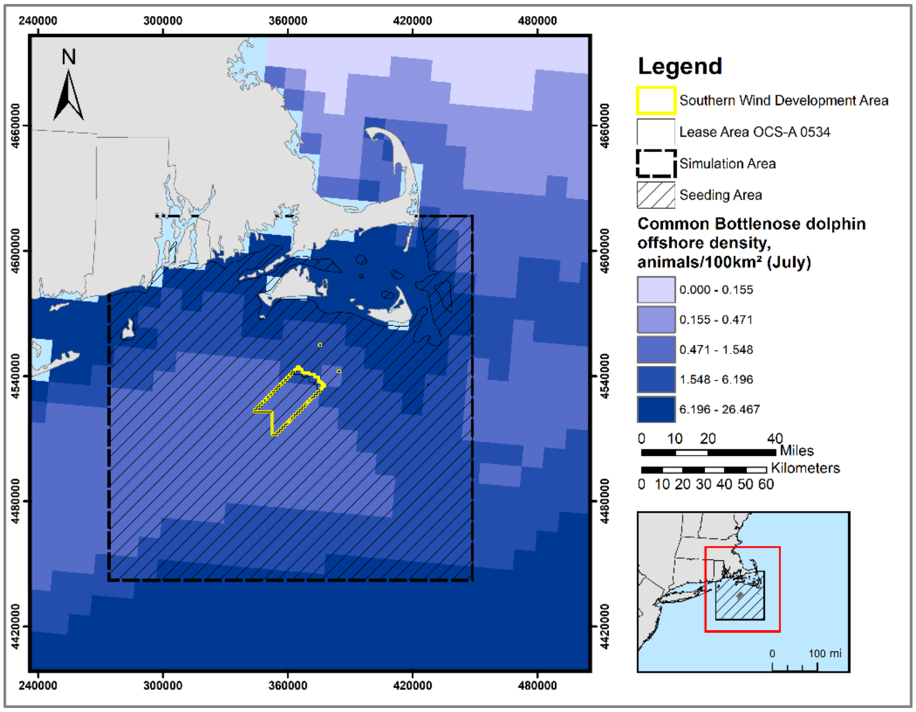

Figure H-9. Map of bottlenose dolphin seeding area range for July, the month with the highest density.

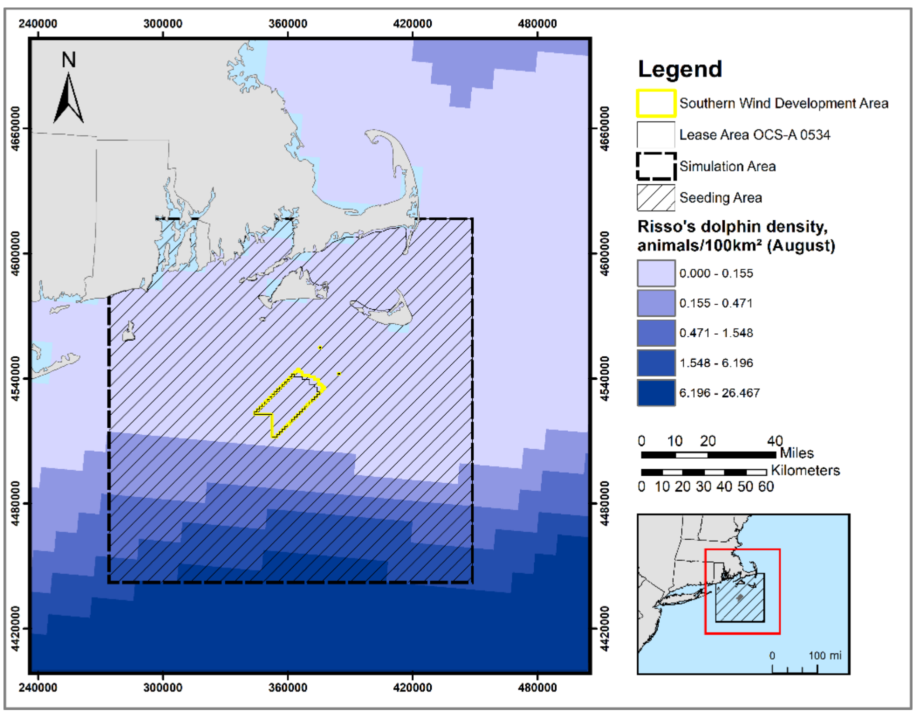

Figure H-10. Map of Risso's dolphin seeding area range for August, the month with the highest density.

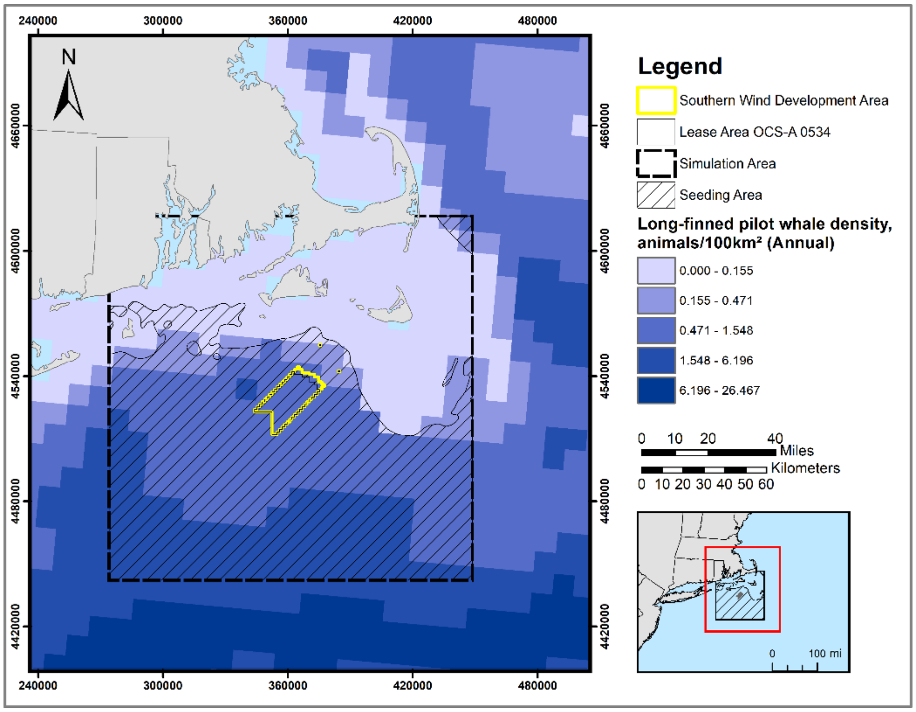

Figure H-11. Map of long-finned pilot whale seeding area range.

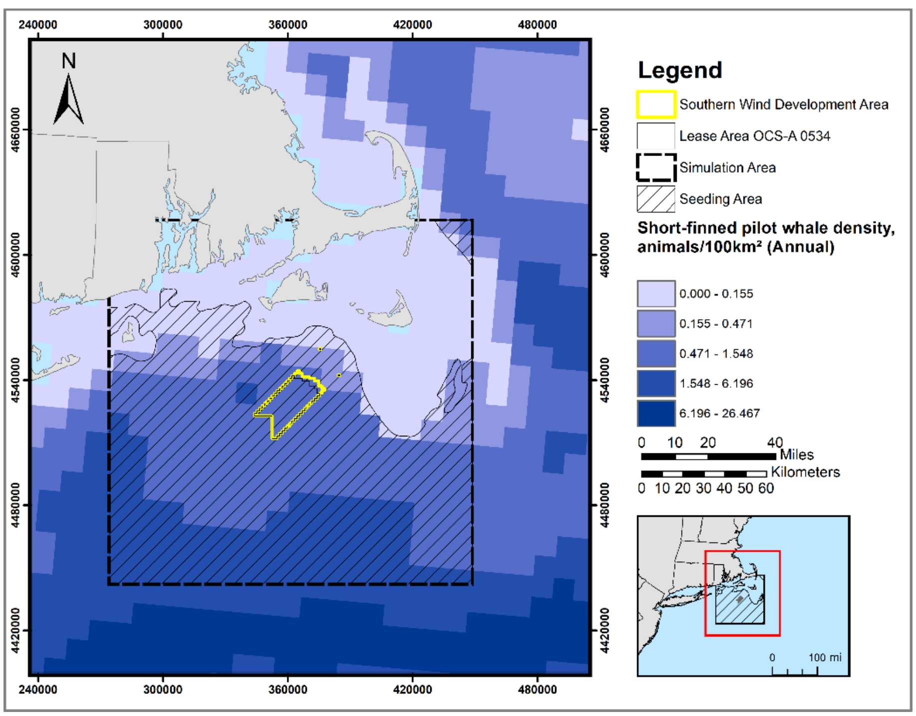

Figure H-12. Map of short-finned pilot whale seeding area range.

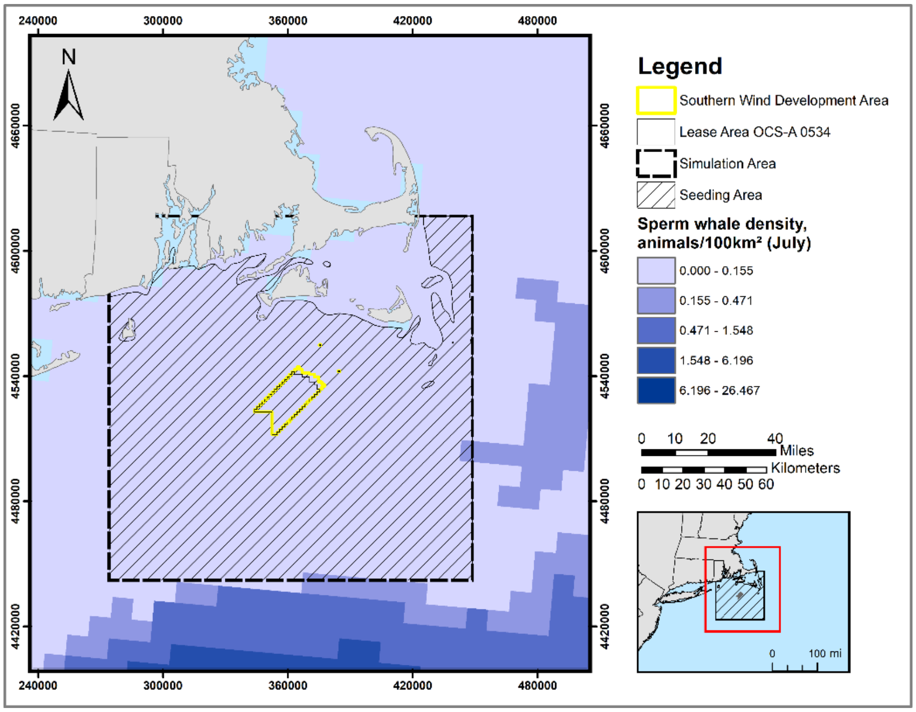

Figure H-13. Map of sperm whale seeding area range for July, the month with the highest density.

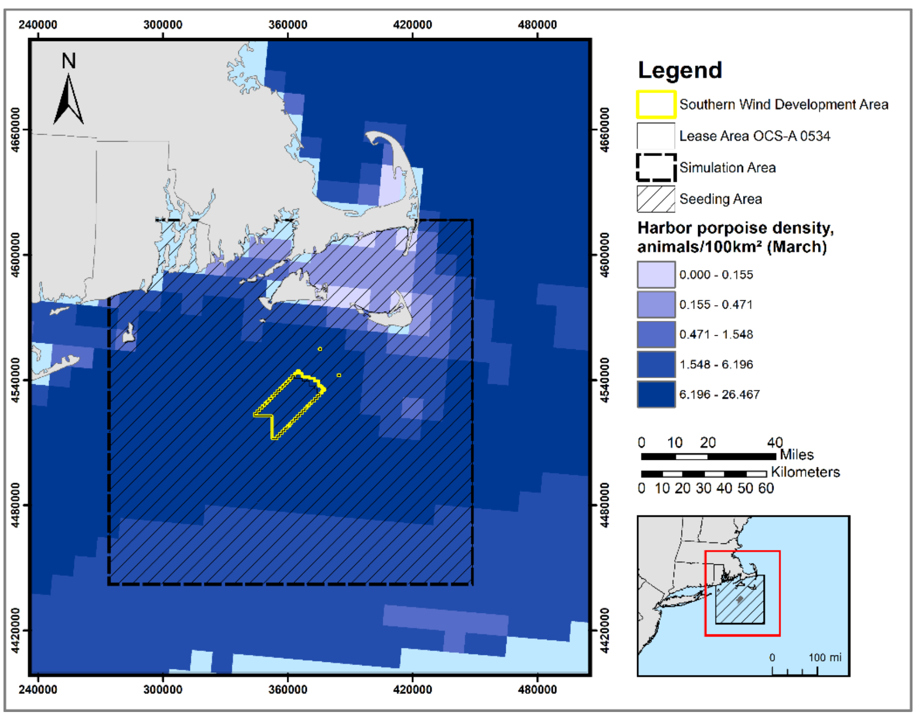

Figure H-14. Map of harbor porpoise seeding area range for March, the month with the highest density.

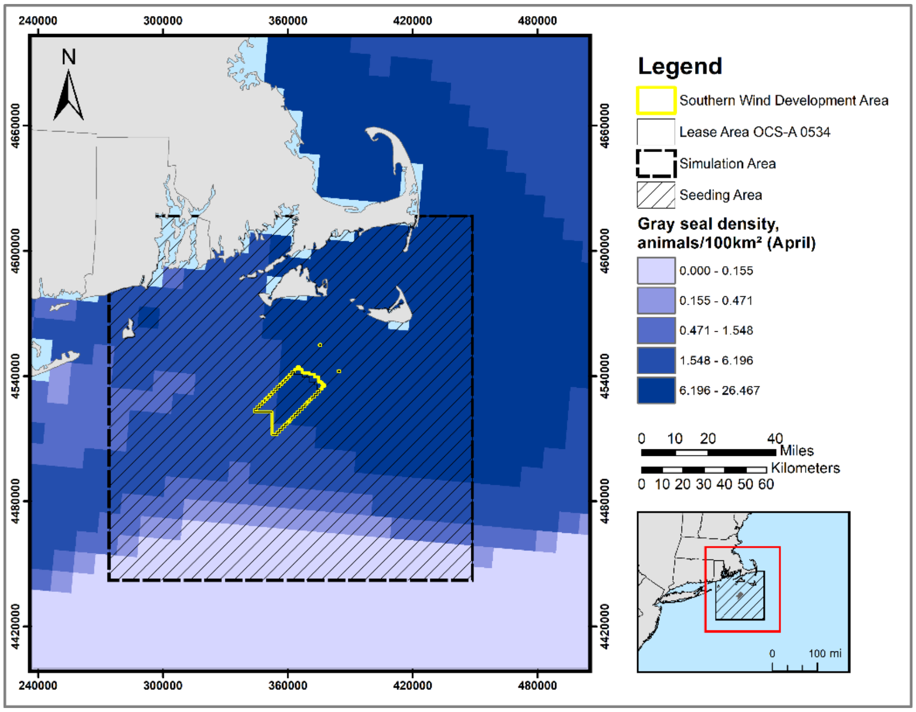

Figure H-15. Map of gray seal seeding area range for April, the month with the highest density.

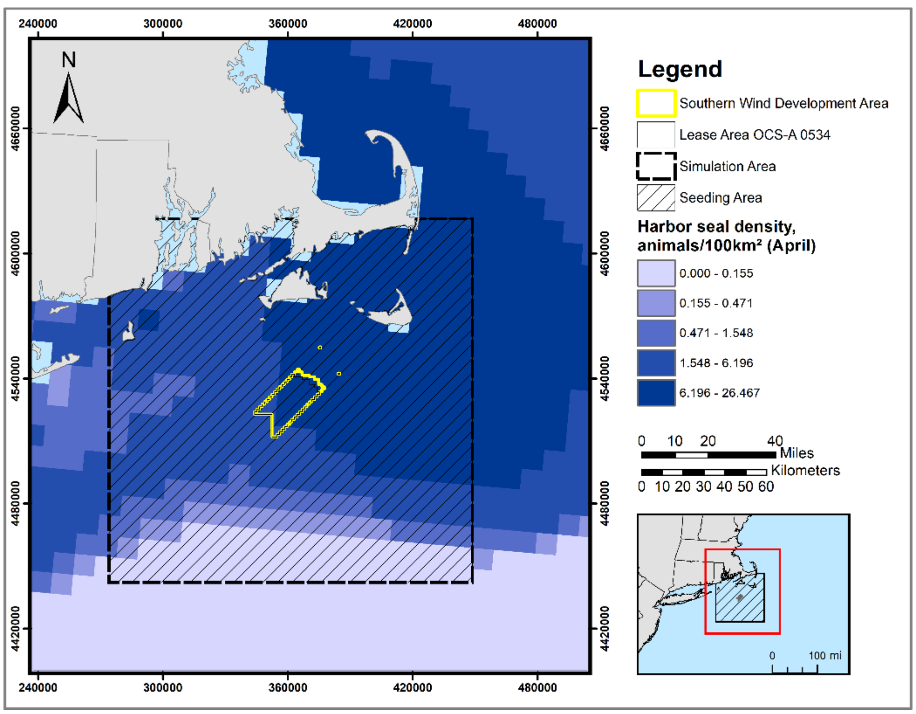

Figure H-16. Map of harbor seal seeding area range for April, the month with the highest density.

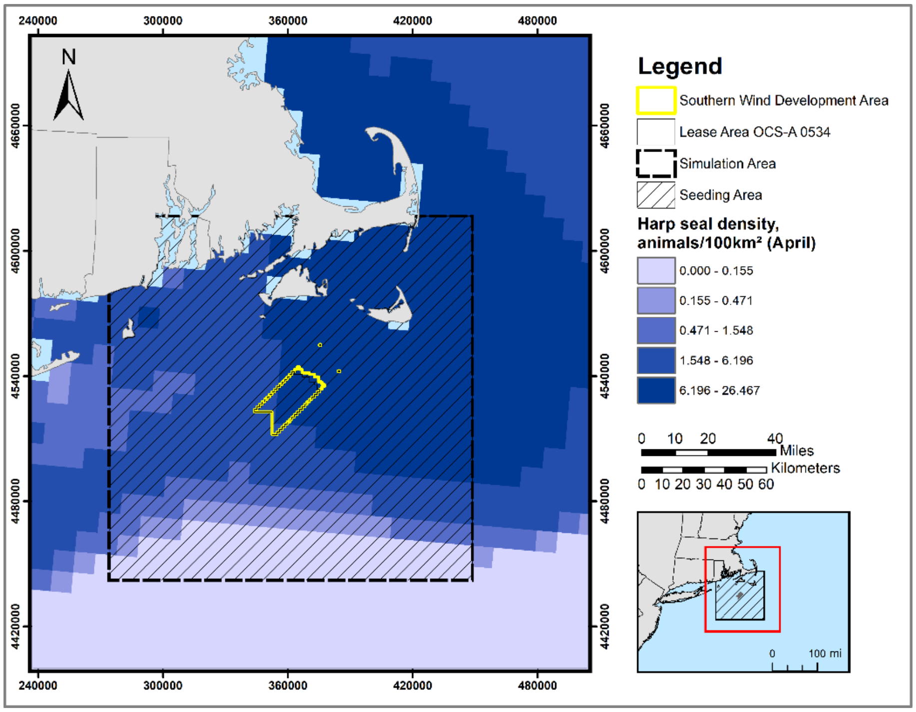

Figure H-17. Map of harp seal seeding area range for April, the month with the highest density

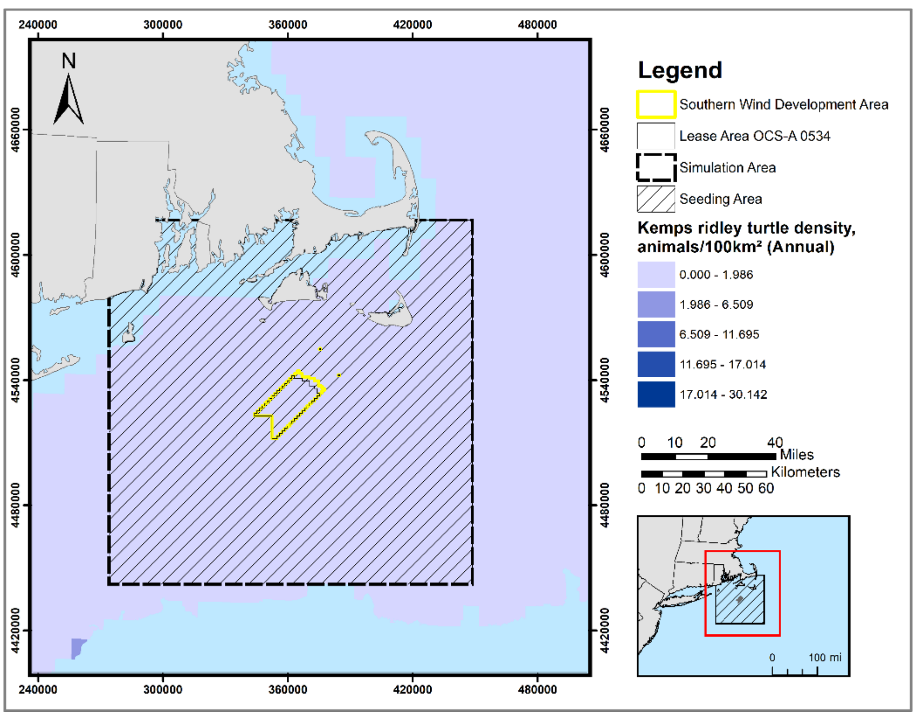

Figure H-18. Map of Kemp's ridley sea turtle seeding area range (DoN 2017). Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

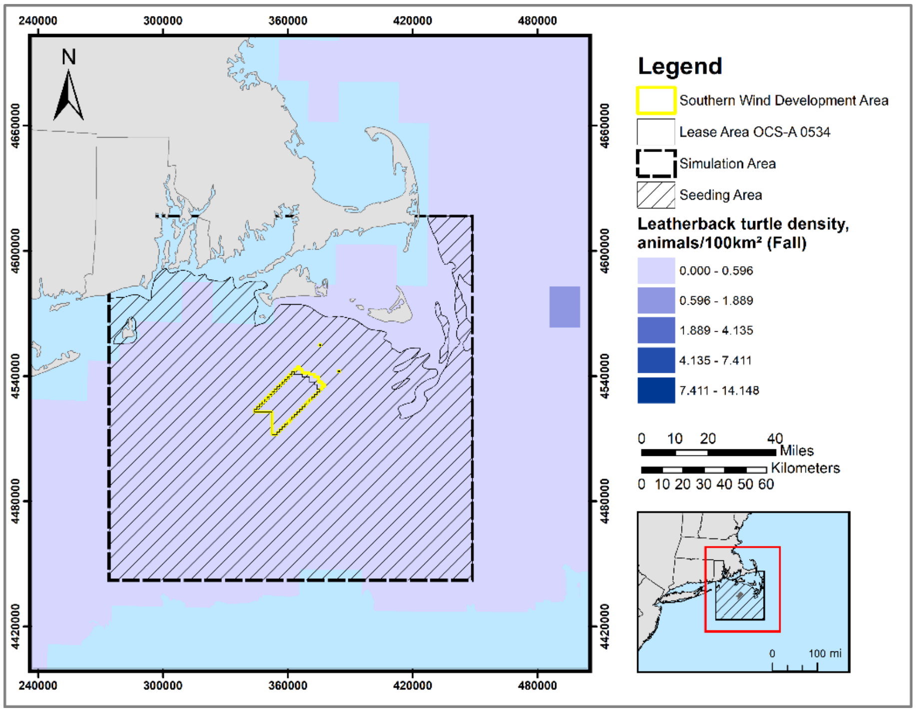

Figure H-19. Map of leatherback sea turtle seeding area range (DoN 2017). Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

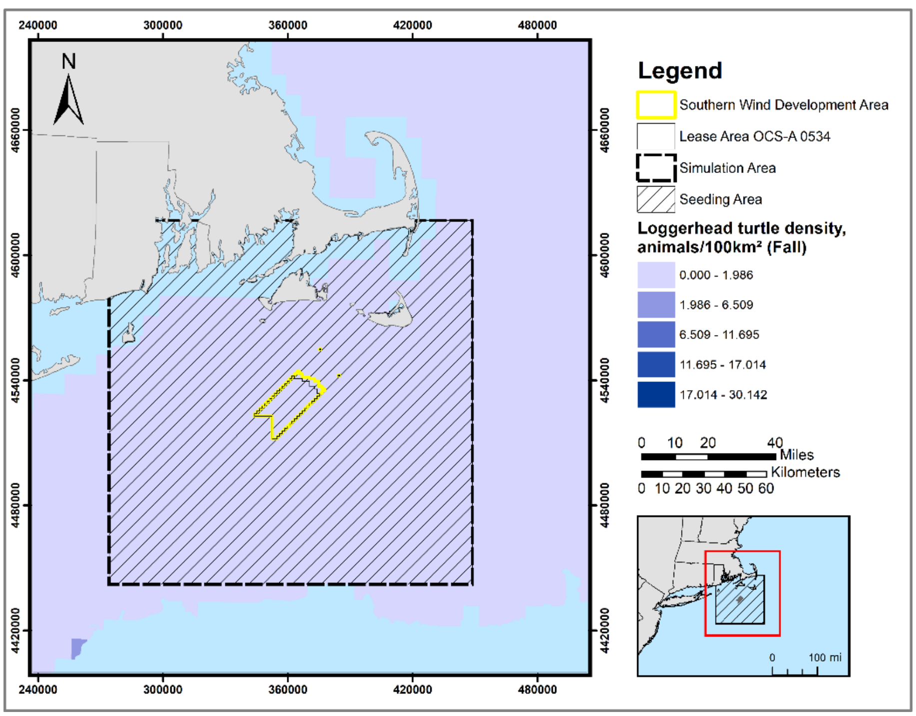

Figure H-20. Map of loggerhead sea turtle seeding area range (DoN 2017). Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

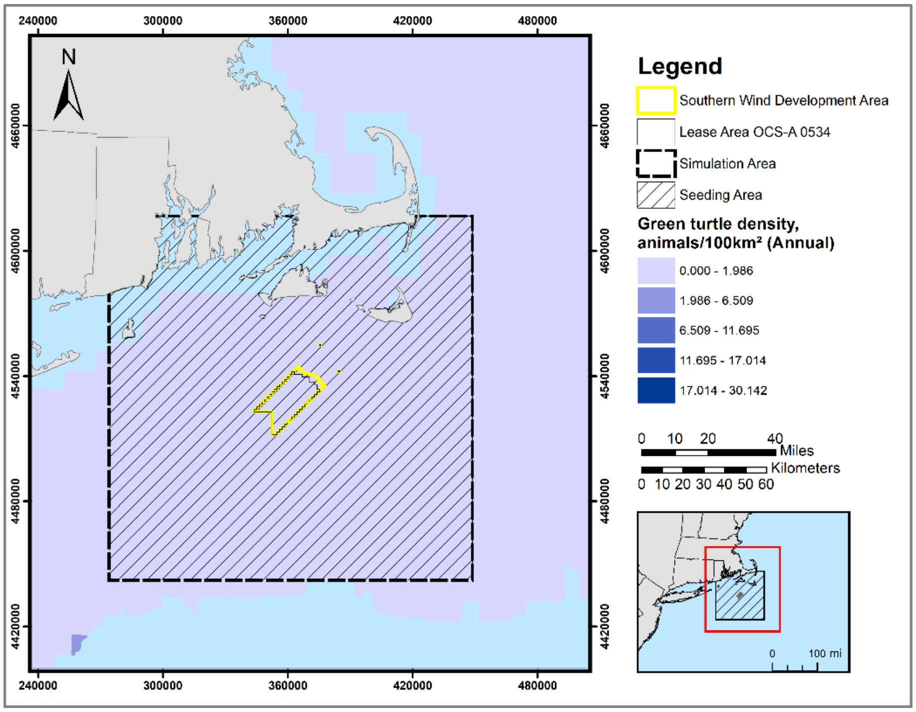

Figure H-21. Map of green sea turtle seeding area range (DoN 2017), showing Kemp's ridley sea turtle density as an example. Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

Appendix I. High-Resolution Geophysical Survey Exposure Analysis

Memo

DATE: 23 June 2022

Version: 3.0

FROM: Susan Dufault, Karlee Zammit, Madison Clapsaddle, and David Zeddies
(JASCO Applied Sciences [USA] Inc.)

TO: Park City Wind LLC

Subject: Marine Mammal Exposure Estimates for High Resolution Geophysical Survey Activities During New England Wind Construction

Marine mammals may be exposed to sound from high resolution geophysical (HRG) equipment used during surveys associated with construction of New England Wind. The amount and severity of exposure has been estimated for two deep seismic profilers: the Applied Acoustics AA251 boomer and GeoMarine's Geo Spark 2000 (400 tip) sparker system. JASCO conducted acoustic modeling for this geophysical equipment. Details of that modeling effort are included as Appendix I.

Appendix I, Table 5 provides the model-predicted horizontal impact distances to Level A and Level B thresholds in meters for the various marine mammal hearing groups. The model results for the two deep seismic profiling sources are reproduced here in Table 1 for clarity. No Level A exposures are expected to occur given the short distances to the Level A thresholds and the mitigation measures to be implemented during the surveys.

Table 1. Horizontal impact distances (in meters) to Level A and Level B threshold criteria.

Source	Level A (PK)				Level A (SEL)				Level B (SPL)
	LF	MF	HF	PW	LF	MF	HF	PW	
	Threshold (dB re 1 µPa)				Threshold (dB re 1 µPa²·s)				(dB re 1 µPa)
	219	230	202	218	183	185	155	185	160
Applied Acoustics AA251 Boomer	—	—	3	—	<1	<1	53	<1	178
GeoMarine Geo Spark 2000 (400 tip)	—	—	4	—	<1	<1	4	<1	141

Both sources were considered impulsive. Threshold criteria are defined in Appendix I, Appendices I.1.2 and I.1.3.

Assumptions

Exposure calculations assumed that there would be 25 days of HRG surveying per year over each of 5 years, beginning in the first year of foundation installation and extending two years beyond the estimated 3-year duration of foundation installation. For the purpose of the Letter of Authorization Request, a start year of 2025 is assumed. A distance of 80 km/day was assumed to be the maximum HRG survey distance possible in a 24-hour period and therefore this was used in the exposure calculations.

Because the exact dates of HRG surveys are unknown, as a conservative measure, for each species, it was assumed that the 25 days of surveying each year would occur during the highest density month for that species. Additional details of the density calculations are provided below.

Zone of Influence

The zone of influence (ZOI) is a representation of the maximum extent of the ensonified area around a sound source over a 24-hour period. The ZOI for each of the two deep seismic profilers was calculated using the following equation, which defines ZOI for mobile sources:

$$\mathrm{ZOI} = \left(\frac{\mathrm{distance}}{\mathrm{day}} \times 2r\right) + \pi r^2 , \qquad (1)$$

where distance/day is the linear distance traveled by the survey vessel per day, in this case, 80 km, and r is the horizontal distance to the relevant acoustic threshold. The results of this calculation are provided in Table 2.

Table 2. Zone of influence (km^2) for the two modeled deep seismic profilers.

Source	Level B Zone of Influence
Applied Acoustics AA251 Boomer	28.58
GeoMarine Geo Spark 2000 (400 tip)	22.62

Density Calculations

Marine mammal densities in the potential impact area were estimated using the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the U.S. Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b). Densities in the MGEL/Duke models are provided as the number of animals per 100 square kilometers (animals/100 km^2) and given for each 10 × 10 km cell in the U.S. Atlantic for most species, with a cell size of 5 × 5 km for the North Atlantic right whale (NARW).

To calculate marine mammal densities for the potential HRG survey impact area, it was assumed that the surveys would occur in four areas of interest (see Figure 1):

1. Phase 2 South Coast Variant Offshore Routing Envelope,
2. New England Wind Offshore Export Cable Corridor,
3. Phase 2 OECC Western Muskeget Variant, and
4. Maximum Size of the Southern Wind Development Area.

Monthly density was calculated for each area of interest and for each species as the average of the densities from all MGEL/Duke model grid cells that overlap partially or completely with each area of interest. Cells entirely on land were not included, but cells that overlap only partially with land were included. As a conservative measure, the month with the highest density among the four areas of interest for each species was carried forward to the exposure calculations.

Because the MGEL/Duke model for pilot whales considers long- and short-finned pilot whales together as the pilot whale guild, densities for these two species were scaled by their relative abundances using the following example equation:

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned}+a_{long-finned}}\right), \quad (2)$$

where d is density and a is abundance. Also note that the MGEL/Duke model for the pilot whale guild (Roberts et al. 2016a, 2016b, 2017) provides only an annual density, not monthly, so the densities for these two species are predicted annual densities.

Harbor and gray seals were similarly scaled by their relative abundances using the MGEL/Duke model for the seals guild (Roberts et al. 2016a, 2016b, 2018). The seals guild model is based primarily on harbor and gray seals and harp seals are considered uncommon in the area so lack sufficient data to provide a density estimate. As a conservative approach, the gray seal density (i.e., lesser of gray and harbor seal density) was used as a surrogate for harp seal density.

The monthly densities for each species used to estimate exposures above Level B acoustic thresholds during HRG surveys of New England Wind are shown in Table 3.

Table 3. Maximum monthly density (animals/100 km^2) used to estimate exposures above acoustic thresholds during HRG surveys for New England Wind.

Species	Maximum monthly density (animals/100 km^2)
Fin whale	0.37
Minke whale	0.26
Humpback whale	0.29
North Atlantic right whale	0.90
Sei whale	0.05
Atlantic white-sided dolphin	7.87
Atlantic spotted dolphin	0.13
Short-beaked common dolphin	27.63
Bottlenose dolphin	35.81
Risso's dolphin	0.05
Long-finned pilot whale[a]	0.59
Short-finned pilot whale[a]	0.44
Sperm whale	0.04
Harbor porpoise	15.68
Gray seal[b]	36.59
Harbor seal[b]	82.20
Harp seal[b]	36.59

[a] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[b] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

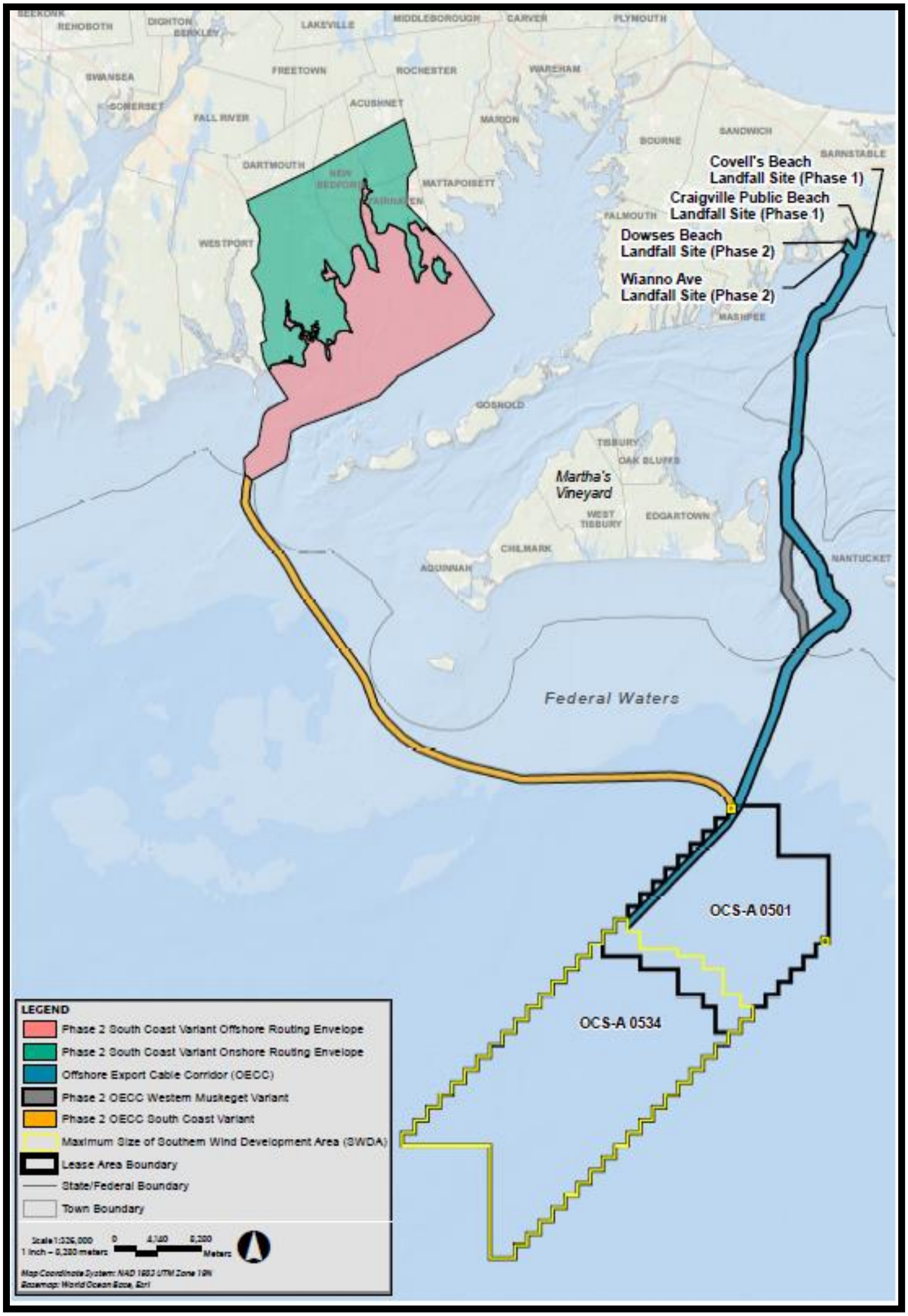

Figure 1. Map showing two potential Phase 2 offshore export cable variants. The four areas of interest used in the HRG survey exposure calculations are: (1) Phase 2 South Coast Variant Offshore Routing Envelope, (2) New England Wind Offshore Export Cable Corridor, (3) Phase 2 OECC Western Muskeget Variant, and (4) Maximum Size of the Southern Wind Development Area.

Estimated Exposures

Exposures above the Level B acoustic thresholds were estimated using the formula:

$$\text{exposures} = \text{ZOI} \times (\text{days}) \times \text{density}\,, \tag{3}$$

where ZOI is defined in Equation 1, days = 25, and density is from Table 3.

The results of these calculations are shown in Table 4.

Table 4. Estimated exposures: Number of animals of each species estimated to receive sound levels above the Level B threshold annually during HRG surveys of New England Wind.

Species	Applied Acoustics AA251 boomer	GeoMarine Geo Spark 2000
Fin whale[a]	2.67	2.11
Minke whale	1.82	1.44
Humpback whale	2.09	1.65
North Atlantic right whale[a]	6.44	5.10
Sei whale[a]	0.32	0.26
Atlantic white-sided dolphin	56.24	44.52
Atlantic spotted dolphin	0.93	0.73
Short-beaked common dolphin	197.42	156.27
Bottlenose dolphin	255.89	202.55
Risso’s dolphin	0.38	0.30
Long-finned pilot whale	4.22	3.34
Short-finned pilot whale	3.12	2.47
Sperm whale[a]	0.26	0.21
Harbor porpoise	112.02	88.67
Gray seal	261.41	206.92
Harbor seal	3.29	587.32
Harp seal	1.46	261.41

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Distances to Acoustic Thresholds for High Resolution Geophysical Sources

New England Wind HRG Incidental Harassment Authorization Calculations

Submitted to:
Cynthia Pyć (Avangrid)

Authors:
Matthew Koessler
Zizheng Li

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Distance to Acoustic Thresholds for High Resolution Geophysical Sources

I.1. Methods

In this analysis, we compute horizontal impact ranges for High-Resolution Geophysical (HRG) sound sources. We consider both the contribution from the main lobe (in-beam) energy of the source, which is directed toward the seafloor, as well as side-lobe (out-of-beam) energy that propagates horizontally (see Figure I-1). The larger of these two is reported.

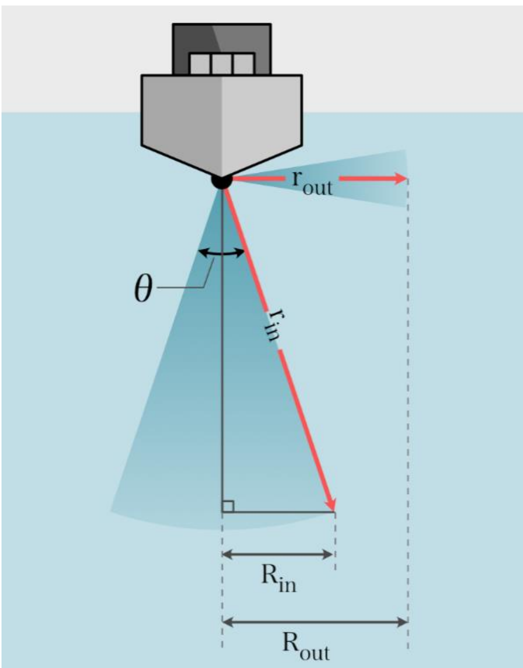


Figure I-1. Geometry used in computing horizontal impact ranges based on in-beam and out-of-beam energy.

Our methodology for computing the horizontal component of the main lobe follows the approach described by NMFS (2019) and Guan (2020). We elected to focus on the more conservative case wherein depth is not limited, which allows for more operational flexibility. For computing the horizontal extent of side-lobe energy, we start with a lower source level and assume that the sound energy propagates horizontally. Propagation loss in both cases is estimated using a modified spreading equation.

Section I.1.1 provides an overview of calculations. Sections I.1.2 and I.1.3 describe how Level A and Level B ranges are determined.

I.1.1. Calculation Summary

Propagation Loss

The sonar equation is used to calculate the received sound pressure level:

$$SPL(r) = SL - PL(r), \tag{I-1}$$

where *SPL* is the sound pressure level (dB re 1 µPa), *r* is the distance (slant range) from the source (m), *SL* is the source level (dB re 1 µPa m), and *PL* is the propagation loss as a function of distance. The propagation loss is calculated using a modified spreading equation:

$$PL(r) = 20\log_{10}\left(\frac{r}{1\text{ m}}\right)\text{ dB} + \alpha(f)\cdot r/1000, \tag{I-2}$$

where $\alpha(f)$ is the absorption coefficient (dB/km) and f is frequency (kHz). The absorption coefficient is approximated by discarding the boric acid term from Ainslie (2010; p29; eq 2.2):

$$\alpha(f) \approx 0.000339f^2 + 48.5f^2/(75.6^2 + f^2)\,. \tag{I-3}$$

When a range of frequencies is produced by a source, we use the lowest frequency to determine the absorption coefficient.

The predicted received level is used to determine the distance at which a threshold level is reached (i.e., solving Equation I-1 for slant range r).

Horizontal range estimation

For a downward-pointing source with a beam width less than 180°, the horizontal impact distance (R_{in}) is calculated from the in-beam slant range using:

$$R_{in} = r_{in}\cdot\sin\left(\frac{\delta\theta}{2}\right), \tag{I-4}$$

where $\delta\theta$ is the -3 dB beamwidth.

To account for energy emitted outside of the primary beam of the source, we estimate a representative out-of-beam source level and propagate the energy horizontally (see Figure I-1). In this method, the horizontal component R_{out} of the out-of-beam energy is equivalent to the out-of-beam slant range:

$$R_{out} = r_{out}. \tag{I-5}$$

The larger of the two horizontal range estimates was then selected for assessing impact distance (presented in Section I.4):

$$R = \max(R_{in}, R_{out}). \tag{I-6}$$

For an omni-directional source the horizontal impact distance (*R*) was calculated based on horizontally propagating energy (i.e., this is equivalent to a beamwidth of 180°).

Out-of-beam source level adjustment

Side lobe energy is generally lower than the main lobe energy. An estimate of the reduction relative to the main lobe energy was generated as a function of the main lobe beam width. Separate approaches were taken for narrow-beam sources (up to 36° beam width), intermediate-beam sources (36° to 90° beam width), and broad-beam sources. Broad-beam sources were treated as omni-directional and had no out-of-beam reduction. The out-of-beam reduction for narrow beam sources was approximated using a theoretical beam pattern. The out-of-beam reduction for intermediate-beam sources was interpolated between the other two approximations.

The narrow-beam side lobe level reduction is estimated by taking the arithmetic average of the upper and lower bounds of the sidelobe levels of an unshaded circular transducer beam pattern. This beam pattern $b(u)$ is described as:

$$b(u) = (2\ J_1(u)/u)^2, \tag{I-7}$$

where $J_1(u)$ is a first order Bessel function of the first kind, whose argument is a function of off-axis angle θ and beam width (full width at half maximum) $\delta\theta$

$$u = u_0 \frac{\sin\theta}{\sin\frac{\delta\theta}{2}}, \tag{I-8}$$

where $u_0 = 1.614$.

For the upper limit we choose the highest sidelobe level of the beam pattern, given by (Ainslie 2010; p265; Table 6.2)

$$B_{\text{max}} = -17.6\ \text{dB}. \tag{I-9}$$

For the lower limit we consider the asymptotic behavior of the beam pattern in the horizontal direction

$$J_1(u) \sim \sqrt{\frac{2}{\pi u}} \cos\left(u - \frac{3\pi}{4}\right), \tag{I-10}$$

where

$$u = \frac{u_0}{\sin\frac{\delta\theta}{2}}. \tag{I-11}$$

In this way we obtain the lower limit as

$$B_{\text{min}} = 10 \log_{10}\left(\frac{8}{\pi\, u_0^3} \sin^3 \frac{\delta\theta}{2}\right) \text{dB}. \tag{I-12}$$

Finally, the out-of-beam source level is found by reducing the in-beam source level by the arithmetic mean of B_{min} and B_{max}. The resulting correction as a function of beam width is shown in Figure I-2. Note that narrower beam sources have a larger reduction in side lobe levels than wider beam sources.

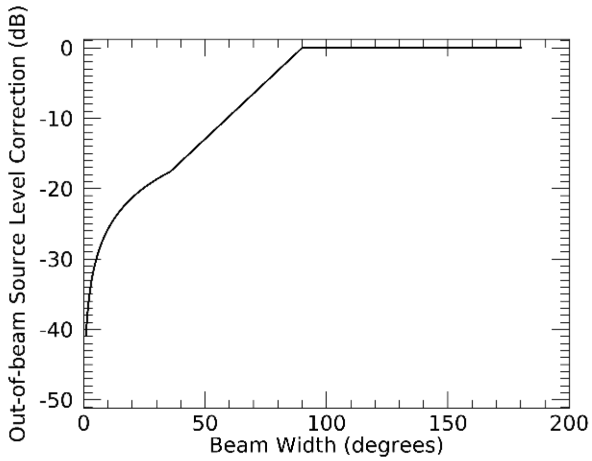


Figure I-2. Correction for calculating out-of-beam source level (i.e., in the horizontal direction) from in-beam source level, as a function of main lobe beam width.

The out-of-beam source level for a given HRG source was calculated by adding the dB correction (Figure I-2) to the in-beam source level. The corrections computed for the sources considered in this study can be found in Table I-4.

I.1.2. Level A

This section describes the methods used to estimate the horizontal distances to the National Marine Fisheries Service (NMFS) acoustic thresholds for injury (Table I-1). There are different thresholds for impulsive and non-impulsive sounds. According to Southall et al. (2007), "Harris (1998) proposed a measurement-based distinction of pulses and non-pulses that is adopted here in defining sound types. Specifically, a ≥3-dB difference in measurements between continuous and impulse [sound level meter] setting indicates that a sound is a pulse; a <3 dB difference indicates that a sound is a non-pulse. We note the interim nature of this distinction for underwater signals and the need for an explicit distinction and measurement standard such as exists for aerial signals (ANSI 1986)."

Classification of impulsive signals is inconsistent across standards, criteria, and guidance. Southall et al. (2007), Finneran et al. (2017), and NMFS (2018) each have different criteria for classifying a signal as impulsive or non-impulsive. The Southall et al. (2007) method described above was used for all of the sources analyzed in this work. Finneran et al. (2017) state that harmonic signals with more than 10 cycles in a pulse are considered steady state (i.e., non-impulsive). NMFS (2018) cites the standard for measurement of sound levels in air (ANSI 2010), but removes the quantitative criteria resulting in a definition that impulsive sound sources "produce sounds that are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay." The ANSI (2010) classification, while more specific than NMFS (2018), does not preclude harmonic signals, especially frequency modulated signals, from being classified as impulsive.

NMFS has determined that deep seismic profilers such as sparkers and boomers are classified as impulsive sources. This classification is based on NMFS' qualitative assessment of the generated waveforms (pers comm, Benjamin Laws [NMFS] 2020).

Table I-1. Peak sound pressure level (PK, dB re 1 µPa) and sound exposure level (SEL, dB re 1 µPa^2·s) thresholds for injury (PTS onset) for marine mammals for impulsive sound sources (NMFS 2018).

Functional hearing group	Impulsive source	
	PK	Weighted SEL_{24h}
Low-frequency cetaceans (LFC)	219	183
Mid-frequency cetaceans (MFC)	230	185
High-frequency cetaceans (HFC)	202	155
Phocid pinnipeds in water (PPW)	218	185
Otariid pinnipeds in water (OPW)	232	203

NMFS provides a spreadsheet to calculate these distances, but it is not designed for high-resolution geophysical survey sources. The spreadsheet does not consider seawater absorption or beam patterns, both of which can substantially influence received sound levels. In order to account for these effects, we model sound levels using Equations I-1 to I-12, as follows.

Distances to peak thresholds were calculated using the peak source level and applying propagation loss from Equation A-2. Peak levels were assessed for both in-beam and out-of-beam levels (the latter was assessed using the out-of-beam source level correction described previously).

Range to SEL thresholds were calculated for source locations along a hypothetical survey line. Source spacing was determined from the assumed vessel speed of 3.5 kts and the repetition rate for each source. A single set of fixed receiver locations extended perpendicularly from the middle of the survey line. The propagation loss between each source and receiver pair was calculated (Equation I-2), and then using the appropriate (in beam or out of beam) weighted source level and pulse length (Figure I-2 and Table I-2), the received level from all of the source locations for each receiver was determined. The received levels at a given receiver location from all source locations were summed. The greatest range where the summed SEL exceeded the criteria threshold was the range to impact (Table I-1). This range was determined separately for all sources and all functional hearing groups.

This method accounts for the hearing sensitivity of the marine mammal group, seawater absorption, and beam width for downwards-facing transducers.

In cases where the pulse duration for a source was unknown. The pulse duration was calculated from the difference between source level (SL) and energy source level (ESL) using:

$$T = 10^{(ESL-SL)/10}. \quad \text{(I-13)}$$

I.1.3. Level B

This section describes the methods used to estimate the horizontal distance to the root-mean-square sound pressure level (SPL) 160 dB re 1 µPa isopleth for the purposes of estimating Level B harassment (NOAA 2005). Distances to SPL thresholds were calculated using the source level and applying the method described above. SPL levels were assessed for both in-beam and out-of-beam levels (the latter was assessed using the out-of-beam source level correction described previously).

I.2. Sources

The following subsections describe the source characteristics of HRG equipment provided by Vineyard Wind. The horizontal impact distance to the Level A (Table I-1) and Level B (160 dB re 1 µPa) thresholds were computed for each source by applying the methods from Section Appendix I. We used the following assumptions when calculating impact distances:

- For sources that operate with different beam widths, we used the beam width associated with operational characteristics reported in Crocker and Fratantonio (2016).
- We use the lowest frequency of the source when calculating the absorption coefficient.

I.3. Overview of Source Properties

Table I-2 lists geophysical survey sources considered in this assessment that produce underwater sound at or below 180 kHz frequencies, and their acoustic characteristics. Table I-3 provides the accompanying data source reference.

Table I-2. Considered geophysical survey sources.

Equipment	System	Frequency (kHz)	Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)	Energy source level (dB re 1 µPa^{2}s m^2)	Beam width (°)	Pulse duration (ms)	Repetition rate (Hz)
Deep seismic profilers	Applied Acoustics AA251 Boomer	0.2–15	205	212	174	180	0.8	2
	GeoMarine Geo Spark 2000 (400 tip)	0.05–3	203	213	178	180	3.4	1

Table I-3. Data reference for considered geophysical survey sources.

Equipment	System	Frequency	Source level	Peak source level	Energy source level	Beam width	Pulse duration	Repetition rate
Deep seismic profilers	Applied Acoustics AA251 Boomer	Estimated from Figs 14 and 16 in Crocker and Fratantonio (2016)	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	Crocker and Fratantonio (2016), after correcting for full pulse duration	Vineyard Wind indicates they will use this repetition rate
	GeoMarine Geo Spark 2000 (400 tip)	Source specifications provided by Vineyard Wind.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Assume omnidirectional source to be conservative.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Vineyard Wind indicates they will use this repetition rate

I.3.1. Derived Out-of-beam Levels

Table I-4 lists the corrections applied to obtain out-of-beam source levels.

Table I-4. Correction factors for out-of-beam source levels.

Description		In-beam		Correction (dB)	Out-of-beam	
Equipment	System	Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)		Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)
Deep seismic profilers	Applied Acoustics AA251 Boomer	205	212	0.0	205.0	212.0
	GeoMarine Geo Spark 2000 (400 tip)	203	213	0.0	203.0	213.0

I.4. Distances

Table I-5 lists the geophysical survey sources and the horizontal impact distances to the Level A and B criteria that were obtained by applying the methods from Appendix I with the source parameters in Appendix I.3.

Table I-5.Horizontal distance to Level A and Level B impact threshold.

Equipment	System	Level A horizontal impact distance (m) to PK threshold					Level A horizontal impact distance (m) to SEL threshold					Level B horizontal impact distance (m)
		LFC	MFC	HFC	PPW	OPW	LFC	MFC	HFC	PPW	OPW	
Deep seismic profilers	Applied Acoustics AA251 Boomer	—	—	3	—	—	<1	<1	53	<1	<1	178
	GeoMarine Geo Spark 2000 (400 tip)	—	—	4	—	—	<1	<1	4	<1	<1	141

A dash (—) indicates that a source level is less than threshold level.

The methods used here are approximate, and a rigorous propagation loss model coupled with a full beam pattern and spectral source model would result in more accurate impact distances.

I.5. Equipment Specification Reference Sheets

I.5.1. GeoMarine Geo Spark 2000 (400 tip)

Geo

Geo-Source 200 - 400

Marine Multi-Tip Sparker System

Operational Features

- Powerful hi-resolution seismic source
- Primary pulse < 1ms, no ringing
- Proven operation in 1000 m water depth
- Penetration to 400 ms below seabed, depending on geology and survey conditions
- Vertical resolution < 30 cm

Ideal seismic profiling system for small and large vessels

- Site & route surveys
- Offshore engineering
- Mineral exploration
- Oceanographic research

INNOVATIVE Preserving Electrode Mode

The innovative Geo-Source 200 has been designed for operation with the Geo-Spark 1000 pulsed power supply (PPS) using the patented **Preserving Electrode Mode.** This mode uses a NEGATIVE electric discharge pulse instead of a positive pulse.

(Please note that this negative pulse is NOT the same as the simple reversal of the positive polarity of a 'standard' power supply.)

Maintenance free electrodes 5 year guarantee

The Preserving Electrode Mode **reduces the tip wear to practically zero**. You can shoot day after day, week after week, month after month with practically **NO tip maintenance.**

Always a stable acoustic pulse

Zero tip wear is essential for the **acoustic repeatability** of the pulse, which depends largely on a constant, unaltered electrode surface and tip insulation.

Efficient & Cost Effective

With the Geo-Spark HV power supplies you will save a lot of time and money, since the electrodes do NOT burn off like in all other systems.

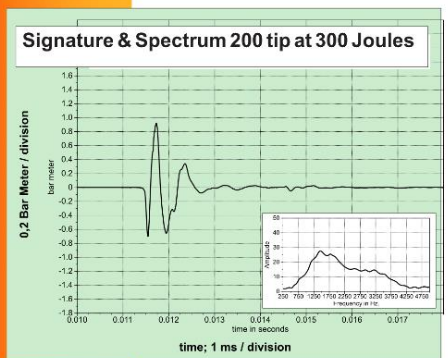
You don't need to trim tips during the survey. There is no need to have any stock of consumables.

Examples of Records

To see examples of our sparker records, please visit the 'Downloads' page on our website: ***www.geo-spark.com***

Geo-Source 200-400

Technical Specifications



Electrodes Geometry

The electrode modules are evenly spaced in a planar array of 0.75 m x 1.00 m. This geometry not only enhances the downward projection of the acoustic energy, it also reduces the primary pulse length, since all tips are perfectly in phase.

Control of Source Parameters 200 - 400 tips

The advanced Geo-Source 200-400 design gives you total control of the source depth and the energy (Joules) per tip

Source depth

Two floats provide a stable towing configuration and insure the proper depth of the electrode tips. This is critical to achieve constructive interference between the primary pulse and its own sea-surface reflection (surface ghost)

Number of tips in use and Energy per tip

Four individually powered electrode modules of 50 or 100 tips each allow you to distribute the energy from the Geo-Spark power supply over 50, 100......, up to 400 tips. (Each tip has an exposed surface area of 1.4 mm^2.)

200 tips, the classic 200 tip configuration is normally used with the Geo-Spark 1000 PPS and consists of four 50-tip electrode modules. This configuration gives an excellent hi-res pulse over the 100 to 500 J power range.

400 tips, for higher energies above 1000 J, and in particular with the Geo-Spark 2000X, we recommend a 400 tip configuration with 4 x 100-tip electrode modules

Maintenance free electrodes, no trimming, stable signature

Coaxial High Voltage (HV) Power/Tow Cable

The Geo-Source 200 is towed by a very high quality, Kevlar-reinforced, coaxial power/tow cable with stainless steel kellum grip. This dedicated high voltage (HV) cable contains **4 x 10 mm^2** inner cores (negative) plus a **40 mm^2** braiding (ground-referenced). It is designed to have a very low self-inductance to preserve the high dI/dt pulse output of the Geo-Spark 1000 PPS.

The coaxial structure of the HV cable reduces the electromagnetic interference to the absolute minimum.

The wet end of the cable is terminated with four special HV connectors to the electrode modules and a ground connector to the frame. Connecting or disconnecting the cable to the Geo-Source 200 takes only 10 minutes; so you can handle the sparker sled and the HV cable as independent units.

The dry end of the cable is terminated at the Geo-Source 200 patch panel, which allows you to select the number of electrode arrays in use

GEO Marine Survey Systems b.v.
Sheffieldstraat 8, 3047 AP Rotterdam
The Netherlands
Phone: + 31 10 41 55 755
Fax: +31 10 41 55 351
info@geomarinesurveysystems.com
Website: www.geo-spark.com

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Appendix J. Unexploded Ordnance Exposure Analysis

Memo

DATE: 23 June 2022

Version: 3.0

FROM: David Hannay, Madison Clapsaddle, and David Zeddies
(JASCO Applied Sciences [USA] Inc.)

TO: Park City Wind LLC

Subject: Marine Mammal Level A and Level B Exposure Estimates for Potential Unexploded Ordinance Detonation During New England Wind Construction

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

Park City Wind LLC (Park City Wind) is currently assessing the risk of encountering unexploded ordnance (UXO) within the New England Wind southern wind development area (SWDA) and offshore export cable corridors (OECCs). In instances where avoidance, physical UXO removal, or alternative combustive removal technique (e.g., deflagration) is not feasible due to layout restrictions or considered safe for project personnel, UXOs may need to be detonated in situ to conduct seabed-disturbing activities such as foundation installation and cable laying during construction of New England Wind. The selection of the disposal method will be determined by the size, location, and condition of each individual UXO that the project may encounter.

The project team is continuing to evaluate the risk of encountering potential UXO. Geophysical surveys to identify the amount and magnitude of potential UXO within the SWDA and OECC are ongoing. As these surveys and analysis of survey data are still in progress, the number, location, and type of UXO in the project area is not known at this time. Initial survey data, however, suggests that there are potential areas of moderate risk for UXO presence (Figure 1). Water depth at these locations range from approximately 2 to 62 m (Mills 2021).

Geophysical survey operations and the development of UXO risk analysis and mitigation strategy for New England Wind are currently in line with requirements for COP development and will be further matured as the project timeline progresses towards construction.

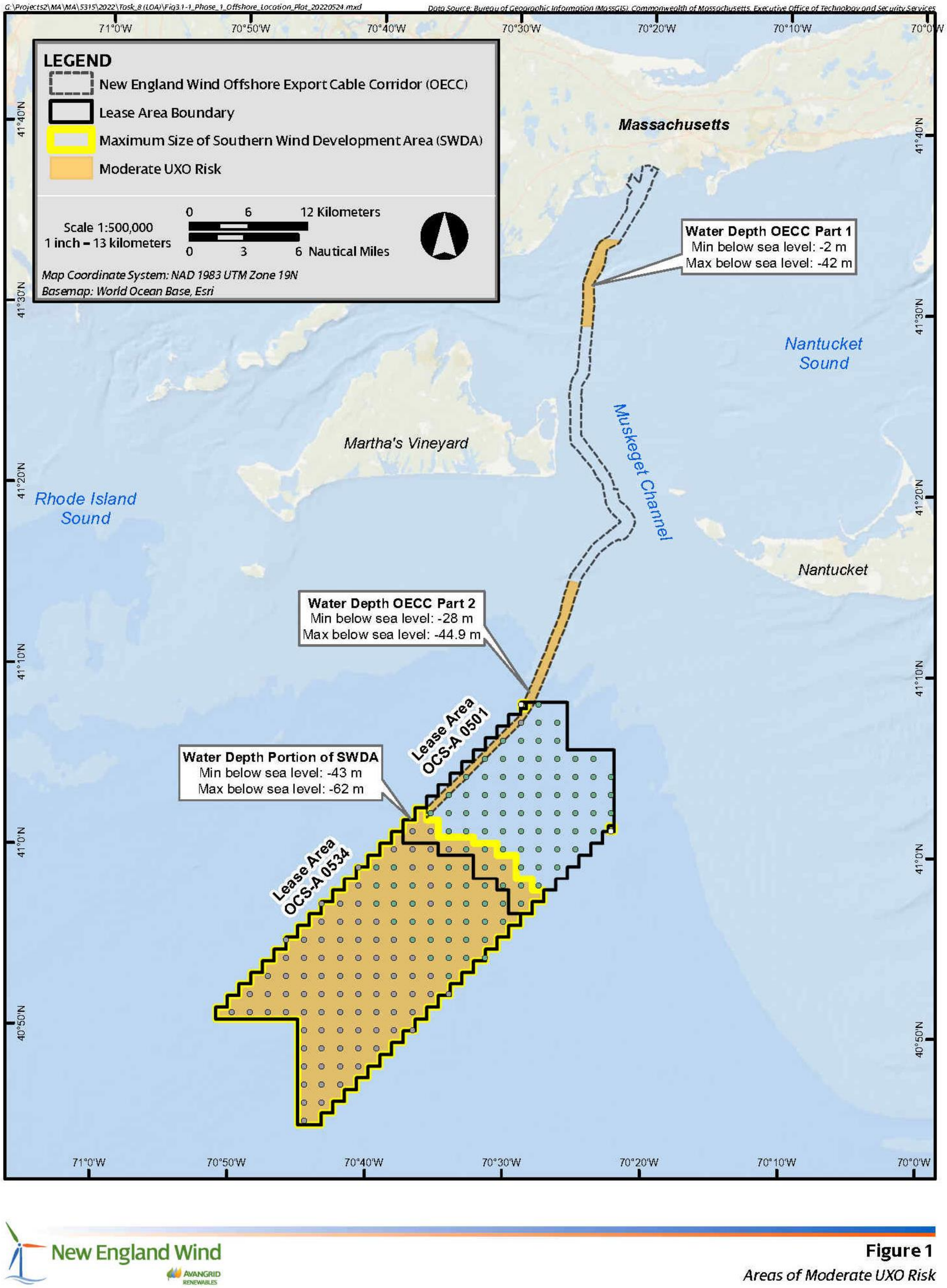

Figure 1
Areas of Moderate UXO Risk

J.1. Baseline Threat Assessment

Park City Wind has commissioned a UXO desktop study in which a comprehensive historic analysis of all activities which may have contributed to potential UXO-related contamination have been considered and are summarized. The conclusion of this historical research is presented in Table J-1 and Table J-2. The probability of encounter of UXOs within the entire New England Wind project area is classified as possible to improbable for all but one classification of UXO.

Table J-1. Probability levels.

Probability Assessment Levels		
Grade	**Probability level**	**Rationale**
A	Highly Probable	Clear evidence that this type of munition would be encountered.
B	Probable	Significant evidence to indicate that this type of munition would be encountered.
C	Possible	Evidence suggests that this type of munition could be encountered.
D	Remote	Evidence suggest that these munitions have been found in the wider area but not specifically on the site.
E	Improbable	Not considered likely to encounter this type of munition on site, but not possible to discount completely.
F	Highly Improbable	No evidence that this type of munition would be encountered on site or the immediate vicinity.

Source: Mills (2021)

Table J-2. Probability of encounter for each ordnance type.

UXO		Probability	
Small Arms Ammunition		E	Improbable
Land Service Ammunition		E	Improbable
≤155 mm Projectiles		D	Remote
≥155 mm Projectiles		D	Remote
HE Bombs	Allied Origin	B	Probable
	Axis Origin	E	Improbable
Sea Mines	Allied Origin	E	Improbable
	Axis Origin	D	Remote
	Axis Origin (Non-Ferrous)	E	Improbable
Torpedoes		C	Possible
Depth Charges		C	Possible
Dumped Conventional Munitions		C	Possible
Dumped Chemical Munitions		E	Improbable
Missiles/Rockets		D	Remote

Source: Mills (2021)

J.2. Acoustic Modeling Methodology and Assumptions

An acoustic modeling study of peak pressure, acoustic impulse and sound exposure level from UXO detonation was performed recently for the Revolution Wind project, an Orsted and Eversource Investment joint venture (Hannay and Zykov 2022), which is geographically adjacent to the New England Wind project area. Although this study was targeted for the Revolution Wind project, the results are being applied to Orsted's Ocean Wind 1 and Sunrise Wind projects due to site similarities such as water depth and seabed sediment properties. This modeling study is currently available as Appendix B in the *Revolution Wind Petition for Incidental Take Regulations for the Construction and Operation of the Revolution Wind Offshore Wind Farm* starting at Page 329 of that application (available at https://media.fisheries.noaa.gov/2022-03/RevWind_ITR_App_OPR1.pdf; LGL Ecological Research Associates, Inc. 2022) and Appendix C in the *Ocean Wind Offshore Wind Farm Application for Marine Mammal Protection Act (MMPA) Rulemaking and Letter of Authorization (LOA)* (available at https://media.fisheries.noaa.gov/2022-03/OceanWind1OWF_2022_508APP_OPR1.pdf; HDR 2022).

The modeling study employed an approach adopted from the US Navy of 'binning' items of UXO which may be encountered on the site and may need to be mitigated through detonation. The study included acoustic ranges for potential UXO detonations for four different water depths (12, 20, 30, and 45 m) within the Revolution Wind project area and for five different UXO charge weight bins (E4 [2.3 kg], E6 [9.1 kg], E8 [45.5 kg], E1b0 [227 kg], and E12 [454 kg]; Table J-3) (Hannay and Zykov 2022). The modeling locations were chosen at two sites along the Revolution Wind subsea export cable route in Narragansett Bay in water depths of 12 m and 20 m, and two sites within the Revolution Wind lease area at depths of 30 m and 45 m.

Table J-3. Navy "bins" and corresponding maximum UXO charge weights (Maximum equivalent weight trinitrotoluene [TNT]) to be modeled.

Navy Bin	Maximum equivalent weight TNT	
	(kg)	(lbs)
E4	2.3	5
E6	9.1	20
E8	45.5	100
E10	227	500
E12	454	1000

Source: Hannay and Zykov (2022)

The acoustic modeling considered injurious effects to lung and gastrointestinal tracts of marine mammals using peak pressure and acoustic impulse metrics. Auditory system injury zones were assessed using Sound Exposure Level (SEL) based on Permanent Threshold Shift (PTS) onset. Disturbance to marine mammals was based on Temporary Threshold Shift (TTS) onset. Injury to fish zones were assessed using peak pressure and SEL thresholds. This modeling also considered the use of sound reduction/mitigation technologies that would reduce the produced pressures by 10 dB across all acoustic frequencies. This amount of reduction is expected to be possible using noise mitigation systems (NMS) such as modern air curtains.

The peak pressure and acoustic impulse levels and effects threshold exceedance zones depend only on charge weight, water depth, animal mass and submersion depth. They depend only slightly on local bathymetry that could affect the maximum submersion depth of nearby animals. These results do not depend on seabed composition or acoustic reflectivity. Therefore, the peak pressure and impulse results are expected to be directly relevant for use with New England Wind activities, as long as those activities are performed similarly (i.e., by detonating the same UXO charge sizes, performing only one charge detonation per 24 hours, and using an NMS capable of reducing pressures by at least 10 dB).

The water depths considered in the acoustic modeling study (i.e., 12, 20, 30, and 45 m) are relevant to the New England Wind project areas that may require UXO detonation, although the export cable route for New England Wind comes to shore northeast of Cape Cod Island and not into Narragansett Bay, as was considered in the modeling study. The modeled SEL from Revolution Wind are mostly transferable to similar depth sites over New England Wind's project area, with the possible exception of the shallowest site (12 m) that is located in a constrained channel in Narragansett Bay with nearby islands blocking sound propagation in some directions. The area of possible effects threshold exceedances could be larger for other sites with similar water depths when islands or shoals are not nearby to block sound propagation. The SEL results from the other Revolution Wind model sites will be approximately transferable to New England Wind sites of the same depth. Those results, however, depend on the sound propagation loss that is specific to the bathymetric variations along multiple radials leading away from each model site. In general, the bathymetry near the Revolution Wind model sites was gently sloping, but there were some non-uniform bathymetry features included. This could lead to slight differences in the sizes of the effects threshold exceedance zones. Nevertheless, differences of charge sizes within each UXO weight range bin and the unknown fraction of contained explosive that will detonate are likely to produce much more variability in noise level for each bin size than location-dependent effects.

The maximum equivalent weight of the UXO types indicated as possible to be encountered by the New England Wind project fall within or below bin E12, and possible UXO types expected within the footprint of New England Wind generally fall in bin E10 and below (Mills 2021). Park City Wind will employ avoidance through microrouting/micrositing of project infrastructure. Due to this avoidance measure, the low likelihood of encounter, and the similarity in bathymetry between the Revolution Wind and New England Wind project areas, the modeling study (Hannay and Zykov 2022) is proposed to be sufficient for New England Wind.

J.3. Acoustic Ranges

New England Wind construction operations may encounter UXO along the OECC and within the SWDA. UXO encountered during New England Wind construction activities are expected to be of the same type and sizes considered for the Ocean Wind 1 project (Mills 2021; HDR 2022). For the purposes of the New England Wind LOA application, the same UXO risk assumptions as the Ocean Wind application (HDR 2022) have been made for the New England Wind project, whereby up to 10 E12-bin UXOs were assumed between the various depths expected to be encountered in the project area, estimating 2 UXOs at 12 m, 3 UXOs at 20 m, 3 UXOs at 30 m, and 2 UXOs at 40 m. Based on the results of the UXO desktop study (Mills 2021), Park City Wind does not expect that 10 E12-size UXOs will be present, but a combination of up to 10 UXOs may be encountered. As a conservative measure the larger E12 bin will be used to analyze potential effects.

Table J-4 presents SEL-based $R_{95\%}$ PTS (Level A) and TTS (Level B) isopleths and their equivalent areas, which include both no attenuation results and results with an assumed 10 dB of attenuation due to the use of NMS (Bellmann and Betke 2021). New England Wind will use NMS with an expected 10 dB of attenuation (Bellmann and Betke 2021).

Table J-4. SEL-based criteria ranges (m) and equivalent areas (km^2) to PTS- and TTS-onset ($R_{95\%}$) for various depths assuming no attenuation and 10 dB attenuation.

Hearing Group	Threshold (dB re 1 µPa^{2}s)	No Attenuation				10 dB of Attenuation			
		12 m	20 m	30 m	45 m	12 m	20 m	30 m	45 m
Radii									
Level A (PTS-onset)									
LF	183	7,640	8,800	8,440	8,540	3,220	3,780	3,610	3,610
MF	185	1,540	1,450	1,480	1,410	461	386	412	412
HF	155	11,300	11,000	10,700	10,900	6,200	6,190	6,190	6,160
PW	185	4,340	4,500	4,450	4,520	1,600	1,430	1,480	1,350
Level B (TTS-onset)									
LF	168	18,300	19,200	19,300	19,000	11,000	11,900	11,500	11,800
MF	170	5,860	5,850	5,840	5,810	2,550	2,430	2,480	2,480
HF	140	20,200	20,200	20,200	20,000	14,100	13,800	13,300	13,700
PW	170	13,300	13,200	12,800	13,300	6,750	6,990	6,900	7,020
Area									
Level A (PTS-onset)									
LF	183	183.37	243.28	223.79	229.12	32.57	44.89	40.94	40.94
MF	185	7.45	6.61	6.88	6.25	0.67	0.47	0.53	0.53
HF	155	401.15	380.13	359.68	373.25	120.76	120.37	120.37	119.21
PW	185	59.17	63.62	62.21	64.18	8.04	6.42	6.88	5.73
Level B (TTS-onset)									
LF	168	1,052.09	1,158.12	1,170.21	1,134.11	380.13	444.88	415.48	437.44
MF	170	107.88	107.51	107.15	106.05	20.43	18.55	19.32	19.32
HF	140	1,281.90	1,281.90	1,281.90	1,256.64	624.58	598.28	555.72	589.65
PW	170	555.72	547.39	514.72	555.72	143.14	153.50	149.57	154.82

Source: Hannay and Zykov (2022)
LF = low-frequency cetaceans; MF = mid-frequency cetaceans; HF = high-frequency cetaceans; PW = phocid pinnipeds in water

J.4. Density Calculations

Marine mammal densities in the project area were estimated using the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the U.S. Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b). Densities in the MGEL/Duke models are provided as the number of animals per 100 square kilometers (animals/100 km^2) and given for each 10 × 10 km cell in the U.S. Atlantic for most species, with a cell size of 5 × 5 km for the North Atlantic right whale (NARW).

The UXO desktop study (Mills 2021) identified three areas as moderate UXO risk within the project area (Figure 1):

1. The shallow water segment of the OECC (OECC Part 1);
2. The deepwater segment of the OECC (OECC Part 2); and
3. The SWDA.

To calculate marine mammal densities for the 10 potential UXO detonations, whereby 2 UXOs would be assumed at the 12 m depth location, 3 UXOs at 20 m, 3 UXOs at 30 m, and 2 UXOs at 40 m, monthly density was calculated for each species at the shallow portion of the OECC (representing the 12 m depth location) and the combined deepwater segment of the OECC and SWDA (20 m – 62 m depths). As a conservative measure, the month with the highest density among the areas of interest for each species was carried forward to the exposure calculations.

Because the MGEL/Duke model for pilot whales considers long- and short-finned pilot whales together as the pilot whale guild, densities for these two species were scaled by their relative abundances using the following example equation:

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned}+a_{long-finned}}\right), \quad \text{(J-1)}$$

where d is density and a is abundance. Also note that the MGEL/Duke model for the pilot whale guild (Roberts et al. 2016a, 2016b, 2017) provides only an annual density, not monthly, so the densities for these two species are predicted annual densities.

Harbor and gray seals were similarly scaled by their relative abundances using the MGEL/Duke model for the seals guild (Roberts et al. 2016a, 2016b, 2018). The seals guild model is based primarily on harbor and gray seals and harp seals are considered uncommon in the area so lack sufficient data to provide a density estimate. As a conservative approach, the gray seal density (i.e., lesser of gray and harbor seal density) was used as a surrogate for harp seal density.

The monthly densities for each species used to estimate exposures above the Level A and Level B acoustic thresholds during potential UXO detonations for New England Wind are shown in Table J-5.

Table J-5. Maximum monthly density (animals/100 km^2) at the moderate UXO risk areas used to estimate exposures above the Level A and Level B acoustic thresholds during potential detonations for New England Wind.

Species		Maximum monthly density (animals/100 km^2)	
		Shallow OECC Segment	Deep OECC Segment and SWDA
LF	Fin whale[a]	0.000305	0.003792
	Minke whale	0.000478	0.002696
	Humpback whale	0.001510	0.004146
	North Atlantic right whale[a,]	0.000288	0.009282
	Sei whale[a]	0.000011	0.000497
MF	Atlantic white-sided dolphin	0.001318	0.066818
	Atlantic spotted dolphin	0.000005	0.001325
	Short-beaked common dolphin	0.000846	0.308527
	Bottlenose dolphin	0.370979	0.099623
	Risso's dolphin	0.000001	0.000487
	Long-finned pilot whale[b]	0.000009	0.006294
	Short-finned pilot whale[b]	0.000007	0.004642
	Sperm whale[a]	0.000003	0.000332
HF	Harbor porpoise	0.027993	0.165059
PPW	Gray seal[c]	0.321642	0.072733
	Harbor seal[c]	0.722646	0.163411
	Harp seal[c]	0.321642	0.072733

[a] Listed as Endangered under the Endangered Species Act.
[b] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[c] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

J.5. Exposure Calculations

To calculate potential marine mammal exposures, the area distances in Table J-5 were multiplied by the highest monthly species density in the deepwater OECC segment and the SWDA for the 20–45 m depths, and by the highest monthly species density in the shallow water OECC segment for the 12 m depth. The result of the areas multiplied by the densities were then multiplied by the number of UXOs estimated at each of the depths to calculate total estimated exposures. The UXO removal processes for New England Wind are expected to be similar as the Ocean Wind 1 project, with the same commitment for a single detonation removal per 24-hour period to reduce accumulated sound exposures and to limit behavioral response.

J.6. Estimated Level A Exposures

SEL-based PTS exposures for potential UXO detonations are listed in Table J-6 as Level A exposures, below. Level A exposures are unlikely during UXO detonation, but possible. Table J-6 presents unmitigated and mitigated Level A exposure estimates for comparison. To reduce potential exposures, the use of NMS (e.g., bubble curtain system or other system) to achieve broadband noise attenuation is planned to be used during UXO detonations. NMS-use is expected to achieve a broadband attenuation level of 10 dB (Bellman et al. 2020; Bellmann and Betke 2021) and will minimize the size of the ensonified zones, thereby reducing the number of potential marine mammal PTS exposures.

Table J-6. Estimated potential maximum Level A exposures of marine mammals resulting from the possible detonations of up to 10 UXOs assuming both no attenuation and 10 dB of attenuation.

Species		Estimated Level A Exposures (PTS SEL)	
		No Attenuation	10 dB Attenuation
LF	Fin whale[a]	7.16	1.31
	Minke whale	5.19	0.95
	Humpback whale	8.26	1.51
	North Atlantic right whale[a,b]	17.37	3.17
	Sei whale[a]	0.93	0.17
MF	Atlantic white-sided dolphin	3.56	0.27
	Atlantic spotted dolphin	0.07	0.01
	Short-beaked common dolphin	16.36	1.25
	Bottlenose dolphin	10.80	0.90
	Risso's dolphin	0.03	0.00
	Long-finned pilot whale	0.33	0.03
	Short-finned pilot whale	0.25	0.02
	Sperm whale[a]	0.02	0.00
HF	Harbor porpoise[c]	1,120.62	165.32
PPW	Gray seal	74.86	8.91
	Harbor seal	168.18	20.01
	Harp seal	74.86	8.91

a Listed as Endangered under the Endangered Species Act.
b Level A exposures were estimated for this species, but due to mitigation measures (described in the New England Wind Letter of Authorization Request, Section 11), no Level A takes are expected.
c Potential Level A exposures for harbor porpoise with no attenuation were estimated using the distance to PK threshold (PTS = 16,098 m), which is larger than the distance to their PTS SEL threshold.

J.7. Estimated Level B Exposures

SEL-based TTS exposures for potential UXO detonations and are listed in Table J-7 as Level B exposures, below. The use of NMS and mitigation measures described in Section 11 of the New England Wind Letter of Authorization Request will reduce received sound levels and the size of the ensonified zones, thereby reducing the number of potential marine mammal TTS exposures.

Table J-7. Estimated potential maximum Level B exposures of marine mammals resulting from the possible detonations of up to 10 UXOs assuming both no attenuation and 10 dB of attenuation.

Species		Estimated Level B Exposures (TTS SEL)	
		No Attenuation	10 dB Attenuation
LF	Fin whale[a]	35.73	13.34
	Minke whale	25.95	9.68
	Humpback whale	41.54	15.48
	North Atlantic right whale[a]	86.49	32.30
	Sei whale[a]	4.62	1.73
MF	Atlantic white-sided dolphin	57.49	10.23
	Atlantic spotted dolphin	1.14	0.20
	Short-beaked common dolphin	264.31	47.01
	Bottlenose dolphin	165.33	30.33
	Risso's dolphin	0.42	0.07
	Long-finned pilot whale	5.39	0.96
	Short-finned pilot whale	3.98	0.71
	Sperm whale[a]	0.28	0.05
HF	Harbor porpoise[b]	4,209.95	801.06
PPW	Gray seal	670.08	180.73
	Harbor seal	1,505.48	406.05
	Harp seal	670.08	180.73

[a] Listed as Endangered under the Endangered Species Act.

[b] Potential Level B exposures for harbor porpoise with no attenuation were estimated using the distance to PK threshold (TTS = 31,202 m), which is larger than the distance to their TTS SEL threshold.

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Appendix K. Vibratory Pile Setting Exposure Analysis

Memo

DATE: 13 July 2022

Version: 4.0

FROM: Susan Dufault, Karlee Zammit, Madison Clapsaddle, and David Zeddies
(JASCO Applied Sciences [USA] Inc.

TO: Park City Wind, LLC

Subject: Marine Mammal Exposure Estimates for Vibratory Setting of Piles During New England Wind Construction

During construction of the New England Wind project, it may be necessary to start pile installation using a vibratory hammer rather than using an impact hammer, a technique known as vibratory setting of piles. The vibratory method is particularly useful when soft seabed sediments are not sufficiently stiff to support the weight of the pile during the initial installation, increasing the risk of ‘pile run’ where a pile sinks rapidly through seabed sediments. In foundation positions where sediment information indicates risk of pile run, vibratory pile driving may be used to support the pile, thus reducing the safety risk of this event. The vibratory hammer installation method can continue until the pile is inserted to a depth that is sufficient to fully support the structure, and then the impact hammer can be positioned and operated to complete the pile installation. The average expected duration of vibratory setting is approximately 30 minutes per pile for the New England Wind project.

New England Wind conducted a seabed drivability analysis to estimate the number of foundation positions that could potentially require vibratory setting of piles. The analysis suggested that up to 50% of foundations (~66 foundations) could require vibratory setting. Adding 20% conservatism to this estimate (20% of 66 is ~13 additional foundations) results in approximately 79 foundations that may require vibratory setting. This information was used to estimate the number of days of vibratory setting shown in the pile installation schedules provided in this memo.

K.1. Acoustic Ranges

The Proponent is not aware of publicly available acoustic measurements of vibratory pile driving of large (>2 m) monopiles. Vibratory driving of smaller 72-inch steel pipe piles has an apparent source level of SPL ~167-180 dB re 1 µPa at 10 m (Molnar et al. 2020). Recognizing that the maximum pile size of this Project is larger than 72 inches, it is assumed that these source levels may not be indicative of what would be measured during construction of the Project, so a method to estimate expected levels by extrapolation from smaller piles was used. Extrapolation of piling sound levels for larger piles has previously been conducted in Europe for impact pile driving (Bellmann et al. 2020). A similar approach has been used here, which is consistent with extrapolation work undertaken on other Avangrid Renewables projects in non-US jurisdictions.

Data for smaller piles are compiled in the GARFO Acoustics Tool (https://s3.amazonaws.com/media.fisheries.noaa.gov/2020-09/GARFO-Sect7-PileDriving-AcousticsTool-09142020.xlsx?.Egxagq5Dh4dpIwJQsmN1gV0nggnk5qX). Received SEL levels at 10 m for round steel pile driven with vibratory hammers was plotted as a function of pile diameter and fitted with a power function (method previously accepted by European authorities for impact piling extrapolation for Avangrid Renewables) (Figure 1). As seen in Figure 1, the power function represents the SEL trend as a function of pile diameter with an R^2 value of 0.6465 for piles 12 inches to 72 inches in diameter. Extrapolating to 13 m piles, with a diameter of 512 inches, results in a received level at 10 m of SEL ~198 dB re 1 µPa2·s (~188 dB re 1 µPa2·s assuming a noise attenuation system [NAS] and 10 dB of attenuation).

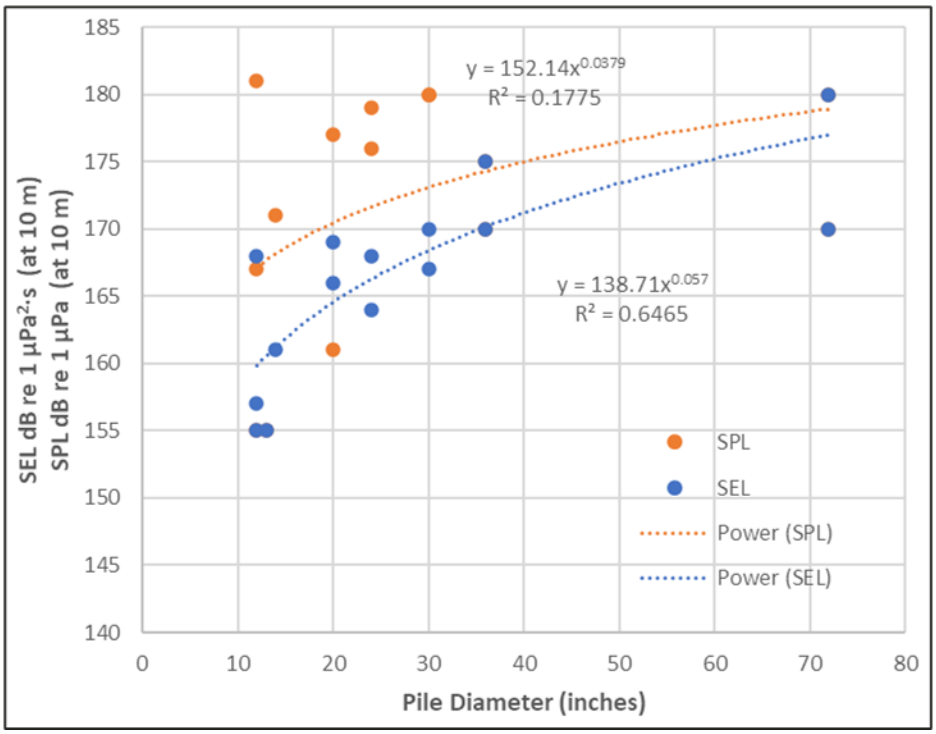

Figure 1. SEL (blue) and SPL (orange) received levels as a function of pile diameter, in inches, from the GARFO Acoustics Tool.

Assuming (1) a received SEL ~188 dB re 1 µPa2·s at 10 m for 13 m monopiles using NAS, (2) sound propagation by the practical spreading loss model (15 Log(range)), and (3) an average vibratory setting duration of 30 minutes per pile (1 hour per day assuming 2 monopiles), the PTS ranges calculated using the NMFS online User Spreadsheet Tool (NMFS 2020, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fmedia.fisheries.noaa.gov%2F2021-02%2F2020_BLANK_USER_SPREADSHEET_508_DEC.xlsx&wdOrigin=BROWSELINK) are as follows:

- LF cetaceans = 430.9 m
- MF cetaceans = 38.2 m
- HF cetaceans = 637.1 m

- Phocid pinnipeds = 261.9 m

Due to the small size of the PTS ranges and the mitigation that will be applied during construction, no Level A exposures are expected, nor have they been calculated for this activity.

The threshold criterion for Level B harassment for vibratory hammering, a non-impulsive sound, is 120 dB re 1µPa root mean square (rms) unweighted sound pressure level (SPL). The power function fit described above for the received SPL at 10 m is poor, so an alternative approach is needed. Noting that animals are not expected to experience a behavioral response at distances greater than 50 km (Dunlop et al. 2017a; Dunlop et al. 2017b), the source level necessary to produce a received level of 120 dB at 50 km was found. Assuming practical spreading loss (15 Log(range)), a source level of 190.5 dB will result in received levels of 120 dB at 50 km. Because vibratory driving of smaller 72-inch steel pipe piles has an apparent source level of SPL ~167-180 dB re 1 µPa at 10 m (Molnar et al. 2020), it is assumed that the sound levels for a 13 m pile could exceed the behavioral threshold to 50 km. All animals within a 50-km radius around a given foundation location would be exposed above the 120 dB SPL threshold for any given day on which vibratory setting was used for pile installation. Therefore, the acoustic range to the Level B threshold is 50 km, and the daily impact area is a circle with radius of 50 km (7,854 km^2).

K.2. Density Calculations

Monthly marine mammal densities in the potential impact area used the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the U.S. Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b). Densities in the MGEL/Duke models are provided as the number of animals per 100 square kilometers (animals/100 km^2) and given for each 10 × 10 km cell in the U.S. Atlantic for most species, with a cell size of 5 × 5 km for the North Atlantic right whale (NARW).

The monthly density of each species within the impact area was calculated as the average of all MGEL/Duke density cells overlapping partially or completely with a 50-km buffer around the Southern Wind Development Area (SWDA) (cells entirely on land were not included, but cells that overlap only partially with land were included).

Because the MGEL/Duke model for pilot whales considers long- and short-finned pilot whales together as the pilot whale guild, densities for these two species were scaled by their relative abundances using the following example equation:

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned}+a_{long-finned}}\right), \quad \text{(K-1)}$$

where d is density and a is abundance. Also note that the MGEL/Duke model for the pilot whale guild (Roberts et al. 2016a, 2016b, 2017) provides only an annual density, not monthly, so the densities for these two species are predicted annual densities.

Harbor and gray seals were similarly scaled by their relative abundances using the MGEL/Duke model for the seals guild (Roberts et al. 2016a, 2016b, 2018). The seals guild model is based primarily on harbor and gray seals and harp seals are considered uncommon in the area so lack sufficient data to provide a density estimate. As a conservative approach, the gray seal density (i.e., lesser of gray and harbor seal density) was used as a surrogate for harp seal density.

The monthly densities for each species used to estimate exposures above Level B acoustic thresholds during vibratory setting of piles for New England Wind are shown in Table K-1.

Table K-1. Mean monthly marine mammal density estimates for all modeled species in a 50-km buffer around the SWDA, used to calculate exposures above the 120 dB behavioral threshold for vibratory hammering sounds.

Species	Monthly density (animals/100 km^2)												Annual mean	May to Dec mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Fin whale[a]	0.173	0.169	0.193	0.331	0.327	0.334	0.348	0.316	0.276	0.183	0.148	0.151	0.246	0.260
Minke whale	0.055	0.068	0.070	0.166	0.268	0.240	0.095	0.062	0.064	0.080	0.029	0.040	0.103	0.110
Humpback whale	0.035	0.023	0.045	0.153	0.179	0.183	0.108	0.066	0.190	0.148	0.083	0.055	0.106	0.126
North Atlantic right whale[a]	0.517	0.607	0.640	0.694	0.276	0.020	0.003	0.002	0.003	0.008	0.045	0.247	0.255	0.076
Sei whale[a]	0.002	0.002	0.001	0.041	0.035	0.021	0.008	0.004	0.007	0.002	0.002	0.002	0.011	0.010
Atlantic white-sided dolphin	2.985	1.726	1.800	3.748	6.753	6.195	3.828	2.010	2.356	3.322	3.657	4.271	3.554	4.049
Atlantic spotted dolphin	0.002	0.001	0.003	0.013	0.027	0.050	0.092	0.127	0.127	0.179	0.066	0.008	0.058	0.084
Short-beaked common dolphin	15.796	4.541	2.212	4.236	6.703	8.475	7.293	10.472	14.493	17.788	13.446	20.900	10.530	12.446
Bottlenose dolphin, offshore	0.641	0.175	0.073	1.215	1.417	3.748	7.478	6.064	6.925	5.759	2.911	1.395	3.150	4.462
Risso's dolphin	0.044	0.025	0.013	0.016	0.036	0.052	0.116	0.213	0.136	0.052	0.051	0.086	0.070	0.093
Long-finned pilot whale[b]	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434	0.434
Short-finned pilot whale[b]	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320
Sperm whale[a]	0.005	0.006	0.005	0.008	0.012	0.014	0.032	0.030	0.012	0.011	0.009	0.004	0.012	0.015
Harbor porpoise	3.609	5.809	9.848	7.146	3.811	1.136	0.836	0.853	0.625	0.544	1.913	2.099	3.186	1.477
Gray seal[c]	3.446	2.735	2.749	5.640	5.551	1.733	0.386	0.199	0.228	0.474	1.138	3.669	2.329	1.672
Harbor seal[c]	7.743	6.145	6.176	12.672	12.471	3.893	0.866	0.447	0.513	1.065	2.556	8.244	5.233	3.757
Harp seal[c]	3.446	2.735	2.749	5.640	5.551	1.733	0.386	0.199	0.228	0.474	1.138	3.669	2.329	1.672

[a] Listed as Endangered under the ESA.

[b] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.

[c] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

K.3. Estimated Level B Exposures

The following were used to estimate potential Level B exposures for vibratory setting of piles:

- All animals within a 50-km radius around a given foundation location would be exposed above the 120 dB SPL threshold for any given day on which vibratory setting was used for pile installation.
- The daily impact area is a circle with radius of 50 km (7,854 km^2).
- Because of the long-expected ranges to the 120 dB behavioral threshold for continuous sound from vibratory hammering, it was assumed that all animals within a 50-km radius (7,854 km^2) around a given foundation location would be exposed above the 120 dB SPL threshold for any given day on which vibratory setting of piles was used.
- Each monthly density value was multiplied by the 7,854 km^2 impact area to estimate the number of exposures that could occur on a given day during each month in the May through December proposed pile installation period.
- Soil sediment data gathered during geotechnical coring campaigns in the SWDA were analyzed to estimate the number of project foundation positions that might be at risk for pile run. Approximately 50% of positions (~66 foundations) were determined to have the sediment conditions that might indicate a risk of pile run. A 20% contingency on this percentage was added to account for additional sediment data analysis or installation contractor-provided information (20% of 66 foundations, or 13 additional foundations). This brought the total number of positions to approximately 79.
- The daily Level B exposure estimates based on 79 foundation positions were multiplied by the number of days with vibratory setting of piles each month from the two construction schedules. The monthly exposures were then summed to get yearly exposure estimates as well as species-specific exposure estimates for the complete project buildout.

Daily exposure estimates above the 120 dB threshold criterion calculated using these assumptions and methods are shown in Table K-2 for each day of vibratory hammering depending on the month in which it occurs.

Table K-2. Density-based estimates of the number of marine mammals of each species that could be exposed to sound above the 120 dB behavioral threshold criterion per day of vibratory hammering based on their average monthly density within a 50 km buffer of the SWDA and assuming a range to threshold of 50 km.

Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fin whale	25.64	26.24	27.33	24.79	21.68	14.41	11.66	11.83
Minke whale	21.05	18.86	7.42	4.88	5.05	6.26	2.26	3.17
Humpback whale	14.06	14.41	8.47	5.20	14.94	11.60	6.49	4.29
North Atlantic right whale	21.64	1.59	0.26	0.18	0.23	0.60	3.55	19.41
Sei whale	2.72	1.63	0.59	0.30	0.54	0.13	0.17	0.17
Atlantic white-sided dolphin	530.39	486.55	300.64	157.90	185.06	260.91	287.23	335.47
Atlantic spotted dolphin	2.09	3.90	7.21	9.95	10.00	14.03	5.16	0.66
Short-beaked common dolphin	526.47	665.63	572.78	822.43	1138.26	1397.04	1056.03	1641.49
Bottlenose dolphin, offshore	111.26	294.39	587.33	476.27	543.86	452.33	228.60	109.54
Risso's dolphin	2.81	4.07	9.10	16.73	10.72	4.12	4.03	6.75
Long-finned pilot whale	34.11	34.11	34.11	34.11	34.11	34.11	34.11	34.11
Short-finned pilot whale	25.16	25.16	25.16	25.16	25.16	25.16	25.16	25.16
Sperm whale	0.91	1.10	2.49	2.35	0.96	0.86	0.72	0.31
Harbor porpoise	299.33	89.23	65.69	67.01	49.05	42.75	150.25	164.88
Gray seal	435.96	136.09	30.29	15.64	17.93	37.23	89.34	288.18
Harbor seal	979.49	305.75	68.05	35.14	40.28	83.64	200.72	647.47
Harp seal	435.96	136.09	30.29	15.64	17.93	37.23	89.34	288.18

The number of pile driving days during which vibratory setting could be used per month and per schedule as well as the total days per year and for the full project buildout are shown in Table K-3 and Table K-4. These were multiplied by the monthly exposure estimates to obtain exposures by year and for the full buildout of New England Wind.

Table K-3. Schedule A: Number of pile driving days during which vibratory setting may be required, used in exposure estimation.

Month	Schedule A		
	Year 1	Year 2	2-Year total
May	2	1	3
Jun	4	2	6
Jul	5	3	8
Aug	9	4	13
Sep	7	4	11
Oct	2	3	5
Nov	2	2	4
Dec	0	0	0
Total	31	19	50

Table K-4. Schedule B: Number of pile driving days during which vibratory setting may be required, used in exposure estimation.

Month	Schedule B			
	Year 1	Year 2	Year 3	3-Year total
May	2	1	1	4
Jun	4	4	1	9
Jul	7	8	3	18
Aug	7	8	3	18
Sep	4	7	3	14
Oct	3	3	1	7
Nov	1	1	1	3
Dec	0	0	0	0
Total	28	32	13	73

Table K-5 and Table K-6 show the number of animals that could be exposed above the Level B threshold during a single construction year and for the full buildout of the project using Construction Schedule A and Schedule B, respectively.

Table K-5. Construction Schedule A: Number of Level B exposures calculated for vibratory setting of piles, assuming vibratory hammering is required for 79 foundations and using a 50-km impact radius.

Species	Level B harassment exposure estimate		
	Year 1	Year 2	2-Year total
Fin whale	719.90	412.53	1,132.44
Minke whale	250.97	144.07	395.04
Humpback whale	315.64	196.61	512.25
North Atlantic right whale	62.48	36.14	98.62
Sei whale	22.00	11.85	33.85
Atlantic white-sided dolphin	8,322.95	5,134.42	13,457.37
Atlantic spotted dolphin	253.69	163.69	417.37
Short-beaked common dolphin	26,855.21	17,722.03	44,577.24
Bottlenose dolphin, offshore	13,792.05	8,356.74	22,148.79
Risso's dolphin	309.34	168.48	477.82
Long-finned pilot whale	1,057.36	648.06	1,705.43
Short-finned pilot whale	779.89	477.99	1,257.88
Sperm whale	49.68	27.82	77.51
Harbor porpoise	2,616.51	1,567.87	4,184.38
Gray seal	2,087.12	1,223.64	3,310.76
Harbor seal	4,689.21	2,749.21	7,438.42
Harp seal	2,087.12	1,223.64	3,310.76

Table K-6. Construction Schedule B: Number of Level B exposures calculated for vibratory setting of piles, assuming vibratory hammering is required for 79 foundations and using a 50-km impact radius.

Species	Level B harassment exposure estimate			
	Year 1	Year 2	Year 3	3-Year total
Fin whale	662.70	754.21	299.36	1,716.27
Minke whale	244.92	251.31	100.49	596.72
Humpback whale	282.46	326.89	132.38	741.73
North Atlantic right whale	58.98	38.47	29.39	126.85
Sei whale	20.93	20.72	8.95	50.60
Atlantic white-sided dolphin	8,026.92	8,510.24	3,495.86	20,033.03
Atlantic spotted dolphin	227.09	272.15	106.63	605.86
Short-beaked common dolphin	23,282.16	27,565.68	11,245.59	62,093.43
Bottlenose dolphin, offshore	12,606.33	15,190.23	5,908.96	33,705.52
Risso's dolphin	262.00	317.18	124.69	703.87
Long-finned pilot whale	955.04	1,091.47	443.41	2,489.92
Short-finned pilot whale	704.41	805.04	327.05	1,836.50
Sperm whale	47.21	54.02	20.97	122.20
Harbor porpoise	2,359.21	2,339.74	1,126.83	5,825.78
Gray seal	2,010.52	1,674.27	890.19	4,574.98
Harbor seal	4,517.11	3,761.66	2,000.03	10,278.79
Harp seal	2,010.52	1,674.27	890.19	4,574.98

K.4. Literature Cited

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Appendix L. Drilling Exposure Analysis

Memo

DATE: 13 July 2022

Version: 4.0

FROM: Susan Dufault, Karlee Zammit, Madison Clapsaddle, and David Zeddies (JASCO Applied Sciences [USA] Inc.

TO: Park City Wind LLC

Subject: Marine Mammal Exposure Estimates for Drilling Activities During Pile Installation for New England Wind

There may be instances during construction of New England Wind where large sub-surface boulders or hard sediment layers are encountered, requiring drilling to pass through these barriers. New England Wind conducted a seabed drivability analysis to estimate the number of foundation positions that could potentially require drilling during pile installation. The analysis suggested that up to 30% of foundations (~40 foundations) could require drilling. Adding 20% conservatism to this estimate (20% of 40 is ~8 foundations) results in approximately 48 foundations that may requiring drilling. This information was used to estimate the number of days of drilling shown in the pile installation schedules provided in this memo.

L.1. Acoustic Ranges

The Proponent is not aware of acoustic measurements of very large rotational drills specifically for this purpose, but comprehensive measurements of large seabed drills are available from projects in the Alaskan Chukchi and Beaufort Seas. In particular, measurements were made during use of mudline cellar drilling with a 6 m diameter bit (Austin et al. 2018). The mudline cellar is a circular area centered on an oil or gas well on the seabed for the purpose of placing well heads and blow-out preventers below the seafloor elevation. Mudline cellars are important in shallow arctic waters, where deep ice keels can destroy equipment that sits above the seafloor grade. Austin et al. (2018) measured SPL of ~140 dB re µPa at 1000 m and estimated the broadband source level for this device as 191 dB re µPa^{2}m^2 at 1 m. The source level that Austin et al. (2018) estimated did not assume practical spreading loss, so this source level is not used. When assuming practical spreading loss, the source level back-propagated to 1 m is 185 dB re µPa^{2}m^2.

The mudline cellar drilling in the Chukchi Sea was measured at a site with water depth 46 m, which is similar to depths at the deeper sections of the New England Wind project area. Seabed sediment geoacoustic properties differ: the Chukchi Sea drilling site had softer surface sediments with a 14.5 m thick top layer of constant sound speed 1630 m/s and density 1.45 g/cm^3, overlying more consolidated sediments with sound speed 2384 m/s and density 2.32 g/cm^3. In comparison, the New England Wind sediments are believed to consist of a top layer of about 15 m thickness with sound speed gradient 1650–

1830 m/s and density 1.87 g/cm^3, overlying more consolidated sands with a sound speed gradient from 1830–2140 m/s through the next 100 m and having density 1.87-2.04 g/cm^3. Overall, the Chukchi Sea surface sediments have a slightly lower sound speed and lower density than the New England Wind site, but the reverse is true for the deeper sediments. Overall, the acoustic reflectivity at lower frequencies is expected to be similar between these sites. The ocean sound speed profiles at both sites are slightly downward refracting in summer, when the activities were measured in the Chukchi and when most pile installations are planned to occur for New England Wind.

A separate modeling study that included mudline cellar drilling was performed to predict noise footprints of that operation in the Chukchi Sea (Quijano et al. 2019). This modeling study found the 120 dB re µPa SPL threshold occurred at a distance of 16 km, which included noise from several vessels near the drillsite on dynamic positioning. We assume that pile installation drilling produces similar sound levels as mudline cellar drilling, and, as a conservative measure, we will use the SPL of 140 dB re µPa at 1000 m (as measured by Austin et al. 2018) along with practical spreading loss to obtain an estimate of 21.5 km to the 120 dB re µPa threshold. If assuming the back-propagated SPL of 185 dB re µPa at 1 m described above, the range to the 120 dB re µPa threshold is the same.

Assuming (1) a sound source level of 185 dB re 1 µPa2·s at 1 m for drilling (2) sound propagation by the practical spreading loss model (15 Log(range)), and (3) 12 hours of drilling per pile (24 hours per day assuming 2 monopiles), the PTS ranges calculated using the NMFS online User Spreadsheet Tool (NMFS 2020, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fmedia.fisheries.noaa.gov%2F2021-02%2F2020_BLANK_USER_SPREADSHEET_508_DEC.xlsx&wdOrigin=BROWSELINK) are as follows:

- LF cetaceans = 226.2 m
- MF cetaceans = 20.1 m
- HF cetaceans = 334.5 m
- Phocid pinnipeds = 137.5 m

Due to the small size of the PTS ranges and the mitigation that will be applied during construction, no Level A exposures are expected, nor have they been calculated for this activity.

The threshold criterion for Level B harassment for drilling, a non-impulsive sound, is 120 dB re 1µPa root mean square (rms) unweighted sound pressure level (SPL). Assuming practical spreading loss (15 Log(range)), a measured SPL of ~140 dB re µPa at 1000 m (Austin et al. 2018) will result in received levels of 120 at 21.5 km. All animals within a 21.5-km radius around a given foundation location would be exposed above the 120 dB SPL threshold for any given day during which drilling is used for pile installation. Therefore, the acoustic range to the Level B threshold is 50 km, and the daily impact area is a circle with radius of 21.5 km (1,452 km^2).

L.2. Density Calculations

Monthly marine mammal densities in the potential impact area used the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the U.S. Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b). Densities in the MGEL/Duke models are provided as the number of animals per 100 square kilometers (animals/100 km^2) and given for each 10 × 10 km cell in the U.S. Atlantic for most species, with a cell size of 5 × 5 km for the North Atlantic right whale (NARW).

The monthly density of each species within the impact area was calculated as the average of all MGEL/Duke density cells overlapping partially or completely with a 21.5-km buffer around the Southern Wind Development Area (SWDA) (cells entirely on land were not included, but cells that overlap only partially with land were included).

Because the MGEL/Duke model for pilot whales considers long- and short-finned pilot whales together as the pilot whale guild, densities for these two species were scaled by their relative abundances using the following example equation:

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned}+a_{long-finned}}\right), \quad \text{(L-1)}$$

where *d* is density and *a* is abundance. Also note that the MGEL/Duke model for the pilot whale guild (Roberts et al. 2016a, 2016b, 2017) provides only an annual density, not monthly, so the densities for these two species are predicted annual densities.

Harbor and gray seals were similarly scaled by their relative abundances using the MGEL/Duke model for the seals guild (Roberts et al. 2016a, 2016b, 2018). The seals guild model is based primarily on harbor and gray seals and harp seals are considered uncommon in the area so lack sufficient data to provide a density estimate. As a conservative approach, the gray seal density (i.e., lesser of gray and harbor seal density) was used as a surrogate for harp seal density.

The monthly densities for each species used to estimate exposures above Level B acoustic thresholds for drilling during pile installation for New England Wind are shown in Table L-1.

Table L-1. Mean monthly marine mammal density estimates for all modeled species in a 21.5-km buffer around the SWDA, used to calculate exposures above the 120 dB SPL behavioral threshold for drilling sounds.

Species	Monthly density (animals/100 km^2)												Annual mean	May to Dec mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Fin whale[a]	0.187	0.169	0.169	0.310	0.325	0.322	0.351	0.325	0.263	0.157	0.140	0.145	0.239	0.254
Minke whale	0.063	0.079	0.081	0.172	0.258	0.236	0.085	0.059	0.061	0.073	0.033	0.046	0.104	0.106
Humpback whale	0.030	0.018	0.031	0.177	0.157	0.153	0.132	0.076	0.255	0.174	0.062	0.032	0.108	0.130
North Atlantic right whale[a]	0.618	0.725	0.755	0.827	0.329	0.021	0.004	0.003	0.003	0.009	0.048	0.262	0.300	0.085
Sei whale[a]	0.002	0.002	0.001	0.043	0.040	0.021	0.006	0.003	0.007	0.001	0.002	0.002	0.011	0.010
Atlantic white-sided dolphin	3.422	1.941	2.083	4.272	7.876	7.453	4.888	2.677	2.895	3.786	4.011	5.182	4.207	4.846
Atlantic spotted dolphin	0.002	0.002	0.003	0.013	0.024	0.045	0.081	0.140	0.136	0.131	0.068	0.009	0.054	0.079
Short-beaked common dolphin	13.980	2.789	1.142	2.777	5.146	5.524	5.748	10.010	16.618	18.872	13.322	23.055	9.915	12.287
Bottlenose dolphin, offshore	0.576	0.058	0.019	0.551	0.598	0.869	1.812	1.605	2.860	3.145	1.485	0.812	1.199	1.648
Risso's dolphin	0.019	0.009	0.004	0.004	0.013	0.015	0.039	0.076	0.056	0.020	0.025	0.044	0.027	0.036
Long-finned pilot whale[b]	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502	0.502
Short-finned pilot whale[b]	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370
Sperm whale[a]	0.002	0.003	0.002	0.003	0.004	0.009	0.034	0.034	0.011	0.010	0.008	0.002	0.010	0.014
Harbor porpoise	4.624	7.291	13.845	9.142	4.362	1.022	0.725	0.670	0.550	0.523	1.304	2.214	3.856	1.421
Gray seal[c]	1.180	2.327	2.411	2.834	3.529	0.452	0.095	0.055	0.088	0.130	0.091	0.511	1.142	0.619
Harbor seal[c]	2.650	5.228	5.417	6.368	7.928	1.015	0.214	0.124	0.198	0.293	0.204	1.149	2.566	1.391
Harp seal[c]	1.180	2.327	2.411	2.834	3.529	0.452	0.095	0.055	0.088	0.130	0.091	0.511	1.142	0.619

[a] Listed as Endangered under the ESA.
[b] Long- and short-finned pilot whale densities are the annual pilot whale guild density scaled by their relative abundances.
[c] Gray and harbor seal densities are the seals guild density scaled by their relative abundances; gray seals are used as a surrogate for harp seals.

L.3. Estimated Level B Exposures

The following were used to estimate potential Level B exposures for drilling that may be required during pile installation:

- All animals within a 21.5-km radius around a given foundation location were assumed to be exposed above the 120 dB SPL threshold for any given day on which drilling was used during pile installation.
- The daily impact area is a circle with radius of 21.5 km (1,452 km^2).
- Because of the long-expected ranges to the 120 dB behavioral threshold for non-impulsive sound from drilling, it was assumed that all animals within a 21.5-km radius (1,452 km^2) around a given foundation location would be exposed above the 120 dB SPL threshold for any given day on which drilling was used during pile installation.
- Each monthly density value was multiplied by the 1,452 km^2 impact area to estimate the number of exposures that could occur on a given day during each month in the May through December proposed pile driving period.
- Soil sediment data gathered during geotechnical coring campaigns in the SWDA were analyzed to estimate the number of project foundation positions that might be at risk for encountering boulders or hard sediments causing pile refusal. Approximately 30% of positions (~40 foundations) were determined to have the sediment conditions that might indicate a risk of boulder encounter or pile refusal. A 20% contingency on this percentage was added to account for additional sediment data analysis or installation contractor-provided information (20% of 40 foundations, or 8 additional foundations). This brought the total number of positions to approximately 48.
- The daily Level B exposure estimates based on 48 foundation positions were multiplied by the number of piling days each month from the two construction schedules where drilling might be used during installation. The monthly exposures were then summed to get yearly exposure estimates as well as species-specific exposure estimates for the complete project buildout.

Daily exposure estimates above the 120 dB threshold criterion calculated based on these methods are shown in Table L-2 for each day of drilling depending on the month in which it occurs.

Table L-2. Density-based estimates of the number of marine mammals of each species that could be exposed to sound above the 120 dB behavioral threshold criterion per day of drilling based on their average monthly density within a 21.5 km buffer of the SWDA and assuming a range to threshold of 21.5 km.

Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fin whale	4.72	4.67	5.10	4.72	3.81	2.29	2.04	2.11
Minke whale	3.74	3.43	1.23	0.86	0.89	1.06	0.47	0.67
Humpback whale	2.28	2.22	1.92	1.10	3.70	2.53	0.90	0.47
North Atlantic right whale	4.78	0.31	0.05	0.04	0.05	0.13	0.69	3.80
Sei whale	0.58	0.31	0.08	0.05	0.09	0.02	0.03	0.02
Atlantic white-sided dolphin	114.37	108.21	70.97	38.88	42.03	54.97	58.25	75.25
Atlantic spotted dolphin	0.35	0.66	1.17	2.03	1.97	1.90	0.99	0.13
Short-beaked common dolphin	74.72	80.21	83.46	145.35	241.30	274.02	193.43	334.76
Bottlenose dolphin, offshore	8.69	12.61	26.32	23.31	41.53	45.66	21.56	11.79
Risso's dolphin	0.19	0.22	0.57	1.11	0.82	0.28	0.37	0.64
Long-finned pilot whale	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29
Short-finned pilot whale	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Sperm whale	0.06	0.13	0.49	0.49	0.15	0.15	0.12	0.03
Harbor porpoise	63.34	14.85	10.52	9.72	7.99	7.59	18.93	32.15
Gray seal	51.24	6.56	1.38	0.80	1.28	1.89	1.32	7.42
Harbor seal	115.11	14.74	3.11	1.80	2.88	4.25	2.97	16.68
Harp seal	51.24	6.56	1.38	0.80	1.28	1.89	1.32	7.42

The number of days per month and year during which drilling may be required during pile installation are shown in Table L-3 and Table L-4, respectively.

Table L-3. Schedule A: Number of pile driving days during which drilling may be required, used in exposure estimation.

Month	Schedule A		
	Year 1	Year 2	2-Year total
May	2	1	3
Jun	4	2	6
Jul	7	2	9
Aug	7	4	11
Sep	8	2	10
Oct	3	2	5
Nov	2	2	4
Dec	0	0	0
Total	33	15	48

Table L-4. Schedule B: Number of pile driving days during which drilling may be required, used in exposure estimation.

Month	Schedule B			
	Year 1	Year 2	Year 3	3-Year total
May	2	1	1	4
Jun	4	4	2	10
Jul	3	4	2	9
Aug	4	4	1	9
Sep	4	4	1	9
Oct	2	1	1	4
Nov	1	1	1	3
Dec	0	0	0	0
Total	20	19	9	48

Table L-5 and Table L-6 show the number of animals that could be exposed above the Level B threshold during a single construction year and for the full buildout of the project using Construction Schedule A and Schedule B, respectively, and assuming drilling is required during pile driving for 48 foundations.

Table L-5. Construction Schedule A: Number of Level B exposures calculated for drilling during pile installation, using a 21.5-km impact radius.

Species		Year 1	Year 2	All Years Combined
LF	Fin whale[a]	138.31	59.42	197.73
	Minke whale	47.08	21.35	68.43
	Humpback whale	73.61	29.24	102.86
	North Atlantic right whale[a]	13.55	7.38	20.93
	Sei whale[a]	4.15	1.82	5.97
MF	Atlantic white-sided dolphin	2,048.15	938.73	2,986.88
	Atlantic spotted dolphin	49.17	21.84	71.01
	Short-beaked common dolphin	5,211.25	2,400.95	7,612.20
	Bottlenose dolphin, offshore	927.56	397.29	1,324.85
	Risso's dolphin	21.18	9.16	30.33
	Long-finned pilot whale	240.45	109.29	349.74
	Short-finned pilot whale	177.35	80.61	257.96
	Sperm whale[a]	9.39	4.09	13.49
HF	Harbor porpoise	452.36	222.00	674.36
PPW	Gray seal	162.58	79.32	241.90
	Harbor seal	365.27	178.21	543.48
	Harp seal	162.58	79.32	241.90

[a] Listed as Endangered under the Endangered Species Act.

Table L-6. Construction Schedule B: Number of Level B exposures calculated for drilling during pile installation, using a 21.5-km impact radius.

Species		Year 1	Year 2	Year 3	All Years Combined
LF	Fin whale[a]	84.17	82.27	37.12	203.56
	Minke whale	34.49	30.92	16.35	81.75
	Humpback whale	44.39	41.49	18.79	104.67
	North Atlantic right whale[a]	12.22	7.37	6.40	25.99
	Sei whale[a]	3.26	2.75	1.55	7.56
MF	Atlantic white-sided dolphin	1,366.30	1,267.93	666.85	3,301.08
	Atlantic spotted dolphin	27.63	26.56	10.90	65.08
	Short-beaked common dolphin	3,008.71	2,743.43	1,256.15	7,008.30
	Bottlenose dolphin, offshore	519.02	490.99	218.61	1,228.61
	Risso's dolphin	11.62	11.72	4.35	27.70
	Long-finned pilot whale	145.73	138.44	65.58	349.74
	Short-finned pilot whale	107.48	102.11	48.37	257.96
	Sperm whale[a]	5.09	5.37	2.20	12.66
HF	Harbor porpoise	322.60	262.20	158.32	743.11
PPW	Gray seal	146.30	94.56	72.42	313.27
	Harbor seal	328.70	212.44	162.70	703.84
	Harp seal	146.30	94.56	72.42	313.27

[a] Listed as Endangered under the Endangered Species Act.

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Appendix B. Level B Take Estimation using Wood et al. (2012) Criteria

An extensive review of behavioral responses to sound was undertaken by Southall et al. (2007). They found varying responses for most marine mammals between sound pressure levels (SPL) of 140 and 180 dB re 1 µPa, but a lack of convergence in the data prevented them from suggesting explicit step functions. Behavioral response criteria were reviewed again recently by Southall et al. (2021), who suggested incorporating new methodological developments into data collection for behavioral response assessment but did not recommend new behavioral exposure criteria. They do, however, advocate for analysis and reporting of a broader range of noise exposure conditions, rather than a single received level metric, and for the use of noise exposure metrics that are context and subject specific. Tyack and Thomas (2019) explored using a dose–response function to evaluate behavioral responses, whereby the probability of an animal responding is a function of the received sound level at a given distance from the source. They provide a simple example showing how using a single sound metric could grossly underestimate the number of animals affected in comparison with the dose–response function.

The Wood et al. (2012) behavioral response criteria (see Table 20) include a graded probability of response approach that takes into account the frequency dependence of animal hearing sensitivity using the M-weighting functions proposed by Southall et al. (2007). The application of marine mammal auditory weighting functions emphasizes the importance of taking measurements and characterizing sound sources in terms of their overlap with biologically important frequencies. Wood et al. (2012) also designated behavioral response categories for sensitive species (including harbor porpoises and beaked whales) and for migrating mysticetes. Although not definitive, these criteria provide a first step toward considering context and subject-specific behavioral reactions to sound as well as considering the sound frequencies used by the animals.

NMFS currently uses a single behavioral response threshold of 160 dB re 1 µPa SPL for impulsive sound, and thus the Level B take requested in this LOA application uses model-predicted exposure estimates based on this threshold. However, the JASCO modeling conducted in support of this LOA application included both the NMFS 160 dB re 1 µPa criterion and the Wood et al. (2012) step function to predict marine mammal exposures above threshold. Detailed results of this modeling can be found in Appendix A. A comparison of the exposure estimates derived from these two behavioral acoustic criteria are shown in Tables 28–34 of Section 6.2.5. This appendix provides Level B take estimates using the Wood et al. (2012) criteria for comparison with those requested as an alternate approach to estimating Level B takes that includes species group specific context. The Wood et al. (2012) 50% response level thresholds of 120 dB for sensitive species (harbor porpoise), 140 dB for migrating mysticetes (minke and sei whales), and 160 dB for all other species were used to calculate acoustic ranges. For exposure estimates, the response probabilities shown in Table 20 were used for the different marine mammal groups. For example, for migrating mysticetes the model counts 10% of animats exposed to SPL 120 dB, 50% of animats exposed to SPL 140 dB, and 90% of animats exposed to SPL 160 dB as receiving Level B harassment.

Estimated Level B takes from impact pile driving using the Wood et al. (2012) criteria are shown in Table B-1. The take calculations use the same methodology as outlined in Section 6, except for application of the different threshold criteria. Using the Wood et al. (2012) criteria increases the estimated Level B takes for the sensitive harbor porpoise and for migrating mysticete whales substantially over what would be expected using the single 160 dB SPL metric. Additionally, all other species' Level B takes can be increased to a lesser degree because 10% of animats are counted as receiving Level B harassment at SPL 140 dB using the Wood et al. (2012) criteria (Table 20).

Table B-1. Number of Level B takes[a] calculated for impact pile driving for modeled species by species and year based on results of acoustic and exposure modeling assuming 10 dB sound attenuation and using the Wood et al. (2012) behavioral response criteria.

Species		Population size	2025[b]	2026	2027	2028–2029	5-Year total
LF	Fin whale[c]	6,802	38	37	16	0	79
	Minke whale	21,968	108	148	66	0	301
	Humpback whale	1,396	19	16	8	0	35
	North Atlantic right whale[c]	368	7	6	2	0	12
	Sei whale[c]	6,292	11	11	6	0	25
MF	Atlantic white-sided dolphin	93,233	521	874	365	0	1,639
	Atlantic spotted dolphin	39,921	30	30	30	0	90
	Short-beaked common dolphin[c]	172,974	2,239	3,177	1,320	0	5,738
	Bottlenose dolphin, offshore	6,2851	118	174	74	0	316
	Risso's dolphin	35,215	7	7	7	0	21
	Long-finned pilot whale	39,215	65	98	41	0	182
	Short-finned pilot whale	28,924	49	73	31	0	136
	Sperm whale[c]	4,349	2	3	2	0	6
HF	Harbor porpoise	95,543	2,807	2,741	1274	0	5,869
PPW	Gray seal	27,300	27	35	7	0	61
	Harbor seal	61,336	53	71	21	0	124
	Harp seal	7,600,000	30	39	11	0	68

[a] Take calculation assumptions are described in Section 6.7.1.1.

[b] For the purpose of this LOA request, Year 1 is assumed to be 2025. These dates reflect the currently projected construction start year and are subject to change because exact project start dates and construction schedules are not currently available.

[c] Listed as Endangered under the ESA.

Appendix C. Framework for Sound Field Verification Plan

C.1. Introduction

Park City Wind LLC (the Proponent) has developed this framework for a sound field verification (SFV) plan for the proposed piled foundation installation activities associated with New England Wind. Sound field verification will include underwater sound measurements during foundation installation to confirm that the sound propagation predicted by hydroacoustic modeling is comparable to, or lower than, measured sound in the field. Such confirmation will help demonstrate that estimated exposures of marine mammals and sea turtles were appropriately predicted.

C.2. Proposed Measurement Plan Framework

The following summarizes the proposed framework for the underwater noise measurement plan:

- All measurements will be performed according to the ISO 18406:2017 standard.
- SFV measurements will be conducted during pile installation with noise attenuation activated. A minimum of three monopile foundation positions and two jacket foundation positions will be measured for comparison with model results. (Note that this will include measurements for the full jacket foundation [three (3) or four (4) pin piles].)
- Foundation positions selected for SFV will be a representative sampling of the project installations. The positions will be agreed with the Federal agencies during the development of the New England Wind SFV Plan.
- Additional SFV measurements may be taken if the Proponent obtains technical information that suggests a subsequent foundation, or foundations, may produce larger sound fields. Additional SFV positions with be agreed with the Federal agencies.
- Sound arising from foundation installation will be measured using acoustic recorders with calibrated omnidirectional hydrophones capable of measuring frequencies between 20 Hz and 20 kHz.
- For SFV, acoustic recorders, each with two hydrophones, will be placed at three measurement distances from the pile (see Figure 1). The two hydrophones will be positioned at different depths in the water column based on the advice of the to-be-selected acoustic consultant. Potential options may include recorders positioned on the seabed or on an autonomous surface vehicle. Hydrophones may then either be floated in the water column using a taut-line mooring with buoyancy (generally at mid-depth in the water column and approximately 2 m above the seafloor), with or without a surface expression, or on a weighted line from the surface. The selected configuration will be described in the SFV Plan. The as-placed position of each hydrophone will be recorded.
- Acoustic recorders will be stationed at various distances from the pile location. Three measurement locations are currently proposed (see Figure 1 for example placement locations). The exact horizontal distances from the pile will be determined in consultation with the to-be-selected acoustic consultant and Federal agency staff. Final measurement locations will contemplate decision influencing variables, including industry standards (e.g., 750 m is a standard for SFV in Europe), modeled distances to Level A and B thresholds, and acoustic conditions at the selected foundation position. Measurement

distances will be agreed in a SFV Plan submitted to regulatory agencies prior to construction. Hydrophone placement will be the same for all SFV measurement locations.

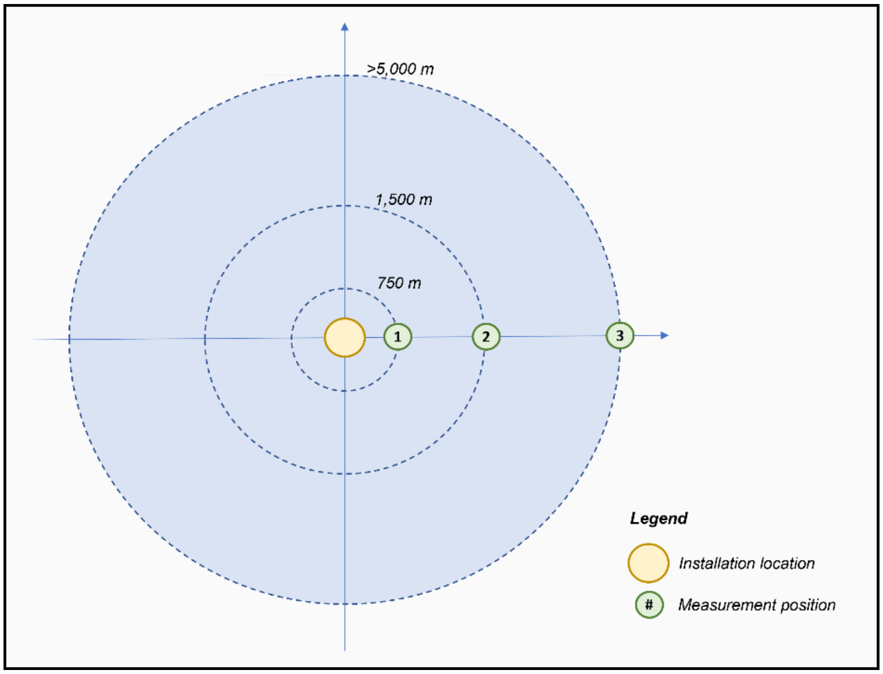

Figure C-1. Representation of example sound field verification measurement locations. Depicted locations are examples and are subject to change.

- The Proponent will provide the initial results of the SFV measurements to NMFS in an interim report as soon as they are available but no later than 48 hours after each installation.
- Final SFV results will be submitted to NMFS as soon as practicable, and no later than within 90 days following completion of impact pile driving.
- A SFV Plan will be submitted to NMFS for review and approval at least 90 days prior to planned start of pile driving.

C.3. Level A Harassment and Level B Harassment Zone Distance Verification

The Proponent will conduct a SFV to empirically determine the distances to the isopleths corresponding to Level A harassment and Level B harassment thresholds for impact pile driving of foundations. This will be done either by extrapolating from in situ measurements conducted at several points from the pile being driven, or by direct measurements to locate the distance where the received levels reach the relevant Level A harassment and Level B harassment thresholds. For verification of the distance to the Level B harassment threshold, the Proponent will report the measured or extrapolated distances where the received sound pressure levels (SPL) decay to 160 dB, as well as integration time for such SPL.

If needed, based on the SFV-informed distances to Level A and Level B harassment thresholds, the adaptive refinement of Clearance Zones, Shutdown Zones and monitoring and mitigation measures (either a decrease or an increase) will be agreed with the Federal agencies. If the initial SFV measurements indicate distances to the isopleths corresponding to Level A harassment and Level B harassment thresholds are greater than the predicted distances (based on modeling assuming 10 dB attenuation), the Proponent will implement additional sound attenuation measures prior to conducting additional pile driving. Such additional measures may first include improving the efficacy of the implemented noise attenuation technology and/or adjusting the piling schedule to reduce the sound source. If these corrective actions do not result in achieving the predicted zones, the Proponent will install an additional noise attenuation system to achieve the modeled ranges and/or will deploy additional observation tools. Each sequential modification will be evaluated empirically by SFV. If SFV measurements continue to indicate distances to isopleths corresponding to Level A harassment and Level B harassment thresholds are consistently larger than those predicted by modeling, the Proponent may request that NMFS expand the relevant clearance and shutdown zones and associated monitoring measures.

Appendix D. Distances to Acoustic Threshold for High Resolution Geophysical Sources

Distances to Acoustic Thresholds for High Resolution Geophysical Sources

New England Wind HRG Incidental Harassment Authorization Calculations

Submitted to:
Cynthia Pyć (Avangrid)

Authors:
Matthew Koessler
Zizheng Li

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Distance to Acoustic Thresholds for High Resolution Geophysical Sources

I.1. Methods

In this analysis, we compute horizontal impact ranges for High-Resolution Geophysical (HRG) sound sources. We consider both the contribution from the main lobe (in-beam) energy of the source, which is directed toward the seafloor, as well as side-lobe (out-of-beam) energy that propagates horizontally (see Figure I-1). The larger of these two is reported.

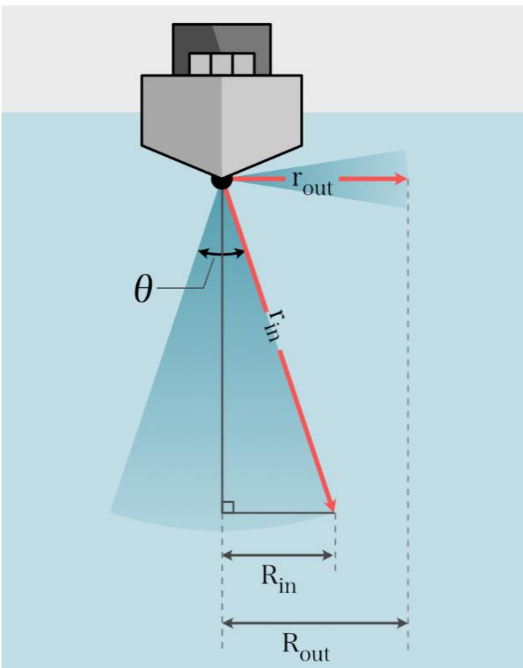


Figure I-1. Geometry used in computing horizontal impact ranges based on in-beam and out-of-beam energy.

Our methodology for computing the horizontal component of the main lobe follows the approach described by NMFS (2019) and Guan (2020). We elected to focus on the more conservative case wherein depth is not limited, which allows for more operational flexibility. For computing the horizontal extent of side-lobe energy, we start with a lower source level and assume that the sound energy propagates horizontally. Propagation loss in both cases is estimated using a modified spreading equation.

Section I.1.1 provides an overview of calculations. Sections I.1.2 and I.1.3 describe how Level A and Level B ranges are determined.

I.1.1. Calculation Summary

Propagation Loss

The sonar equation is used to calculate the received sound pressure level:

$$SPL(r) = SL - PL(r), \tag{I-1}$$

where *SPL* is the sound pressure level (dB re 1 µPa), *r* is the distance (slant range) from the source (m), *SL* is the source level (dB re 1 µPa m), and *PL* is the propagation loss as a function of distance. The propagation loss is calculated using a modified spreading equation:

$$PL(r) = 20\log_{10}\left(\frac{r}{1\text{ m}}\right)\text{ dB} + \alpha(f)\cdot r/1000, \tag{I-2}$$

where $\alpha(f)$ is the absorption coefficient (dB/km) and f is frequency (kHz). The absorption coefficient is approximated by discarding the boric acid term from Ainslie (2010; p29; eq 2.2):

$$\alpha(f) \approx 0.000339f^2 + 48.5f^2/(75.6^2 + f^2)\,. \tag{I-3}$$

When a range of frequencies is produced by a source, we use the lowest frequency to determine the absorption coefficient.

The predicted received level is used to determine the distance at which a threshold level is reached (i.e., solving Equation I-1 for slant range r).

Horizontal range estimation

For a downward-pointing source with a beam width less than 180°, the horizontal impact distance (R_{in}) is calculated from the in-beam slant range using:

$$R_{in} = r_{in}\cdot\sin\left(\frac{\delta\theta}{2}\right), \tag{I-4}$$

where $\delta\theta$ is the -3 dB beamwidth.

To account for energy emitted outside of the primary beam of the source, we estimate a representative out-of-beam source level and propagate the energy horizontally (see Figure I-1). In this method, the horizontal component R_{out} of the out-of-beam energy is equivalent to the out-of-beam slant range:

$$R_{out} = r_{out}. \tag{I-5}$$

The larger of the two horizontal range estimates was then selected for assessing impact distance (presented in Section I.4):

$$R = \max(R_{in}, R_{out}). \tag{I-6}$$

For an omni-directional source the horizontal impact distance (*R*) was calculated based on horizontally propagating energy (i.e., this is equivalent to a beamwidth of 180°).

Out-of-beam source level adjustment

Side lobe energy is generally lower than the main lobe energy. An estimate of the reduction relative to the main lobe energy was generated as a function of the main lobe beam width. Separate approaches were taken for narrow-beam sources (up to 36° beam width), intermediate-beam sources (36° to 90° beam width), and broad-beam sources. Broad-beam sources were treated as omni-directional and had no out-of-beam reduction. The out-of-beam reduction for narrow beam sources was approximated using a theoretical beam pattern. The out-of-beam reduction for intermediate-beam sources was interpolated between the other two approximations.

The narrow-beam side lobe level reduction is estimated by taking the arithmetic average of the upper and lower bounds of the sidelobe levels of an unshaded circular transducer beam pattern. This beam pattern $b(u)$ is described as:

$$b(u) = (2\ J_1(u)/u)^2, \tag{I-7}$$

where $J_1(u)$ is a first order Bessel function of the first kind, whose argument is a function of off-axis angle θ and beam width (full width at half maximum) $\delta\theta$

$$u = u_0 \frac{\sin\theta}{\sin\frac{\delta\theta}{2}}, \tag{I-8}$$

where $u_0 = 1.614$.

For the upper limit we choose the highest sidelobe level of the beam pattern, given by (Ainslie 2010; p265; Table 6.2)

$$B_{\max} = -17.6 \text{ dB}. \tag{I-9}$$

For the lower limit we consider the asymptotic behavior of the beam pattern in the horizontal direction

$$J_1(u) \sim \sqrt{\frac{2}{\pi u}} \cos\left(u - \frac{3\pi}{4}\right), \tag{I-10}$$

where

$$u = \frac{u_0}{\sin\frac{\delta\theta}{2}}. \tag{I-11}$$

In this way we obtain the lower limit as

$$B_{\min} = 10\log_{10}\left(\frac{8}{\pi\, u_0^3}\sin^3\frac{\delta\theta}{2}\right)\text{dB}. \tag{I-12}$$

Finally, the out-of-beam source level is found by reducing the in-beam source level by the arithmetic mean of $B_{\min}$ and $B_{\max}$. The resulting correction as a function of beam width is shown in Figure I-2. Note that narrower beam sources have a larger reduction in side lobe levels than wider beam sources.

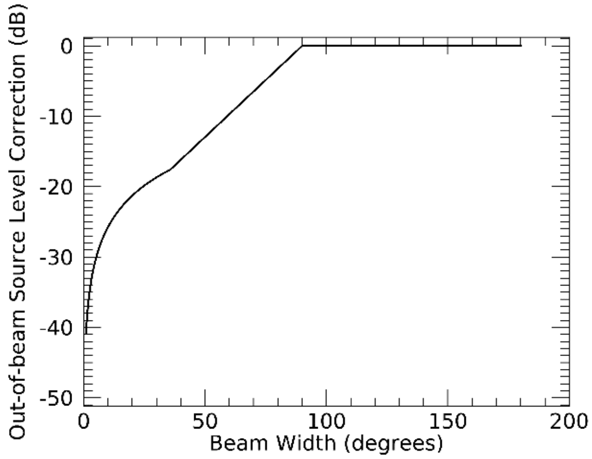


Figure I-2. Correction for calculating out-of-beam source level (i.e., in the horizontal direction) from in-beam source level, as a function of main lobe beam width.

The out-of-beam source level for a given HRG source was calculated by adding the dB correction (Figure I-2) to the in-beam source level. The corrections computed for the sources considered in this study can be found in Table I-4.

I.1.2. Level A

This section describes the methods used to estimate the horizontal distances to the National Marine Fisheries Service (NMFS) acoustic thresholds for injury (Table I-1). There are different thresholds for impulsive and non-impulsive sounds. According to Southall et al. (2007), "Harris (1998) proposed a measurement-based distinction of pulses and non-pulses that is adopted here in defining sound types. Specifically, a ≥3-dB difference in measurements between continuous and impulse [sound level meter] setting indicates that a sound is a pulse; a <3 dB difference indicates that a sound is a non-pulse. We note the interim nature of this distinction for underwater signals and the need for an explicit distinction and measurement standard such as exists for aerial signals (ANSI 1986)."

Classification of impulsive signals is inconsistent across standards, criteria, and guidance. Southall et al. (2007), Finneran et al. (2017), and NMFS (2018) each have different criteria for classifying a signal as impulsive or non-impulsive. The Southall et al. (2007) method described above was used for all of the sources analyzed in this work. Finneran et al. (2017) state that harmonic signals with more than 10 cycles in a pulse are considered steady state (i.e., non-impulsive). NMFS (2018) cites the standard for measurement of sound levels in air (ANSI 2010), but removes the quantitative criteria resulting in a definition that impulsive sound sources "produce sounds that are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay." The ANSI (2010) classification, while more specific than NMFS (2018), does not preclude harmonic signals, especially frequency modulated signals, from being classified as impulsive.

NMFS has determined that deep seismic profilers such as sparkers and boomers are classified as impulsive sources. This classification is based on NMFS' qualitative assessment of the generated waveforms (pers comm, Benjamin Laws [NMFS] 2020).

Table I-1. Peak sound pressure level (PK, dB re 1 µPa) and sound exposure level (SEL, dB re 1 µPa²·s) thresholds for injury (PTS onset) for marine mammals for impulsive sound sources (NMFS 2018).

Functional hearing group	Impulsive source	
	PK	Weighted SEL_{24h}
Low-frequency cetaceans (LFC)	219	183
Mid-frequency cetaceans (MFC)	230	185
High-frequency cetaceans (HFC)	202	155
Phocid pinnipeds in water (PPW)	218	185
Otariid pinnipeds in water (OPW)	232	203

NMFS provides a spreadsheet to calculate these distances, but it is not designed for high-resolution geophysical survey sources. The spreadsheet does not consider seawater absorption or beam patterns, both of which can substantially influence received sound levels. In order to account for these effects, we model sound levels using Equations I-1 to I-12, as follows.

Distances to peak thresholds were calculated using the peak source level and applying propagation loss from Equation A-2. Peak levels were assessed for both in-beam and out-of-beam levels (the latter was assessed using the out-of-beam source level correction described previously).

Range to SEL thresholds were calculated for source locations along a hypothetical survey line. Source spacing was determined from the assumed vessel speed of 3.5 kts and the repetition rate for each source. A single set of fixed receiver locations extended perpendicularly from the middle of the survey line. The propagation loss between each source and receiver pair was calculated (Equation I-2), and then using the appropriate (in beam or out of beam) weighted source level and pulse length (Figure I-2 and Table I-2), the received level from all of the source locations for each receiver was determined. The received levels at a given receiver location from all source locations were summed. The greatest range where the summed SEL exceeded the criteria threshold was the range to impact (Table I-1). This range was determined separately for all sources and all functional hearing groups.

This method accounts for the hearing sensitivity of the marine mammal group, seawater absorption, and beam width for downwards-facing transducers.

In cases where the pulse duration for a source was unknown. The pulse duration was calculated from the difference between source level (SL) and energy source level (ESL) using:

$$T = 10^{(ESL-SL)/10}. \quad \text{(I-13)}$$

I.1.3. Level B

This section describes the methods used to estimate the horizontal distance to the root-mean-square sound pressure level (SPL) 160 dB re 1 µPa isopleth for the purposes of estimating Level B harassment (NOAA 2005). Distances to SPL thresholds were calculated using the source level and applying the method described above. SPL levels were assessed for both in-beam and out-of-beam levels (the latter was assessed using the out-of-beam source level correction described previously).

I.2. Sources

The following subsections describe the source characteristics of HRG equipment provided by Vineyard Wind. The horizontal impact distance to the Level A (Table I-1) and Level B (160 dB re 1 µPa) thresholds were computed for each source by applying the methods from Section Appendix I. We used the following assumptions when calculating impact distances:

- For sources that operate with different beam widths, we used the beam width associated with operational characteristics reported in Crocker and Fratantonio (2016).
- We use the lowest frequency of the source when calculating the absorption coefficient.

I.3. Overview of Source Properties

Table I-2 lists geophysical survey sources considered in this assessment that produce underwater sound at or below 180 kHz frequencies, and their acoustic characteristics. Table I-3 provides the accompanying data source reference.

Table I-2. Considered geophysical survey sources.

Equipment	System	Frequency (kHz)	Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)	Energy source level (dB re 1 µPa^{2}s m^2)	Beam width (°)	Pulse duration (ms)	Repetition rate (Hz)
Deep seismic profilers	Applied Acoustics AA251 Boomer	0.2–15	205	212	174	180	0.8	2
	GeoMarine Geo Spark 2000 (400 tip)	0.05–3	203	213	178	180	3.4	1

Table I-3. Data reference for considered geophysical survey sources.

Equipment	System	Frequency	Source level	Peak source level	Energy source level	Beam width	Pulse duration	Repetition rate
Deep seismic profilers	Applied Acoustics AA251 Boomer	Estimated from Figs 14 and 16 in Crocker and Fratantonio (2016)	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	See Table 5 in Crocker and Fratantonio (2016) source for levels at 300 J	Crocker and Fratantonio (2016), after correcting for full pulse duration	Vineyard Wind indicates they will use this repetition rate
	GeoMarine Geo Spark 2000 (400 tip)	Source specifications provided by Vineyard Wind.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Assume omnidirectional source to be conservative.	Considered SIG ELC 820 Sparker as proxy for source levels as SIG ELC 820 has similar operation settings as Geo Spark 2000 (Sect. I.5.1). See Table 9 in Crocker and Fratantonio (2016) source for levels at 5 m source depth, 750 J setting.	Vineyard Wind indicates they will use this repetition rate

I.3.1. Derived Out-of-beam Levels

Table I-4 lists the corrections applied to obtain out-of-beam source levels.

Table I-4. Correction factors for out-of-beam source levels.

Description		In-beam		Correction (dB)	Out-of-beam	
Equipment	System	Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)		Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)
Deep seismic profilers	Applied Acoustics AA251 Boomer	205	212	0.0	205.0	212.0
	GeoMarine Geo Spark 2000 (400 tip)	203	213	0.0	203.0	213.0

I.4. Distances

Table I-5 lists the geophysical survey sources and the horizontal impact distances to the Level A and B criteria that were obtained by applying the methods from Appendix I with the source parameters in Appendix I.3.

Table I-5.Horizontal distance to Level A and Level B impact threshold.

Equipment	System	Level A horizontal impact distance (m) to PK threshold					Level A horizontal impact distance (m) to SEL threshold					Level B horizontal impact distance (m)
		LFC	MFC	HFC	PPW	OPW	LFC	MFC	HFC	PPW	OPW	
Deep seismic profilers	Applied Acoustics AA251 Boomer	—	—	3	—	—	<1	<1	53	<1	<1	178
	GeoMarine Geo Spark 2000 (400 tip)	—	—	4	—	—	<1	<1	4	<1	<1	141

A dash (—) indicates that a source level is less than threshold level.

The methods used here are approximate, and a rigorous propagation loss model coupled with a full beam pattern and spectral source model would result in more accurate impact distances.

I.5. Equipment Specification Reference Sheets

I.5.1. GeoMarine Geo Spark 2000 (400 tip)

Geo-Source 200 - 400

Marine Multi-Tip Sparker System

Operational Features

- Powerful hi-resolution seismic source
- Primary pulse < 1ms, no ringing
- Proven operation in 1000 m water depth
- Penetration to 400 ms below seabed, depending on geology and survey conditions
- Vertical resolution < 30 cm

Ideal seismic profiling system for small and large vessels

- Site & route surveys
- Offshore engineering
- Mineral exploration
- Oceanographic research

INNOVATIVE Preserving Electrode Mode

The innovative Geo-Source 200 has been designed for operation with the Geo-Spark 1000 pulsed power supply (PPS) using the patented **Preserving Electrode Mode.** This mode uses a NEGATIVE electric discharge pulse instead of a positive pulse.

(Please note that this negative pulse is NOT the same as the simple reversal of the positive polarity of a 'standard' power supply.)

Maintenance free electrodes 5 year guarantee

The Preserving Electrode Mode **reduces the tip wear to practically zero**. You can shoot day after day, week after week, month after month with practically **NO tip maintenance.**

Always a stable acoustic pulse

Zero tip wear is essential for the **acoustic repeatability** of the pulse, which depends largely on a constant, unaltered electrode surface and tip insulation.

Efficient & Cost Effective

With the Geo-Spark HV power supplies you will save a lot of time and money, since the electrodes do NOT burn off like in all other systems.

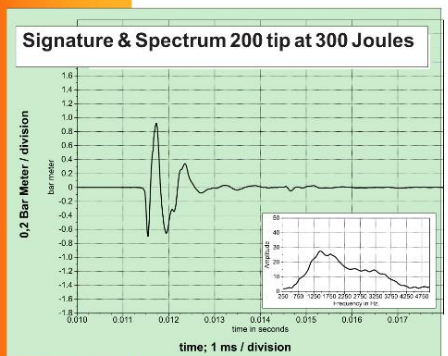
You don't need to trim tips during the survey. There is no need to have any stock of consumables.

Examples of Records

To see examples of our sparker records, please visit the 'Downloads' page on our website: ***www.geo-spark.com***

Geo-Source 200-400

Technical Specifications



Electrodes Geometry

The electrode modules are evenly spaced in a planar array of 0.75 m x 1.00 m. This geometry not only enhances the downward projection of the acoustic energy, it also reduces the primary pulse length, since all tips are perfectly in phase.

Control of Source Parameters 200 - 400 tips

The advanced Geo-Source 200-400 design gives you total control of the source depth and the energy (Joules) per tip

Source depth

Two floats provide a stable towing configuration and insure the proper depth of the electrode tips. This is critical to achieve constructive interference between the primary pulse and its own sea-surface reflection (surface ghost)

Number of tips in use and Energy per tip

Four individually powered electrode modules of 50 or 100 tips each allow you to distribute the energy from the Geo-Spark power supply over 50, 100......, up to 400 tips. (Each tip has an exposed surface area of 1.4 mm^2.)

200 tips, the classic 200 tip configuration is normally used with the Geo-Spark 1000 PPS and consists of four 50-tip electrode modules. This configuration gives an excellent hi-res pulse over the 100 to 500 J power range.

400 tips, for higher energies above 1000 J, and in particular with the Geo-Spark 2000X, we recommend a 400 tip configuration with 4 x 100-tip electrode modules

Maintenance free electrodes, no trimming, stable signature

Coaxial High Voltage (HV) Power/Tow Cable

The Geo-Source 200 is towed by a very high quality, Kevlar-reinforced, coaxial power/tow cable with stainless steel kellum grip. This dedicated high voltage (HV) cable contains **4 x 10 mm^2** inner cores (negative) plus a **40 mm^2** braiding (ground-referenced). It is designed to have a very low self-inductance to preserve the high dI/dt pulse output of the Geo-Spark 1000 PPS.

The coaxial structure of the HV cable reduces the electromagnetic interference to the absolute minimum.

The wet end of the cable is terminated with four special HV connectors to the electrode modules and a ground connector to the frame. Connecting or disconnecting the cable to the Geo-Source 200 takes only 10 minutes; so you can handle the sparker sled and the HV cable as independent units.

The dry end of the cable is terminated at the Geo-Source 200 patch panel, which allows you to select the number of electrode arrays in use

GEO Marine Survey Systems b.v.
Sheffieldstraat 8, 3047 AP Rotterdam
The Netherlands
Phone: + 31 10 41 55 755
Fax: +31 10 41 55 351
info@geomarinesurveysystems.com
Website: www.geo-spark.com

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