New England Wind

AVANGRID RENEWABLES

Construction and Operations Plan

Lease Area OCS-A0534

Volume III Appendices

January 2024

Submitted by
Park City Wind LLC

Submitted to
Bureau of Ocean Energy Management
45600 Woodland Rd
Sterling, VA 20166

Prepared by
Epsilon Associates, Inc.

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In Association with:

Baird & Associates
Biodiversity Research Institute
Capitol Air Space Group
Geo SubSea LLC
Geraldine Edens, P.A.
Gray & Pape
JASCO Applied Sciences
Public Archaeology Laboratory, Inc.
RPS
Saratoga Associates
SEARCH, Inc.
Wood Thilsted Partners Ltd

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Appendix III-M – 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.

10 January 2024

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

Park City Wind LLC (Park City Wind), a wholly owned subsidiary of Avangrid Renewables, LLC (Proponent), is proposing to develop offshore renewable wind energy facilities in the 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. The New England Wind Offshore Wind Farm's (New England Wind; Project) 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 this document, 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.

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. 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.

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 (including Park City Wind)

Phase 1, which includes 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 (including Commonwealth Wind)

Phase 2, which includes 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).

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 (2010b). 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 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 10, 12, and 15 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 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. 2000b) 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. 2000b, 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 2.6)
ER_{max}	maximum Exposure Range (defined in Section 2.6)
ESA	Endangered Species Act
ESP	electrical service platform
ft	feet
FWRAM	Full Wave Range Dependent Acoustic Model
G&G	Geophysical and geotechnical
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
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 Section 4.3.E.4)
RCS	reactive compensation station
RI	Rhode Island
R_{max}	maximum acoustic Range (defined in Section 4.3.E.4)
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

Park City Wind LLC (Park City Wind), a wholly owned subsidiary of Avangrid Renewables, LLC (Proponent), is proposing to develop offshore renewable wind energy facilities in the 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. The New England Wind Offshore Wind Farm's (New England Wind; Project) 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 this document, 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

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. 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.

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 (including Park City Wind)

Phase 1, which includes 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.

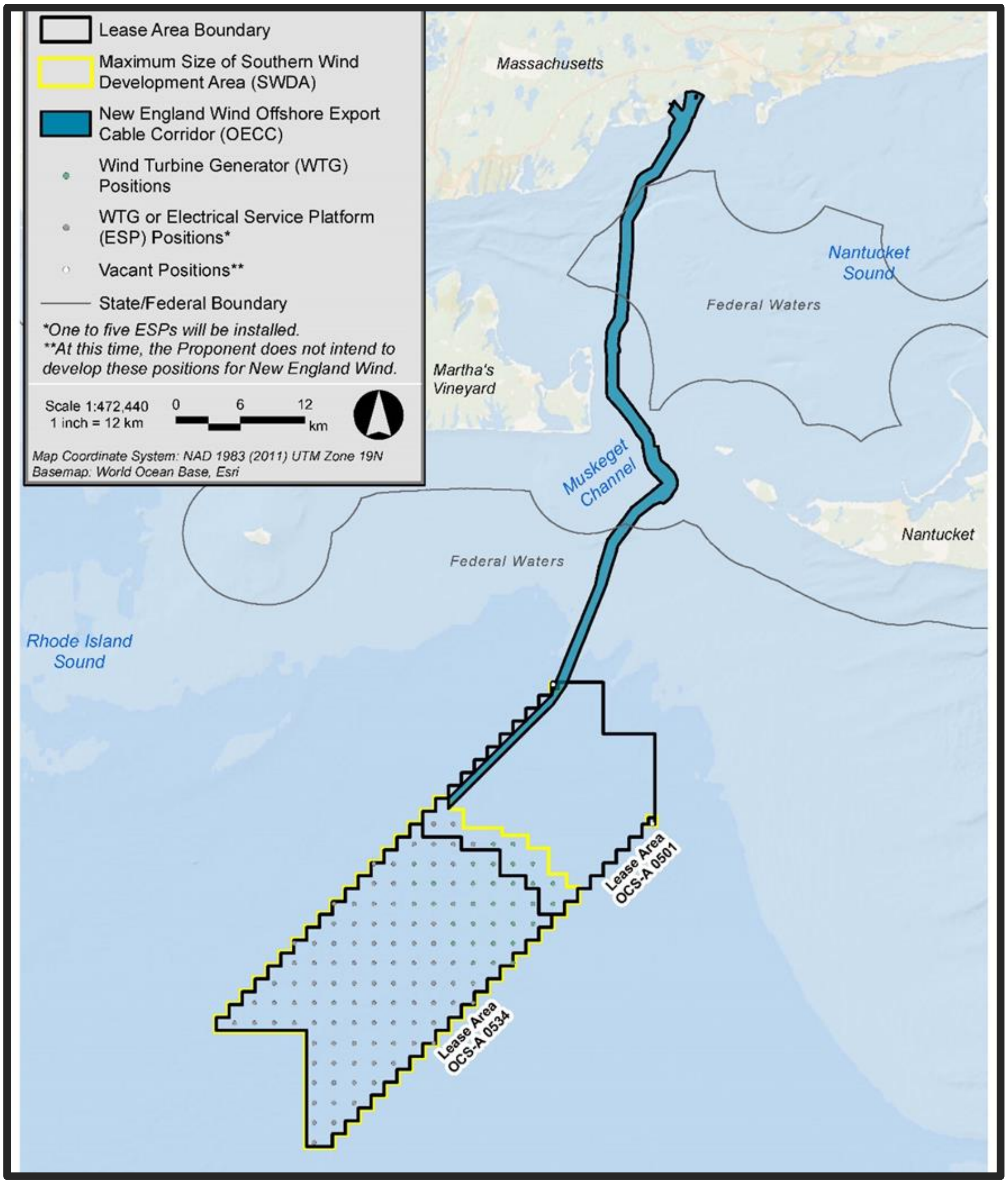

Figure 1. Site of the proposed New England Wind Project in Southern Wind Development Area (SWDA) (Lease Area OCS-A 0534).

Phase 2 of New England Wind (including Commonwealth Wind)

Phase 2, which includes 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).

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 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.

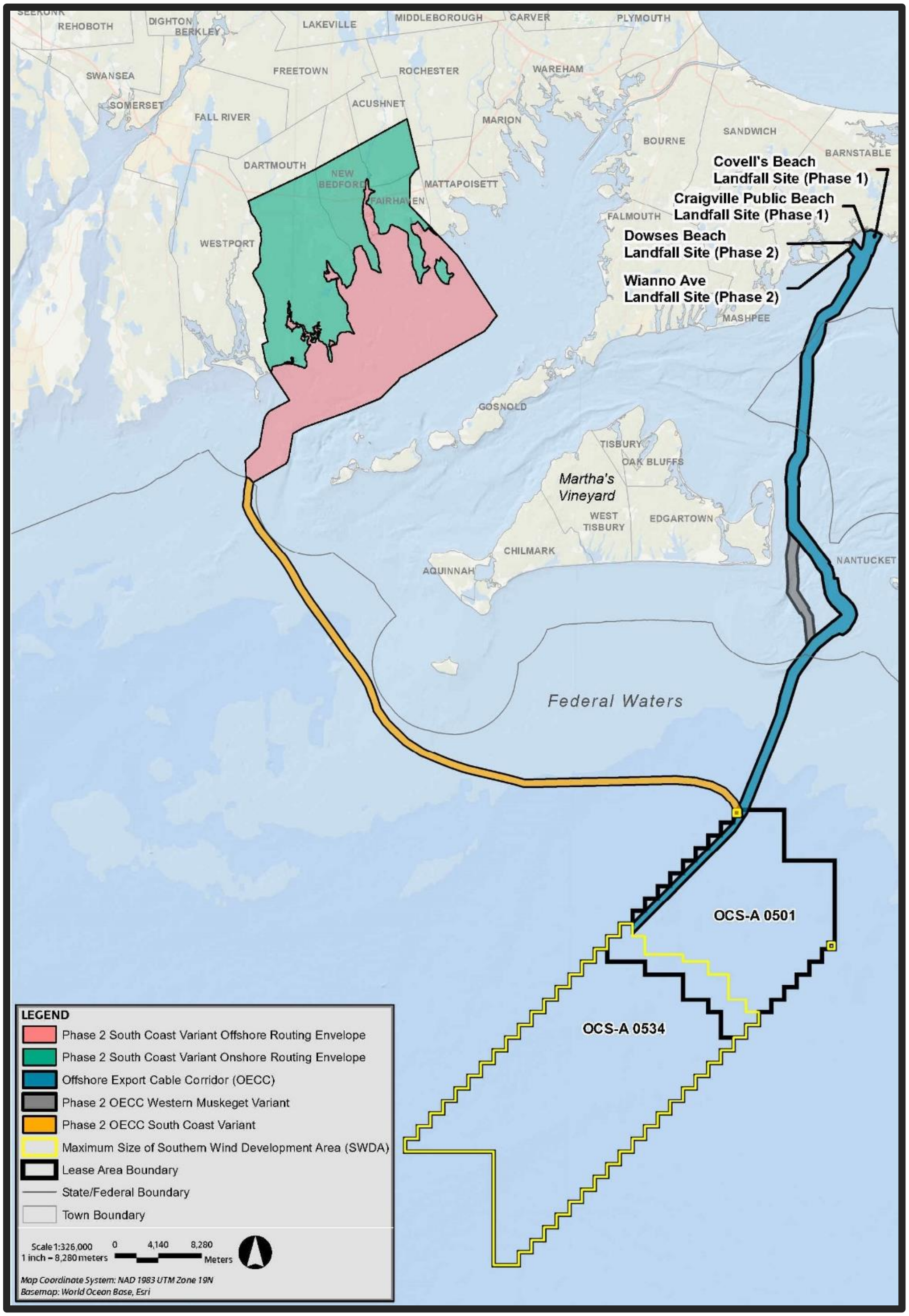

Figure 2. Phase 2 offshore export cable variants.

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 2.6) and exposure numbers for marine mammals and sea turtles.

Although there are several potential anthropogenic sound sources associated with New England Wind, the primary sound sources are impact (impulsive) and vibratory (non-impulsive, continuous) pile driving for foundation installation during the construction stage. Foundation types proposed for the SWDA include monopiles, jacket, and bottom-frame foundations. Monopile foundations consist of a single pile, while jacket 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. Monopiles have been used successfully at many offshore wind energy locations, and currently account for more than 80% of the installed foundations in Europe (>3350 units, (Wind Europe 2017). Monopile foundations may be used for both WTGs and ESPs in both Phases of New England Wind. The monopiles primarily considered in this acoustic assessment are 12 m in diameter (Figure 3), representing the maximum diameter pile that may be installed in Phase 1 and the average diameter monopile in Phase 2. The maximum diameter that may be installed in Phase 2 is 13 m (Figure 4). The 12 m and 13 m monopiles were modeled at 5000 kJ and 6000 kJ hammer energy levels..

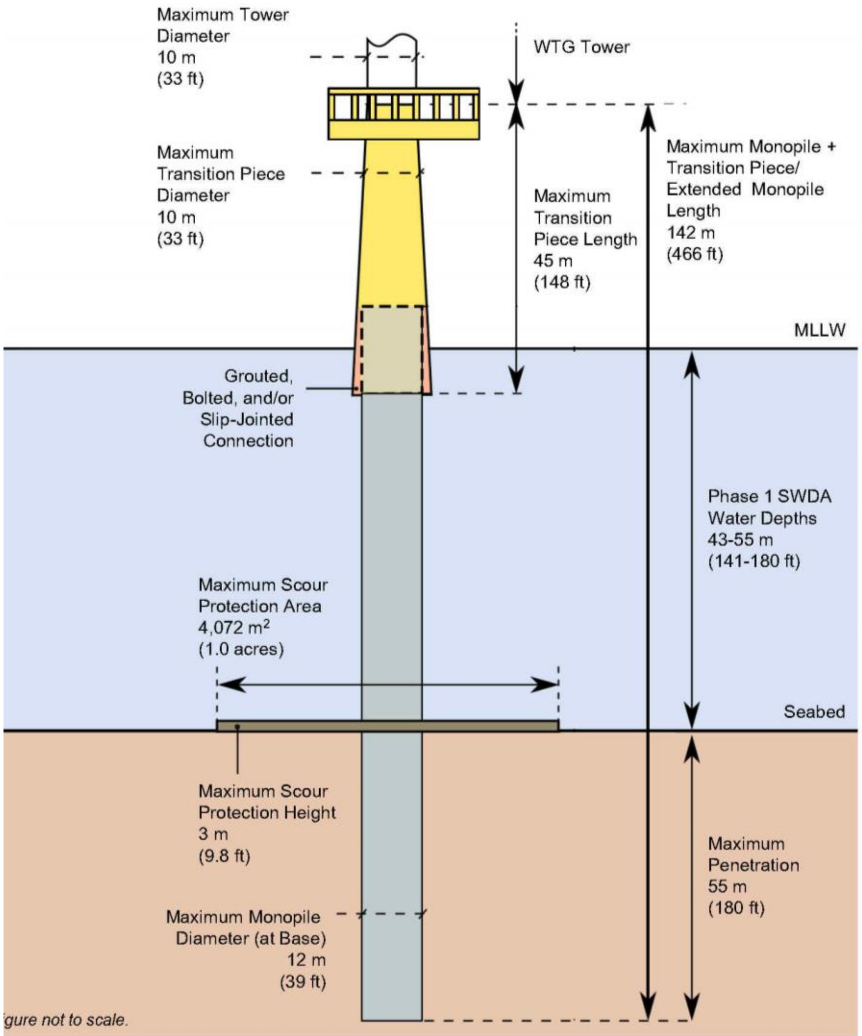

Figure 3. Schematic drawing of a 12 m monopile foundation for wind turbine generators (WTGs).

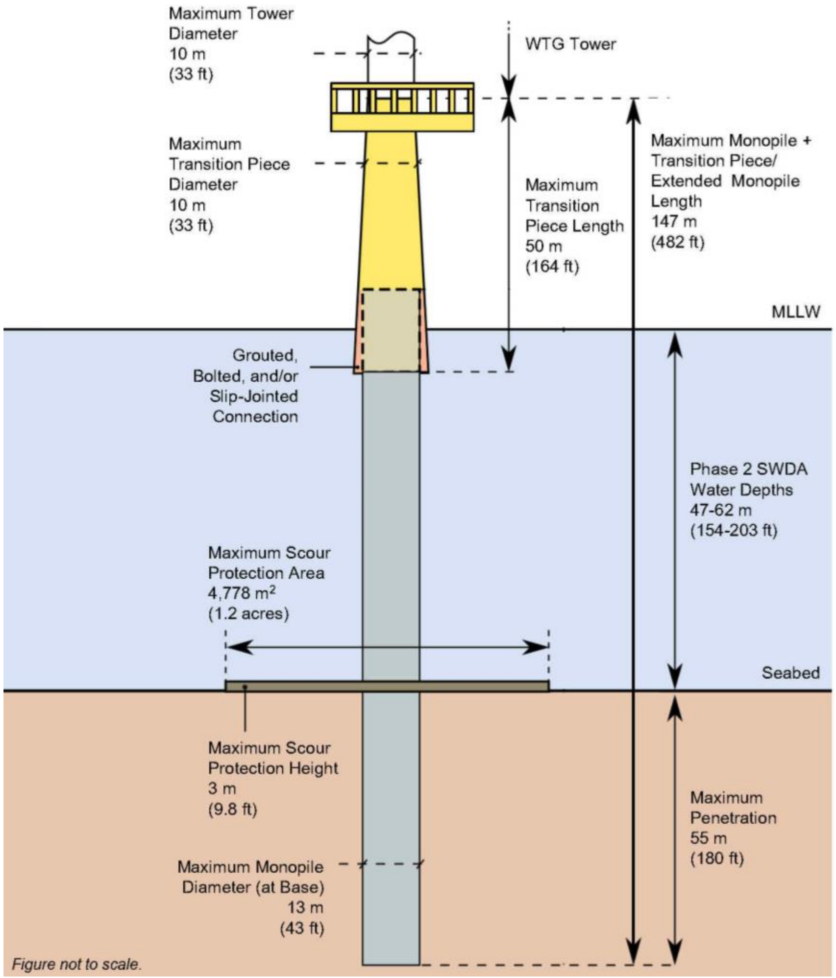

Figure 4. Schematic drawing of a 13 m monopile foundation for wind turbine generators (WTGs).

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 piles (one per leg). Alternatively, the jacket is secured to the sea floor via slender 'pin' piles that are driven through "sleeves" or guides mounted to the base of each leg of the jacket structure. Jackets with piles driven through the sleeves are referred to as post-piled foundations, and these types of jackets radiate additional sound as the piles are driven because the whole structure may vibrate. To account for the larger radiating area, the broadband sound levels estimated for the jacket foundation piles are increased by 2 dB for post-piling scenarios (Bellmann et al. 2020). 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.

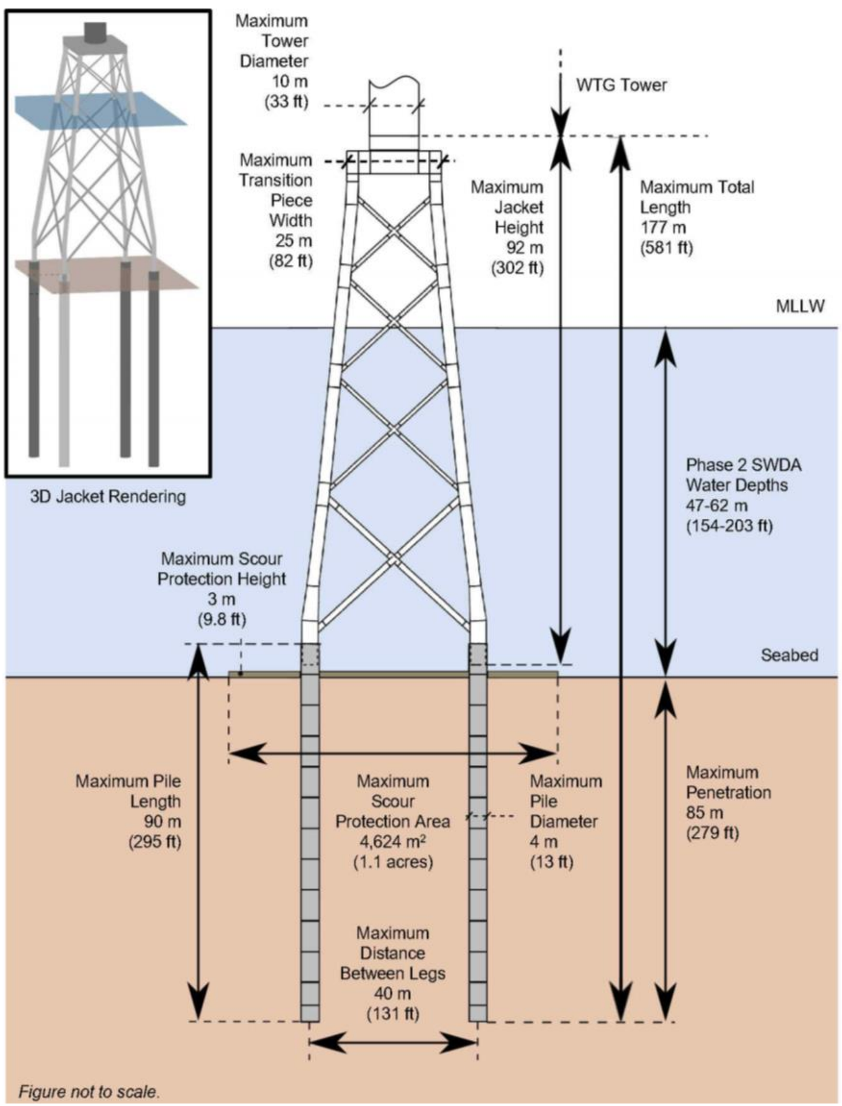

Figure 5. Schematic drawing of a jacket foundation.

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.

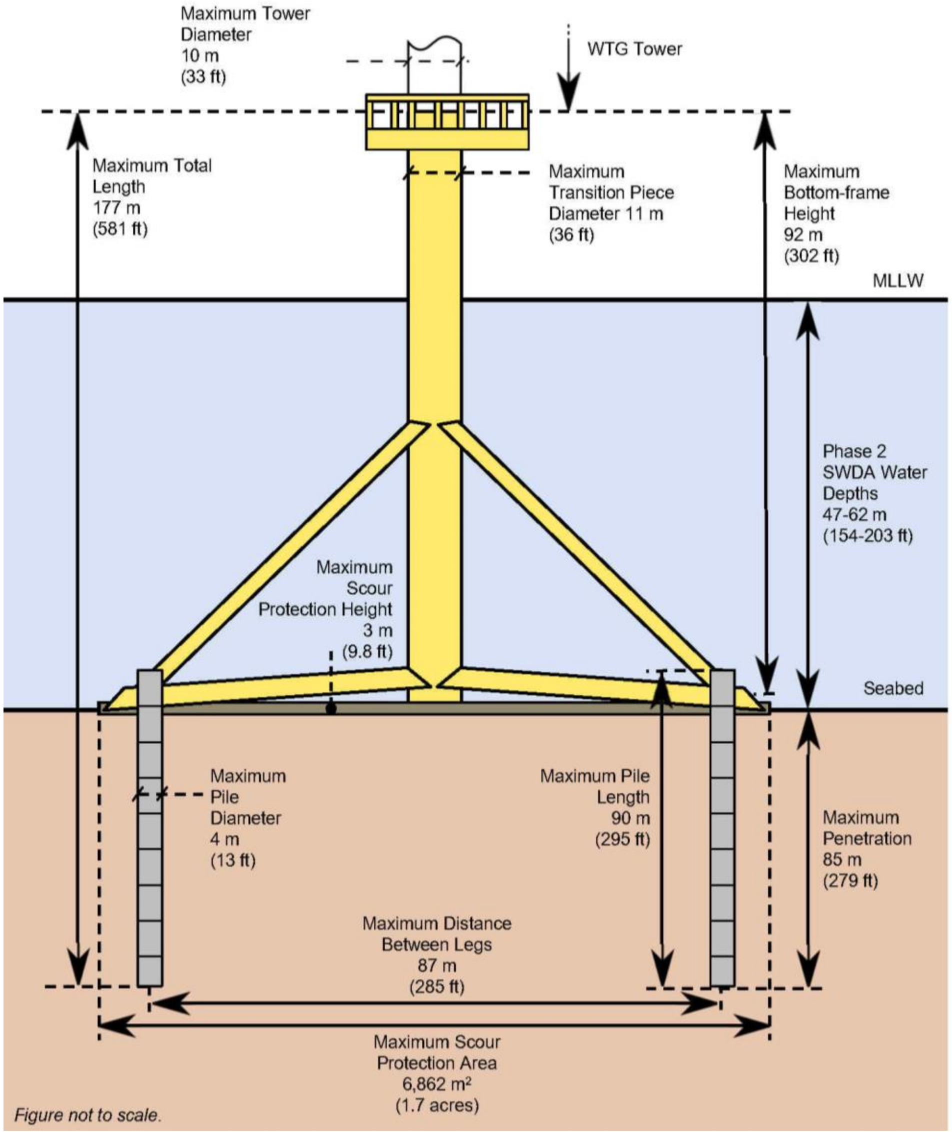

Figure 6. Schematic drawing of a bottom-frame foundation.

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 analysis here is based on 133 foundations.

The New England Wind envelope consisted of 12 and 13 m WTG monopile foundations and jacket foundations with 4 m piles. 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 Tables 2 and 3 for a summary of the modeled foundations.

Table 1. Impact-only installation 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 3.5) and is not considered in the construction schedules (see Tables 5 and 6).

Table 2. Hammer energy and modeled number of blows for vibratory pile-setting followed by impact piling at each energy level for monopiles.

12 m monopile			13 m monopile			12 m monopile			13 m monopile			All monopiles
Vibratory hammer	5000 kJ Impact hammer		Vibratory hammer	5000 kJ Impact hammer		Vibratory hammer	6000 kJ Impact hammer		Vibratory hammer	6000 kJ Impact hammer		
Duration (min)	Energy level (kJ)	Strike count	Duration (min)	Energy level (kJ)	Strike count	Duration (min)	Energy level (kJ)	Strike count	Duration (min)	Energy level (kJ)	Strike count	Pile penetration (%)
60	**-**	-	**60**	**-**	-	**60**	**1000**	-	**60**	**1000**	-	25
-	**1000**	1930	**-**	**1000**	2095	**-**	**2000**	1250	**-**	**2000**	1375	25
-	**2000**	1910	**-**	**2000**	2100	**-**	**3000**	1000	**-**	**3000**	1100	20
-	**3000**	1502	**-**	**3000**	1475	**-**	**4500**	1000	**-**	**4500**	1100	20
-	**5000**	398	**-**	**5000**	555	**-**	**6000**	500	**-**	**6000**	550	10
-	**Total**	5740	**-**	**Total**	6225	**-**	**Total**	3750	**-**	**Total**	4125	100
Frequency: 20 Hz	**Strike rate: 30.0 bpm**		**Frequency: 20 Hz**	**Strike rate: 30.0 bpm**		**Frequency: 20 Hz**	**Strike rate: 25.0 bpm**		**Frequency: 20 Hz**	**Strike rate: 27.6**		

Table 3. Hammer energy and modeled number of blows for vibratory pile-setting followed by impact piling at each energy level for pin piles.

4 m pin pile			
Vibratory Hammer	3500 kJ Impact hammer		
Duration (min)	Energy level (kJ)	Strike count	Pile penetration (%)
60	-	-	25
-	**525**	1925	25
-	**1000**	2165	14
-	**3500**	3445	26
-	**3500**	1395	10
-	**Total**	8930	100
Frequency: 20 Hz	**Strike rate**		30.0 bpm

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 sound speed profile from May to December was used in New England Wind acoustic propagation modeling. See Appendix E 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 at 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 4; 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 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 4. 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).

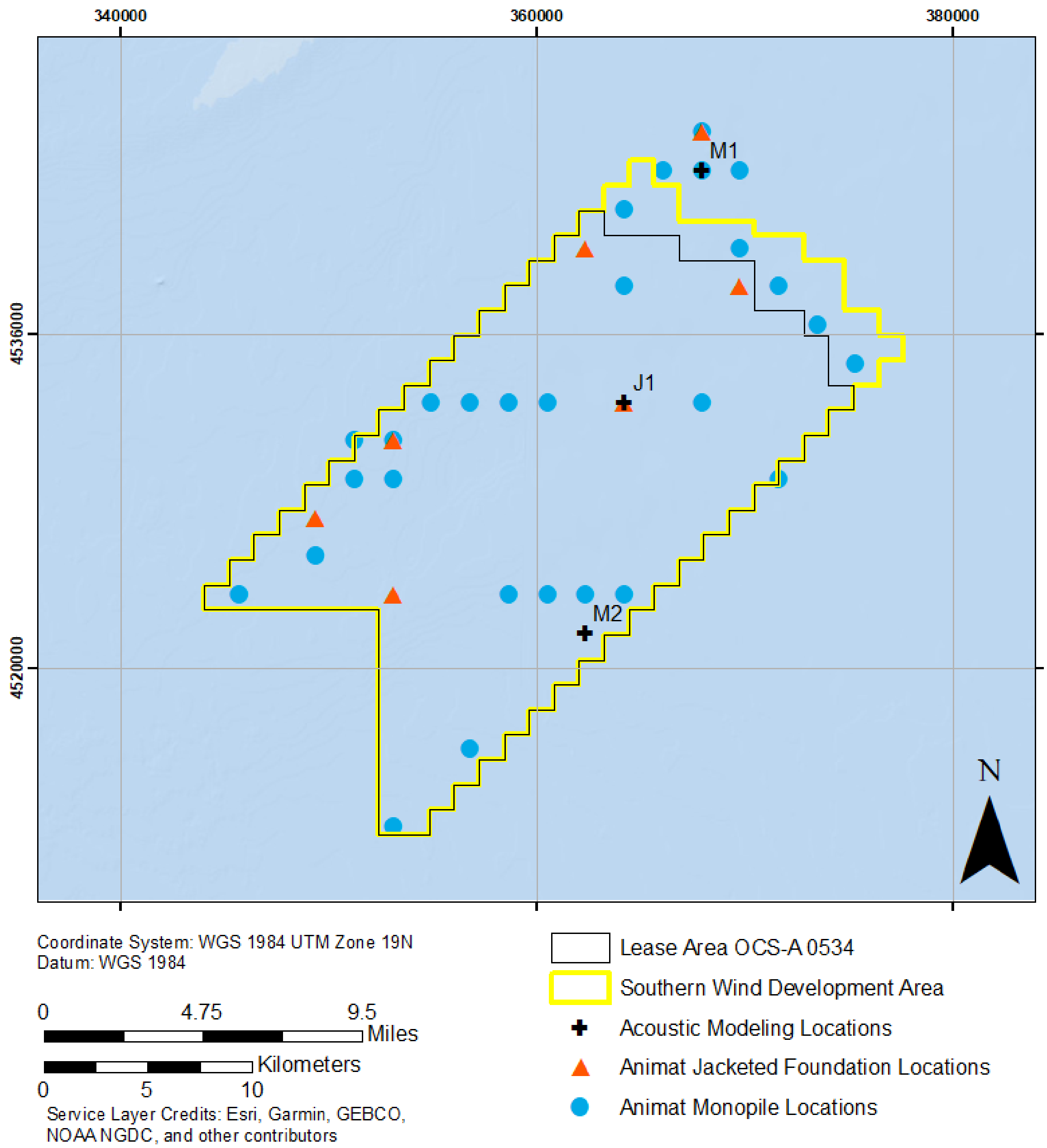

Figure 7. Project pile locations with acoustic propagation modeling and animal movement modeling locations (animat locations) highlighted in the Southern Wind Development Area (SWDA).

1.2.7. Assumed Piling Construction Schedule for Modeling

Construction schedules are difficult to predict because of factors like weather and installation variation related to drivability. To allow some flexibility in the final design and during foundation installation, two construction schedules (Tables 5-11) were used to calculate potential impacts to marine mammals and sea turtles during pile installation. 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.

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 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[7]. 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. 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.

To estimate exposures, it is necessary to predict not only the number of piles per day but also the number of days of piling. To do this, the modeling included installation at a rate of one or two monopiles per day and four pin piles per day. Two possible combinations of these piling rates were modeled (Construction Schedules A and B) so that the combination that produced the greatest number of predicted exposures could be carried forward as a conservative approach to estimating impacts. Tables 5–11 show the number of days of piling under the two different modeled schedules.

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

Table 5. Construction Schedule A, year 1: The number of potential days of pile installation per month for each case, used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation Month	WTG foundations														ESP foundations	
	Impact Only						Vibratory with impact								Impact only	Vibratory with Impact
	12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		13 m MP, 6000 kJ		4 m Pin Pile, 3500 kJ	4 m Pin Pile, 3500 kJ
	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	4 piles per day	4 piles per day
May	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	1	4	0	0	0	0	1	1	0	0	0	0	0	0	0	0
July	0	5	0	0	0	0	0	4	0	0	0	0	0	0	0	0
August	0	3	0	0	0	0	0	6	0	0	0	0	0	0	0	0
September	0	1	0	0	1	2	0	0	0	0	0	4	0	0	2	0
October	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0
November	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0
December	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	5	**13**	**0**	**0**	**5**	**7**	**1**	**11**	**0**	**0**	**0**	**8**	**0**	**0**	**2**	0
Total # days	**30**						**20**								**2**	
Total # piles	**50 monopiles**						**39 monopiles**								**8 pin piles**	
Total # foundations	**50 monopiles**						**39 monopiles**								**2 jackets**	

[a] WTGs are installed on 12 and 13 m monopile foundations. ESPs are installed on jacket foundations with four 4 m pin piles. The schedule includes a combination of foundations installed with impact only piling and foundations installed with vibratory setting of the pile followed by impact pile driving. The modeled parameters for all foundations are shown in Tables 2 and 3.

Table 6. Construction Schedule A, year 2: The number of potential days of pile installation per month for each case, used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation Month	WTG foundations														ESP foundations	
	Impact Only						Vibratory with impact								Impact only	Vibratory with Impact
	12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		13 m MP, 6000 kJ		4 m Pin Pile, 3500 kJ	4 m Pin Pile, 3500 kJ
	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	4 piles per day	4 piles per day
May	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	0	**0**	**4**	**1**	**0**	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**0**	**0**	**5**	**19**
Total # days	**5**						**6**								**24**	
Total # piles	**6 monopiles**						**12 monopiles**								**96 pin piles**	
Total # foundations	**6 monopiles**						**12 monopiles**								**24 jackets**	

[a] WTGs are installed on 12 and 13 m monopile foundations. ESPs are installed on jacket foundations with four 4 m pin piles. The schedule includes a combination of foundations installed with impact only piling and foundations installed with vibratory setting of the pile followed by impact pile driving. The modeled parameters for all foundations are shown in Tables 2 and 3.

Table 7: Construction Schedule A year 1 and year 2 combined. The number of potential days of pile installation per month for each case, used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation Month	WTG foundations														ESP foundations	
	Impact Only						Vibratory with impact								Impact only	Vibratory with Impact
	12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		13 m MP, 6000 kJ		4 m Pin Pile, 3500 kJ	4 m Pin Pile, 3500 kJ
	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	4 piles per day	4 piles per day
May	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
June	1	4	0	1	0	0	1	1	0	2	0	0	0	0	0	0
July	0	5	0	0	0	0	0	4	0	4	0	0	0	0	0	0
August	0	3	0	0	0	0	0	6	0	0	0	0	0	0	0	8
September	0	1	0	0	1	2	0	0	0	0	0	4	0	0	3	6
October	0	0	0	0	0	3	0	0	0	0	0	3	0	0	2	4
November	0	0	0	0	0	2	0	0	0	0	0	1	0	0	1	1
December	0	0	0	0	4	0	0	0	0	0	0	0	0	0	1	0
	5	**13**	**4**	**1**	**5**	**7**	**1**	**11**	**0**	**6**	**0**	**8**	**0**	**0**	**7**	**19**
Total # days	**35**						**26**								**26**	
Total # piles	**56 monopiles**						**51 monopiles**								**104 pin piles**	
Total # foundations	**56 monopiles**						**51 monopiles**								**26 jackets**	

[a] WTGs are installed on 12 and 13 m monopile foundations. ESPs (which include both ESPs and a booster station) are installed on jacket foundations with four 4 m pin piles. The schedule includes a combination of foundations installed with impact only piling and foundations installed with vibratory setting of the pile followed by impact pile driving. The modeled parameters for all foundations are shown in Tables 2 and 3.

Table 8: Construction Schedule B, year 1: The number of potential days of pile installation per month for each case, used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation Month	WTG foundations														ESP foundations	
	Impact Only						Vibratory with impact								Impact only	Vibratory with Impact
	12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		13 m MP, 6000 kJ		4 m Pin Pile, 3500 kJ	4 m Pin Pile, 3500 kJ
	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	4 piles per day	4 piles per day
May	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	6	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
July	0	3	0	0	0	0	0	4	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	1	5	0	0	0	0	0	0	1	0
September	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1
October	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
November	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
December	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	**5**	**0**	**0**	**0**	**0**	**3**	**15**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**2**
Total # days	**17**						**18**								**3**	
Total # piles	**22 monopiles**						**33 monopiles**								**12 pin piles**	
Total # foundations	**22 monopiles**						**33 monopiles**								**3 jackets**	

[a] WTGs are installed on 12 and 13 m monopile foundations. ESPs (which include both ESPs and a booster station) are installed on jacket foundations with four 4 m pin piles. The schedule includes a combination of foundations installed with impact only piling and foundations installed with vibratory setting of the pile followed by impact pile driving. The modeled parameters for all foundations are shown in Tables 2 and 3.

Table 9: Construction Schedule B, year 2: The number of potential days of pile installation per month for each case, used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation Month	WTG foundations														ESP foundations	
	Impact Only						Vibratory with impact								Impact only	Vibratory with Impact
	12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		13 m MP, 6000 kJ		4 m Pin Pile, 3500 kJ	4 m Pin Pile, 3500 kJ
	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	4 piles per day	4 piles per day
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	8
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**28**	**25**
Total # days	**0**						**0**								**53**	
Total # piles	**0 monopiles**						**0 monopiles**								**212 pin piles**	
Total # foundations	**0 monopiles**						**0 monopiles**								**53 jackets**	

[a] WTGs are installed on 12 and 13 m monopile foundations. ESPs (which include both ESPs and a booster station) are installed on jacket foundations with four 4 m pin piles. The schedule includes a combination of foundations installed with impact only piling and foundations installed with vibratory setting of the pile followed by impact pile driving. The modeled parameters for all foundations are shown in Tables 2 and 3.

Table 10 Construction Schedule B, year 3: The number of potential days of pile installation per month for each case, used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation Month	WTG foundations														ESP foundations	
	Impact Only						Vibratory with impact								Impact only	Vibratory with Impact
	12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		13 m MP, 6000 kJ		4 m Pin Pile, 3500 kJ	4 m Pin Pile, 3500 kJ
	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	4 piles per day	4 piles per day
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13**	**9**
Total # days	**0**						**0**								**22**	
Total # piles	**0 monopiles**						**0 monopiles**								**88 pin piles**	
Total # foundations	**0 monopiles**						**0 monopiles**								**22 jackets**	

[a] WTGs are installed on 12 and 13 m monopile foundations. ESPs (which include both ESPs and a booster station) are installed on jacket foundations with four 4 m pin piles. The schedule includes a combination of foundations installed with impact only piling and foundations installed with vibratory setting of the pile followed by impact pile driving. The modeled parameters for all foundations are shown in Tables 2 and 3.

Table 11: Construction Schedule B, year 1,2,3 combined: The number of potential days of pile installation per month for each case, used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation Month	WTG foundations														ESP foundations	
	Impact Only						Vibratory with impact								Impact only	Vibratory with Impact
	12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		12m MP, 5000 kJ		12 m MP, 6000 kJ		13 m MP, 5000 kJ		13 m MP, 6000 kJ		4 m Pin Pile, 3500 kJ	4 m Pin Pile, 3500 kJ
	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	1 pile per day	2 piles per day	4 piles per day	4 piles per day
May	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
June	6	2	0	0	0	0	0	2	0	0	0	0	0	0	9	4
July	0	3	0	0	0	0	0	4	0	0	0	0	0	0	12	7
August	0	0	0	0	0	0	1	5	0	0	0	0	0	0	10	10
September	0	0	0	0	0	0	0	3	0	0	0	0	0	0	7	7
October	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	6
November	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2
December	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	12	**5**	**0**	**0**	**0**	**0**	**3**	**15**	**0**	**0**	**0**	**0**	**0**	**0**	**42**	**36**
Total # days	17						18								78	
Total # piles	**22 monopiles**						**33 monopiles**								**312 pin piles**	
Total # foundations	**22 monopiles**						**33 monopiles**								**78 jackets**	

[a] WTGs are installed on 12 and 13 m monopile foundations. ESPs (which include both ESPs and a booster station) are installed on jacket foundations with four 4 m pin piles. The schedule includes a combination of foundations installed with impact only piling and foundations installed with vibratory setting of the pile followed by impact pile driving. The modeled parameters for all foundations are shown in Tables 2 and 3.

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 and vibratory pile driving sounds are the focus of the modeling presented in the main text of this report. Appendix I provides exposure estimates of marine mammals for HRG survey sounds, Appendix J provides exposure estimates of marine mammals for potential UXO detonation, and Appendix K provides exposure estimates of marine mammals for potential drilling operations.

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 12), 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 2014a). 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 12. 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

2.1.1. Impact Pile Driving

When driven with impact hammers, piles deform, 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 4). 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.

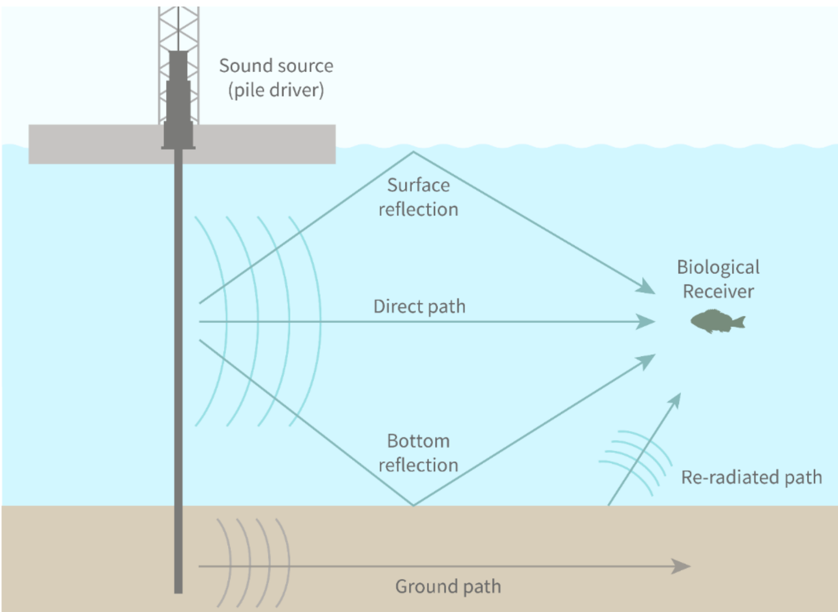

Figure 8. Sound propagation paths associated with pile driving (adapted from Buehler et al. 2015).

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 2010a) to predict source levels associated with impact pile driving activities. Piles are modeled as a vertical installation using a finite-difference structural model of pile vibration based on thin-shell theory. 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 D for a more detailed description.

Forcing functions were computed for the typical and difficult to drive monopiles and jacket foundation piles using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010a). The model assumed direct contact between the representative hammers, helmets, and piles (i.e., no cushioning material). The forcing functions serve as inputs to JASCO's pile driving source model (PDSM), which was used to estimate equivalent acoustic source characteristics detailed in Appendix D.

JASCO's FWRAM (Appendix E.3) propagation model was used to combine the outputs of the source model with spatial and temporal environmental factors (e.g., location, oceanographic conditions, and seabed type) to get time-domain representations of the sound signals in the environment and estimate sound field levels.

This model is used to estimate the energy distribution per frequency (source spectrum) at a close distance from the source (10 m). Examples of decidecade band levels for each pile type, hammer energy, and modeled location, using the average summer and winter sound speed profiles are provided in Section 4.1 for monopiles and jacket foundation piles.

Jacket foundation piles are assumed to be post-piled. Post-piling means that the jacket structure is placed on the seafloor and piles are subsequently driven through guides at the base of each leg. These jacket foundations will also radiate sound as the piles are driven. During the project NavES: Experience Report Pile-Driving Noise, a quantitative comparison between installations of monopiles and main-piles by the post-piling procedure showed an up to 2 dB increased in noise levels due to post-piling (Bellmann et al. 2020).To account for the larger radiating area in post-piled jackets for this study, the broadband sound level was increased by 2 dB for post-piling scenarios. ESP/booster station jacket foundations are expected to be post-piled.

2.1.2. Vibratory Pile Driving

During vibratory pile driving, piles are driven into the substrate due to longitudinal vibration motion at the hammer's operational frequency and corresponding amplitude. This causes the soil to liquefy, allowing the pile to penetrate into the seabed.

One second long vibratory forcing functions were computed for the 12 and 13 m monopile and the 4 m jacket foundations, using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010a). Clamps are used to connect the vibratory hammer to the pile. The model assumed the use of 18 clamps with a total weight of 1182.6 kN for the 12 and 13 m monopile, 4 clamps with total weight of 262.6 kN for the 4 m jacket piles. The number of clamps, and thus the total clamp weight, affects the forcing amplitude of the vibratory hammer on the pile, and is therefore an important factor in accurately modeling vibratory acoustic fields. No cushion between the hammer and pile was used. Non-linearities were introduced to the vibratory forcing functions based on the decay rate observed in data measured during vibratory pile driving of smaller diameter piles (Quijano et al. 2017). The resulting forcing functions serve as inputs to JASCO's pile driving source model (PDSM) used to estimate an equivalent acoustic source represented by a linear array of monopoles evenly distributed along the pile, as detailed in Appendix D. Sound propagation of the vibratory pile driving source signature is performed using FWRAM and modeling details are described in Appendix E. Decidecade band levels at 10 m from the source for each pile type, hammer energy and modeled location sound speed profiles, are provided in Section 4.1.

2.2. Sound Propagation Modeling

Acoustic propagation modeling used JASCO's 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, 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 E 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, 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 F.

2.4. Acoustic Criteria for Marine Fauna

The acoustic criteria used for this study are from the current US regulatory acoustic criteria and are summarized below (further details on these criteria are in Sections 2.4.1 and 2.4.2):

1. Peak sound pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) are from the US National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Technical Guidance (NMFS 2018) for marine mammal injury thresholds.
2. Sound pressure levels (SPL; L_p) for marine mammal behavioral thresholds are based on the unweighted NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria.
3. Injury thresholds (PK and SEL) for fish are from the Fisheries Hydroacoustic Working Group (FHWG 2008) and Stadler and Woodbury (2009) for fish that are equal, greater than, or less than 2 g.
4. Injury thresholds (PK and SEL) for fish are from Popper et al. (2014) for fish without swim bladders, fish with swim bladders not involved in hearing, and fish with swim bladders involved in hearing.
5. Behavioral thresholds for fish are from NMFS ESA Acoustic Thresholds (noaa.gov)
6. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) were used for the onset of permanent threshold shift (PTS) in sea turtles.
7. Behavioral response thresholds for sea turtles were obtained from McCauley et al. (2000a), which was confirmed in Finneran et al. (2017).

2.4.1. Acoustic Criteria–Marine Mammals

The Marine Mammal Protection Act (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 PK (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).

Based on observations of mysticetes (Malme et al. 1983, 1984, Richardson et al. 1986, 1990), sound levels thought to elicit disruptive behavioral responses are described using the SPL metric (NOAA 2005). NMFS currently uses behavioral response thresholds of SPL 160 dB re 1 µPa for marine mammals exposed to non-explosive impulsive sounds, like impact pile driving, and SPL 120 dB re 1 µPa for marine mammals exposed to continuous sounds, like vibratory pile driving or drilling (NMFS 2022). Alternative thresholds used in acoustic assessments include a graded probability of response approach and account for the frequency-dependence of animal hearing sensitivity (Wood et al. 2012).

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 13).

Table 13. 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 [a]	SEL	L_E

[a] The SEL_{cum} metric used by NOAA Fisheries (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.

2.4.1.1. 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 14).

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 14 are used in this analysis.

Table 14. Marine mammal hearing groups (Sills et al. 2014, NMFS 2018).

Hearing Group	Generalized hearing range [a]
Low-frequency (LF) cetaceans	7 Hz to 35 kHz
Mid-frequency (MF) cetaceans	150 Hz to 160 kHz
High-frequency (HF) cetaceans	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.

2.4.1.2. 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 14) 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 15).

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).

2.4.1.3. Marine Mammals Auditory Injury Exposure Criteria

Injury to the hearing apparatus of a marine mammal may result from brief exposure to an intense sound or from longer fatiguing sound exposures. Damage to hearing from brief exposure to intense sounds is independent of the duration of the signal, and the PK metric is used to assess the potential risk for injury. For longer-duration exposures, a measure of the total received sound energy is needed. The SEL metric is proportional to sound energy and is calculated by summing over the duration of the received signal. 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 instantaneous peak (PK) sound pressure levels and sound energy accumulated over 24 h (SEL; L_E) (Table 15).

Different types of sounds affect the ear differently. Impulsive sounds are known to be more damaging than non-impulsive sounds. For this reason, there are lower thresholds for exposure to impulsive sounds than non-impulsive sounds (Table 15. Summary of relevant permanent threshold shift (PTS) onset acoustic thresholds for marine mammal hearing groups). In some cases, an animal may be exposed to a combination of impulsive and non-impulsive sounds, or an impulsive sound may follow exposure to a non-impulsive sound. When concurrent sounds of different types are received, the sound energy from all sources should be summed and the threshold for impulsive sounds should be used because the resultant sound can be thought of as impulses within a background of non-impulsive sound. When impulsive sound (such as impact pile driving) follows exposure to non-impulsive sound (such as vibratory pile driving), potential effects of the non-impulsive sound (vibratory pile driving) should be evaluated first followed by the potential effects of the impulsive sound (impact pile driving). The sound energy from the exposure to non-impulsive sound (vibratory pile driving), however, should be included in the total received energy during the impulsive sound (impact pile driving) if the non-impulsive sound occurs within the time window of evaluation (24 h).

Table 15. Summary of relevant permanent threshold shift (PTS) onset acoustic thresholds for marine mammal hearing groups (NMFS 2018).

Hearing Group	Impulsive signals [a]		Non-impulsive signals
	Unweighted L_{pk} (dB re 1 µPa)	Frequency weighted $L_{E,24h}$ (dB re 1 µPa²s)	Frequency weighted $L_{E,\,24hr}$ (dB re 1 µPa²s)
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.

2.4.1.4. 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, NMFS has not yet released technical guidance on behavioral thresholds for calculating animal exposures (NMFS 2018), and currently uses a step function to assess behavioral impact (NOAA 2005). The step function sets an SPL of 160 dB re 1 µPa as the behavioral disruption threshold for intermittent sound sources. This was based on the responses of mysticete whales to airgun sounds (Malme et al. 1983, 1984); (Richardson et al. 1985)). This threshold was also adopted in the HESS (1999) report. An SPL of 120 dB re 1 µPa was set as the behavioral disruption threshold for continuous sound sources (NOAA 2005). This was based on the responses of gray and bowhead whales to continuous drilling and/or dredging sounds (Malme et al. 1983, 1984; (Richardson et al. 1990, Richardson et al. 1995). 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. NMFS currently uses behavioral response thresholds of SPL 160 dB re 1 µPa for non-explosive, impulsive sounds, such as impact pile driving, and SPL 120 dB re 1 µPa for continuous sounds, like vibratory pile driving and drilling, for all marine mammal species (NMFS 2022).

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 16).

Table 16. Wood et al. (2012) frequency-weighted and NOAA (2005) unweighted acoustic sound pressure level (SPL) thresholds used to evaluate potential behavioral impacts to marine mammals. Probabilities are not additive.

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

2.4.2. Acoustic Criteria – 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 impact pile driving sounds (Stadler and Woodbury 2009) and described by the Fisheries Hydroacoustic Working Group (FHWG 2008). Injury and behavioral thresholds for sea turtles were developed for use by the US Navy (Blackstock et al. 2018) based on exposure studies (e.g., McCauley et al. 2003). These injury and behavioral response levels for fish and sea turtles were compiled and listed in NMFS ESA Acoustic Thresholds (noaa.gov) for assessing the potential effects to ESA-listed fish and sea turtles exposed to elevated levels of underwater sound from pile driving. Dual acoustic thresholds for physiological injury to fish included in the tool are 206 dB PK and either 187 dB SEL (>2 g fish weight) or 183 dB SEL (<2 g fish weight) (Table 17). The behavioral threshold for fish is ≥150 dB SPL (Table 17) (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. 2000b). 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 recommended behavioral threshold is an SPL of 175 dB re 1 µPa (McCauley et al. 2000b, Finneran et al. 2017) (Table 17).

Table 17. Acoustic metrics and thresholds for fish and sea turtles currently used by National Marine Fisheries Service (NMFS) and Bureau of Ocean Energy Management (BOEM) for impact 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), used by BOEM.
[d] Finneran et al. (2017), used by BOEM.
[e] McCauley et al. (2000b), used by BOEM.

2.5. Animal Movement Modeling and Exposure Estimation

JASMINE was used to estimate the probability of exposure of animals to 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. An overview of the exposure modeling process using JASMINE is shown in Figure .

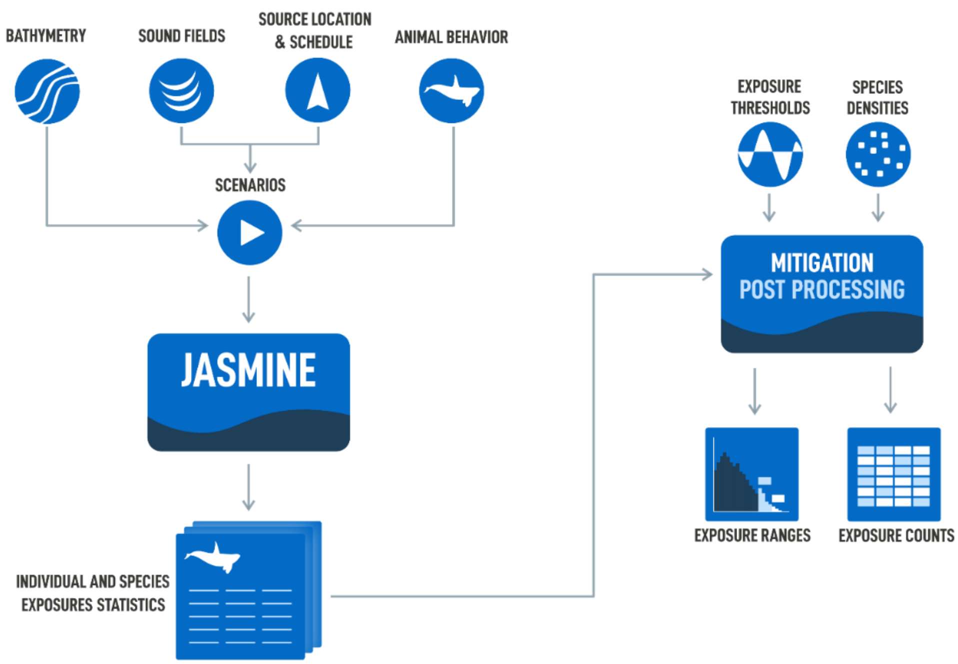

Figure 9. Exposure modeling process overview.

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.2, Figure 10). The predicted sound fields were 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. Received levels are then compared to the threshold criteria described in Section 2.4 within each analysis period. Appendix H provides a fuller description of animal movement modeling and the parameters used in the JASMINE simulations. 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. JASMINE can be used to simulate aversive behaviors, where animals respond to sound. A subset of scenarios was run with aversion and these results are provided for demonstration purposes only (see Section 2.4).

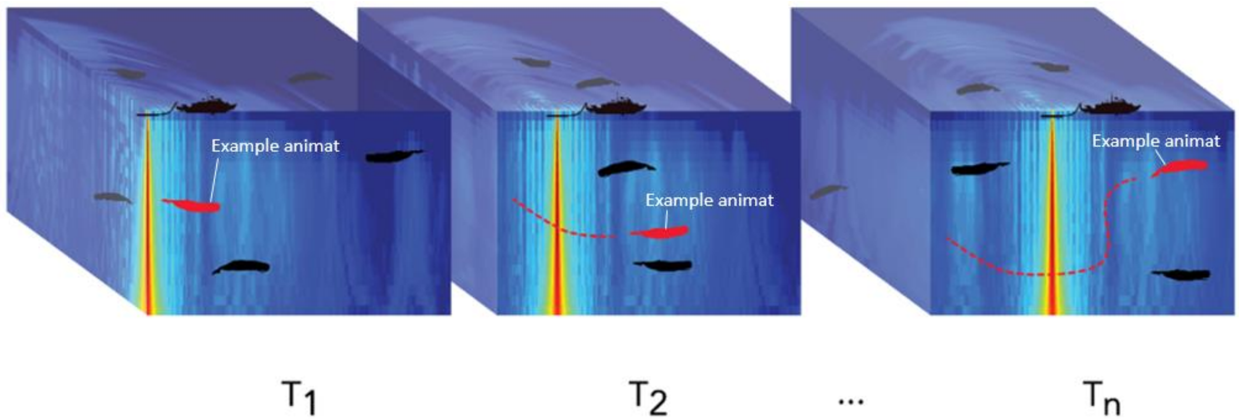

Figure 10. Depiction of animats in an environment with a moving sound field. Example animat (red) shown moving with each time step. The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

2.5.1. Implementing Pile Installation Schedules in JASMINE

Exposure modeling locations were chosen to represent typical expected construction activity in the Lease Area over a seven-day period. The pile installation schedules are described in Section 1.2.7.

The hammering schedule for each foundation type is determined from pile driving parameters. For a single pile, the installation time is calculated using the blow rate and blow count at each hammer energy level. A pile installation schedule is created for the simulation by assigning each strike of the pile to a time in the simulation, along with the closest associated sound field for that pile type and scenario. When multiple piles are driven per day, the same hammering schedule is used for the additional piles, with a delay between piles to allow for vessel movement and set up. Figure 11 displays the pile installation schedule for vibratory followed by impact pile driving operations.

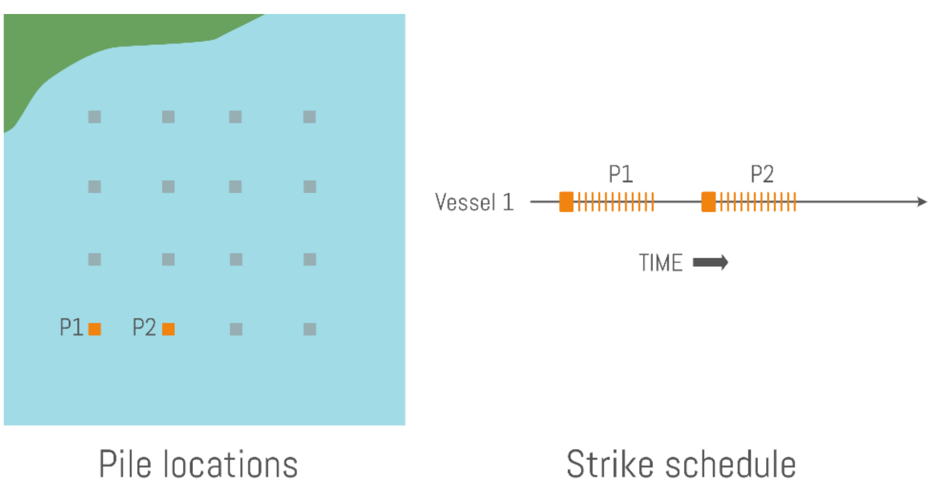

Figure 11. Pile installation schedule for vibratory pile driving followed by impact pile driving. Vertical orange tick marks show conceptual representations of each hammer strike. Solid orange bars preceding the tick marks indicate periods of vibratory pile driving.

The animal movement modeling assumed 60 minutes of vibratory setting of piles for all pile types and installation schedules. For piling of monopile foundations, the model assumed 15 minutes between vibratory and impact pile driving to switch equipment. A strike rate of 30 strikes per minute for the 5000 kJ hammer scenarios, 27.6 strikes per minute for the 6000 kJ hammer 13 m monopile scenarios, and 25 strikes per minute for the 6000 kJ hammer 12 m monopile scenarios was used. The model assumed 30 minutes between foundation installation when more than one foundation was installed per day.

For jacket foundations, the number of strikes required to drive each pile as provided by the Proponent is a conservative estimate, in that it is likely to be an overestimate of the actual number of strikes required. The animal movement modeling is based on exposure levels in a 24 h period to capture 24-hour cumulative metrics (i.e., SEL), so pile installation is constrained to fit within 24 h. To accommodate the high number of strikes for jacket foundations within a 24-hour period, a strike rate of 30 per minute was used to model cases where 4 pin piles were installed in one day. Additionally, the time between pile installation each day was 15 minutes between vibratory and impact pile driving to switch equipment and 15 minutes between foundation installation.

2.6. Summing Different Source Types

When evaluating the potential for injury, the total received acoustic energy (SEL) over a given time period (24 h) is needed. Vibratory setting of piles followed by impact pile driving is being considered for New England Wind for the installation of both monopile and jacket foundations. Although the potential to induce hearing loss is low during vibratory driving, it does introduce sound into the water and must be considered as part of the total received acoustic energy. For this reason, the combined sound energy from vibratory and impact pile driving was computed and is shown Appendix H. The PTS onset SEL thresholds are lower for impact piling than for vibratory piling (Section 2.4), so when estimating animats exposed to potentially injurious sound levels, the lower thresholds were applied to the total received sound energy level from both sources.

Exposure to sound above a behavioral response threshold is a simpler, one-time exposure calculation that is done for vibratory and impact pile driving separately because these two sound sources use different thresholds and are temporally separated. The numbers of animats exposed above these thresholds are calculated individually and then combined to get total behavioral exposures while ensuring that animats exposed above both thresholds are not double counted.

Drilling operations may be needed to pass through large sub-surface boulders or hard sediment layers encountered during pile installation. Acoustic modeling assumed that drilling activity could occur for a full 24 hours during any given day. Although drilling is not expected to be required for 24 hours, all modeling assumed 24 hours of drilling to provide the most conservative estimate. Drilling activities produce non-impulsive sounds that may cause hearing damage, masking of communication signals, and behavioral responses in marine mammals, sea turtles and fishes (McCauley 1994, Popper et al. 2014). Maximum predicted injury exposures were <0.01 for modeled marine mammals and sea turtle species (see Appendix K), where ranges to injurious thresholds are <200 m for all species.

Maximum predicted acoustic ranges to fish injury thresholds are ~2,300 m, with the farthest acoustic ranges predicted for fish <2g. McCauley (1998) determined that effects to fish from sounds produced by marine drilling activity would likely be temporary behavioral changes within a few hundred meters of the source. The available literature suggests that continuous sound produced by drilling operations may mask acoustic signals of fish that convey important environmental information (McCauley 1994, Popper et al. 2014). Furthermore, measured source levels during drilling operations reached 120 dB at 3–5 km, may have caused fish avoidance (McCauley 1998). There are no data linking continuous noise to mortality in fish exposed to non-impulsive sound sources (Popper and Hawkins 2019). Continuous sound has been linked to TTS in some species of fish; however, exposure times to these sounds were at least 12 hours (Amoser and Ladich 2003, Smith et al. 2006).

Sounds emitted by marine drilling operations for wind farm construction are expected to be short-term and intermittent. Overall, drilling is not expected to cause injury to marine fauna but may cause behavioral impacts. For additional information on modeled acoustic ranges and exposure estimates for drilling activities, see Appendix K.

2.7. Estimating Monitoring Zone for Mitigation

Monitoring zones used for mitigation purposes have traditionally been estimated by determining the distance to injury and behavioral thresholds (see Appendix F). This traditional method tacitly assumes that all receivers (animals) in the area remain stationary for the duration of the sound event. Because 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) during 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 12). 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.

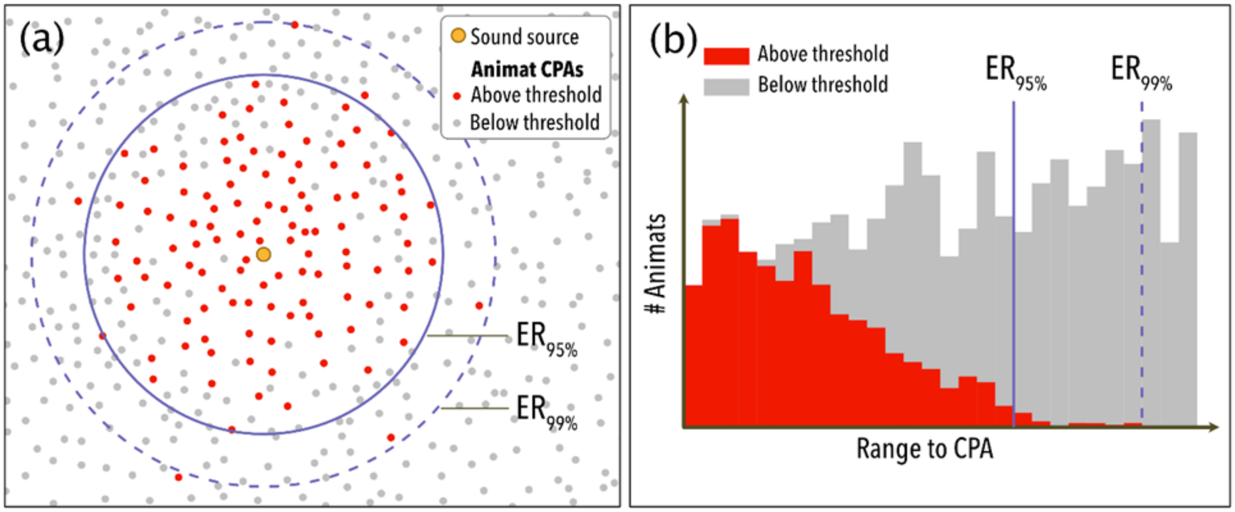

Figure 12. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows the distribution of ranges to animat CPAs. The 95% and maximum Exposure Ranges ($ER_{95\%}$ and ER_{max}) are indicated in both panels.

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). Five marine mammal species know to occur in the Northwest Atlantic OCS region are ESA listed (Table 18). All four species of sea turtle (Table 20) as well as four fish species (Section 3.3) occurring in the Northwest Atlantic OCS region are also ESA listed.

3.1. Marine Mammals that May Occur in the Area

Thirty-nine marine mammal species (whales, dolphins, porpoise, 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, NOAA Fisheries 2023). All 39 marine mammal species identified in Table 18 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, fin whale (*Balaenoptera physalus physalus*), blue whale (*Balaenoptera musculus*), and sei whale (*Balaenoptera borealis borealis*).

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. 2022).

The expected occurrence of each marine mammal species in the SWDA is listed in Table 18. 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;
- 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.

Marine mammal species considered *common* and *uncommon* were selected for quantitative assessment by acoustic impact analysis and exposure modeling. Quantitative assessment of bottlenose dolphins (*Tursiops truncatus*) presumed all impacted individuals belong to the Western North Atlantic Offshore stock because the northern limit of the range of the coastal stock does not extend into the Offshore Development Area. Quantitative assessment of *rare* species was not conducted because impacts to those species approach zero due to their low densities. The modeled species are identified in Table 18. The likelihood of incidental exposure for each species based on its presence, density, and overlap of proposed activities is described in Section 3.8.

Table 18. 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 [c]	*Balaenoptera physalus*	Western North Atlantic	ESA-Endangered	Common	6,802
Humpback whale [c]	*Megaptera novaeangliae*	Gulf of Maine	MMPA	Common	1,396
Minke whale [c]	*Balaenoptera acutorostrata*	Canadian Eastern Coastal	MMPA	Common	21,968
North Atlantic right whale [c]	*Eubalaena glacialis*	Western	ESA-Endangered	Common	338[d]
Sei whale [c]	*Balaenoptera borealis*	Nova Scotia	ESA-Endangered	Common	6,292
Toothed whales (Odontoceti)					
Sperm whales (Physeteroidae)					
Sperm whale [c]	*Physeter macrocephalus*	North Atlantic	ESA-Endangered	Uncommon	4,349
Dwarf sperm whale	*Kogia sima*	Western North Atlantic	MMPA	Rare	7,750[e]
Pygmy sperm whale	*Kogia breviceps*	Western North Atlantic	MMPA	Rare	7,750[e]
Dolphins (Delphinidae)					
Atlantic spotted dolphin [c]	*Stenella frontalis*	Western North Atlantic	MMPA	Uncommon	39,921
Atlantic white-sided dolphin [c]	*Lagenorhynchus acutus*	Western North Atlantic	MMPA	Common	93,233
Bottlenose dolphin [c]	*Tursiops truncatus*	Western North Atlantic, offshore [f]	MMPA	Common	62,851
		Western North Atlantic, Northern Migratory Coastal	MMPA- Strategic	Rare	6,639
Clymene dolphin	*Stenella clymene*	Western North Atlantic	MMPA	Rare	4,237
Common dolphin [c]	*Delphinus delphis*	Western North Atlantic	MMPA	Common	172,974
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 [c]	*Globicephala melas*	Western North Atlantic	MMPA	Uncommon	39,215
Pilot whale, short-finned [c]	*Globicephala macrorhynchus*	Western North Atlantic	MMPA	Uncommon	28,924
Pygmy killer whale	*Feresa attenuata*	Western North Atlantic	MMPA	Rare	Unknown
Risso's dolphin [c]	*Grampus griseus*	Western North Atlantic	MMPA	Uncommon	35,215
Rough-toothed dolphin	*Steno bredanensis*	Western North Atlantic	MMPA	Rare	136
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 [g]
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[h]
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 [c]	*Phocoena phocoena*	Gulf of Maine/ Bay of Fundy	MMPA	Common	95,543
Earless seals (Phocidae)					
Gray seal [c]	*Halichoerus grypus*	Western North Atlantic	MMPA	Common	27,300[i]
Harbor seal [c]	*Phoca vitulina*	Western North Atlantic	MMPA	Common	61,336
Harp seal [c]	*Pagophilus groenlandicus*	Western North Atlantic	MMPA	Uncommon	Unknown [j]
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 (Hayes et al. 2022).

[b] Best available abundance estimate is from NOAA Fisheries Stock Assessment Reports (Hayes et al. 2022).

[c] Modeled species.

[d] Best available abundance estimate is from NOAA Fisheries 2022 draft Stock Assessment (NOAA Fisheries 2023). NARW consortium has released the 2022 report card results predicting a NARW population of 340 for 2021 (Pettis et al. 2023). 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 2022 draft SAR (NOAA Fisheries 2023) will be used to report an unaltered output of the Pace et al. (2017, 2021) model (DoC and NOAA 2020).

[e] This estimate includes both dwarf and pygmy sperm whales. Source: NOAA Fisheries (2023).

[f] Bottlenose dolphins occurring in the Offshore Development Area likely belong to the Western North Atlantic Offshore stock (Hayes et al. 2022).

[g] 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).

[h] 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. (2022)

[i] Estimate of gray seal population in US waters. Data are derived from pup production estimates; (Hayes et al. 2022) 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.

[j] Hayes et al. (2022) report insufficient data to estimate the population size of harp seals in US waters; the best estimate for the whole 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 19. These were obtained using the Duke University Marine Geospatial Ecology Laboratory model (Roberts et al. 2016a, 2022b), which were recently updated for all species. The 2022 updated NARW model (v12) provides model predictions for three eras, 2003–2019, 2003–2009, and 2010–2019, to reflect the apparent shift in NARW distribution around 2010. The modeling reported herein used the 2010–2019 density predictions as recommended by Roberts et al. (2022b). Similarly, the 2022 updated humpback whale model (v11) provides model predictions for three eras, 2002–2019, 2002–2008, and 2009–2019. The modeling reported herein used the 2009-2019 density predictions as recommended by Roberts et al. (2022b).

The mean density for each month was determined by calculating the unweighted mean of all 5 × 5 km grid cells partially or fully within the analysis polygon (Table 19 and Figure 13). Densities were computed monthly, annually, and for the May–December period to coincide with proposed pile driving activities. In cases where monthly densities were unavailable, annual mean densities were used instead.

There are two cases in this study for which the MGEL/Duke models report densities for species guilds: seals and pilot whales. For the recently updated modeling efforts- vibratory setting followed by impact pile driving, impact pile driving alone, and drilling, when calculating exposures for individual pilot whale and seal species, the guild densities provided by Roberts et al. (2016a, 2022b) were scaled by the relative abundances of the species in each guild, using the best available estimates of local abundance, to get species-specific density estimates surrounding the Lease Area. In estimating local abundances, all distribution data from the two pilot whale species and three seal species were downloaded from the Ocean Biodiversity Information System (OBIS) data repository (available at https://obis.org/). After reviewing the available datasets, it was deemed that data available in OBIS in Rhode Island and Massachusetts waters are the best available for the three seals species because of their overlap with the Lease Area. For seals, OBIS reported 86 observations of gray seals, 129 observations of harbor seals, and 93 observations of harp seals. Therefore, the proportions of 0.28 (86/308), 0.42 (129/308), and 0.30 (93/308) were used to scale the seals guild densities for the three seal species, respectively. The best data available for pilot whales came from AMAPPS data in Rhode Island and Massachusetts waters. The proportions of 0.80 for long-finned and 0.20 for short-finned pilot whales were used (Palka et al 2021). For previous modeling efforts- UXO detonation, and HRG surveys, for long- and short-finned pilot whales, the guild density from Roberts et al. (2016a, 2022b) was scaled by the relative stock sizes based on the best available abundance estimate from NOAA Fisheries SARs (Hayes et al. 2022). Similarly, densities are provided for seals as a guild consisting primarily of harbor and gray seals (Roberts et al. 2016a, 2022b). Gray and harbor seal densities were scaled by relative NOAA Fisheries SAR (Hayes et al. 2022) abundance.

For cases with vibratory setting of piles followed by impact pile driving, and impact pile driving alone, densities were calculated within buffered polygons of various ranges around the Lease Area perimeter. The following buffer ranges were pre-selected: 10, 25, 50 km. For each species, foundation type, and attenuation level, the most appropriate density perimeter was selected from this list. The range was selected using the 95th percentile exposure range ($ER_{95\%}$) for each case and rounded up to the next highest buffer range. For example, if the $ER_{95\%}$ was 8.5 km, the 10 km perimeter was used. In cases where the $ER_{95\%}$ was larger than 50 km, the 50-km perimeter was used. The 50 km limit is derived from studies of mysticetes that found limited behavioral response over 50 km from the source (Dunlop et al. 2017).

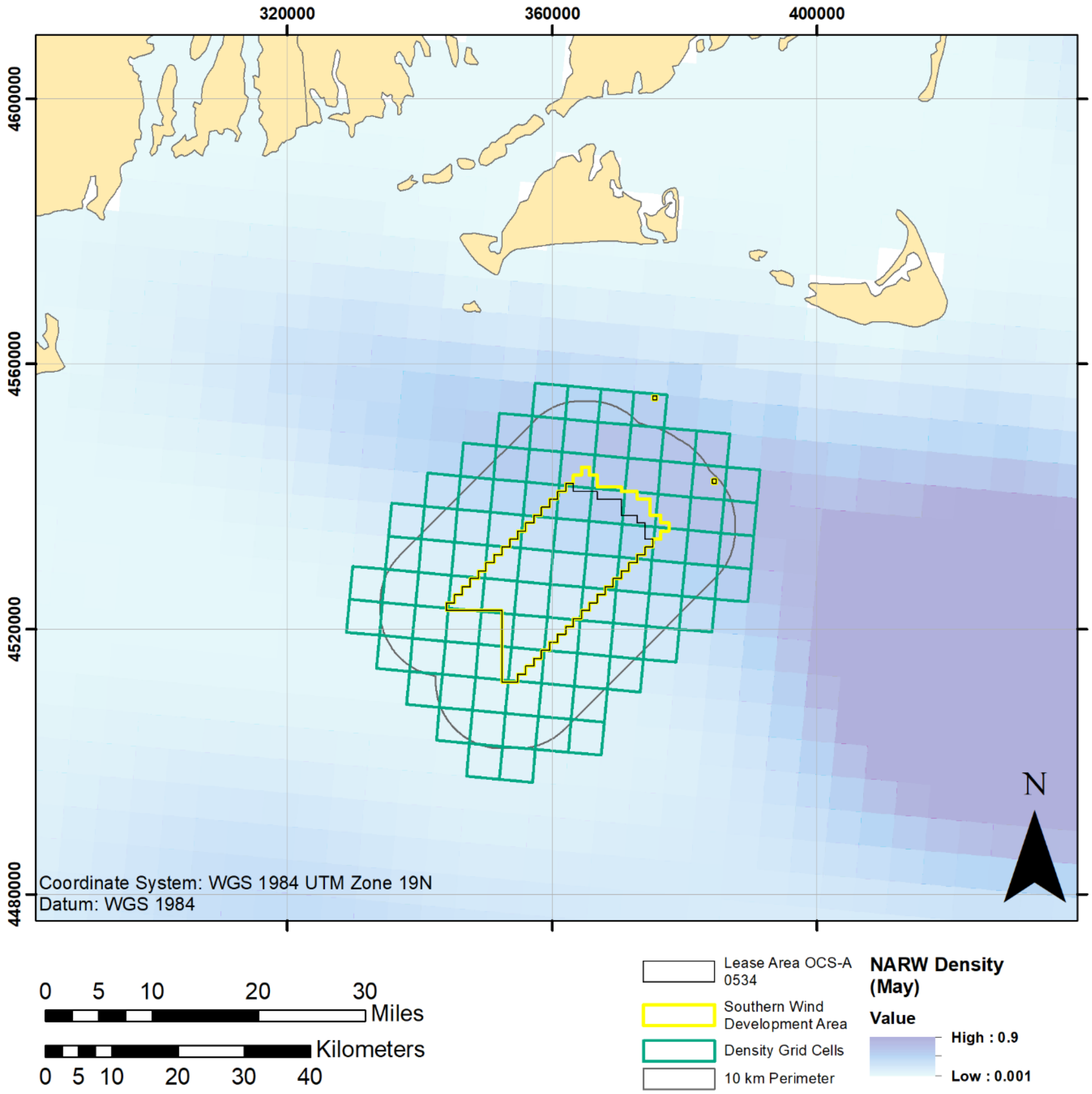

Figure 13. Marine mammal (e.g., NARW) density map (Roberts et al. 2022a) showing highlighted grid cells used to calculate mean monthly species density estimates within a 10-km perimeter around New England Wind, the smallest of the selected ranges (10, 25, 50 km), based on acoustic range to the behavioral threshold (R95%) for vibratory pile setting followed by 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 19. Mean monthly marine mammal density estimates for all modeled species in a 10-km perimeter around New England Wind, used to calculate exposures above the 120 dB SPL behavioral threshold for vibratory pile setting followed by impact pile driving and impact pile driving alone.

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]	0.215	0.166	0.107	0.164	0.272	0.256	0.438	0.366	0.227	0.057	0.051	0.141	0.205	0.226
Minke whale	0.113	0.137	0.136	0.806	1.728	1.637	0.700	0.471	0.516	0.465	0.052	0.077	0.570	0.706
Humpback whale	0.031	0.023	0.043	0.149	0.294	0.307	0.172	0.120	0.167	0.236	0.190	0.030	0.147	0.189
North Atlantic right whale [a]	0.387	0.461	0.456	0.478	0.295	0.050	0.022	0.018	0.028	0.052	0.068	0.197	0.209	0.091
Sei whale [a]	0.039	0.021	0.044	0.112	0.192	0.052	0.013	0.011	0.019	0.036	0.079	0.065	0.057	0.058
Atlantic white-sided dolphin	2.049	1.230	0.850	1.313	3.322	3.003	1.392	0.730	1.654	2.431	1.791	2.440	1.850	2.095
Atlantic spotted dolphin	0.001	<0.001	<0.001	0.003	0.018	0.025	0.031	0.054	0.273	0.431	0.179	0.018	0.086	0.128
Common dolphin	7.130	2.455	1.884	3.258	6.254	13.905	10.533	14.446	25.703	22.676	11.103	10.774	10.844	14.424
Bottlenose dolphin, offshore	0.495	0.111	0.059	0.156	0.814	1.358	1.479	1.659	1.483	1.337	1.255	1.101	0.942	1.311
Risso's dolphin	0.043	0.004	0.002	0.018	0.096	0.048	0.068	0.128	0.158	0.087	0.120	0.179	0.079	0.111
Long-finned pilot whale [b]	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189
Short-finned pilot whale [b]	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
Sperm whale [a]	0.031	0.011	0.013	0.003	0.014	0.028	0.038	0.107	0.070	0.057	0.031	0.020	0.035	0.046
Harbor porpoise	10.007	10.784	10.277	8.914	6.741	0.960	0.880	0.848	0.988	1.271	1.418	5.812	4.908	2.365
Gray seal [b]	5.395	5.603	4.176	3.203	4.716	0.806	0.088	0.094	0.226	0.500	1.768	4.534	2.592	1.591
Harbor seal [b]	8.093	8.404	6.265	4.804	7.074	1.209	0.132	0.140	0.339	0.750	2.652	6.802	3.889	2.387
Harp seal [b]	5.781	6.003	4.475	3.432	5.053	0.864	0.094	0.100	0.242	0.535	1.894	4.858	2.778	1.705

[a] Listed as Endangered under the ESA.
[b] Density adjusted by relative local abundance. Harp seal uses gray seal density.

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 2021b). 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 2014b).

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).

Table 20. Sea turtle species potentially occurring within the regional waters of the Western North Atlantic Outer Continental Shelf (OCS) and Lease Area.

Species	Scientific name	Regulatory status [a]	Relative occurrence in Project Area
Leatherback sea turtle [b]	*Dermochelys coriacea*	ESA Endangered	Common
Loggerhead sea turtle [b]	*Caretta caretta*	ESA Threatened	Common
Kemp's ridley sea turtle [b]	*Lepidochelys kempii*	ESA Endangered	Uncommon
Green sea turtle [b]	*Chelonia mydas*	ESA Threatened	Uncommon

[a] Listing status as stated in NOAA Fisheries n.d., MA NHESP 2019; RI DEM 2011; NYSDEC 2020a.

[b] Modeled species.

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.

3.4.1. Impact Only Pile Driving Density Estimates for Sea Turtles

For cases with impact pile driving only, densities were calculated within a perimeter set at 6.2 km from the Lease Area (Table 21).

Table 21. Sea turtle density estimates for all modeled species in a 6.2-km perimeter around New England Wind.

Species	Density (animals/100 km^2) [a]			
	Spring	Summer	Fall	Winter
Green sea turtle [b]	0.019	0.019	0.019	0.019
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	0.019	0.019	0.019	0.019

[a] Density estimates are extracted from SERDP-SDSS NODE database within a 6.2 km perimeter of New England Wind, 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).

3.4.2. Vibratory and Impact Pile Driving Density Estimates for Sea Turtles

For cases with vibratory setting of piles followed by impact pile driving, densities were calculated within buffered polygons of various ranges around the New England Wind Lease Area perimeter (see Appendix H.3). The following buffer ranges were pre-selected: 10, 25, and 50 km. For each species, foundation type, and attenuation level, the most appropriate density perimeter was selected from this list. The range was selected using the 95th percentile exposure range ($ER_{95\%}$) for each case, using the next highest range.

Table 22. Sea turtle density estimates for all modeled species in a 10-km perimeter around New England Wind.

Species	Monthly densities (animals/100 km²) [a]				Annual mean	May to Dec mean
	Spring	Summer	Fall	Winter		
Green sea turtle [b]	0.015	0.015	0.015	0.015	0.015	0.015
Leatherback sea turtle	0.023	0.630 [c]	0.873[c]	0.023	0.387	0.569
Loggerhead sea turtle	0.107	0.206 [d]	0.633[d]	0.107	0.263	0.341
Kemp's ridley sea turtle	0.015	0.015	0.015	0.015	0.015	0.015

[a] Density estimates are extracted from SERDP-SDSS NODE database within a 10 km perimeter of New England Wind, 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).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 4; Figure 7). This section summarizes the source level modeling results (Section 3.5), both acoustic and exposure ($ER_{95\%}$) ranges (Sections 3.5.1 and 3.8). 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 3.8.

3.5. 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 2010b) and are shown in Figure 14 to Figure 22. The forcing functions serve as the inputs to JASCO's pile driving source models used to estimate equivalent acoustic source characteristics detailed in Appendix D. As no hammer parameters were available for either a 5000 or 6000 kJ hammer, the modeled energies of the 5500 kJ hammer were scaled using their stroke length to represent the effect of the forcing functions for the two different hammers approximated. Decidecade band source levels for each pile type, hammer energy, and modeled location for sound speed profiles are shown in Figures 23–31. Broadband source levels at 10 m (SEL dB re 1 $\mu Pa^2 \cdot s$) for each pile type for average conditions between May and December are shown in Tables 23–28.

3.5.1. Forcing Functions

3.5.1.1. Impact-Only Pile Driving

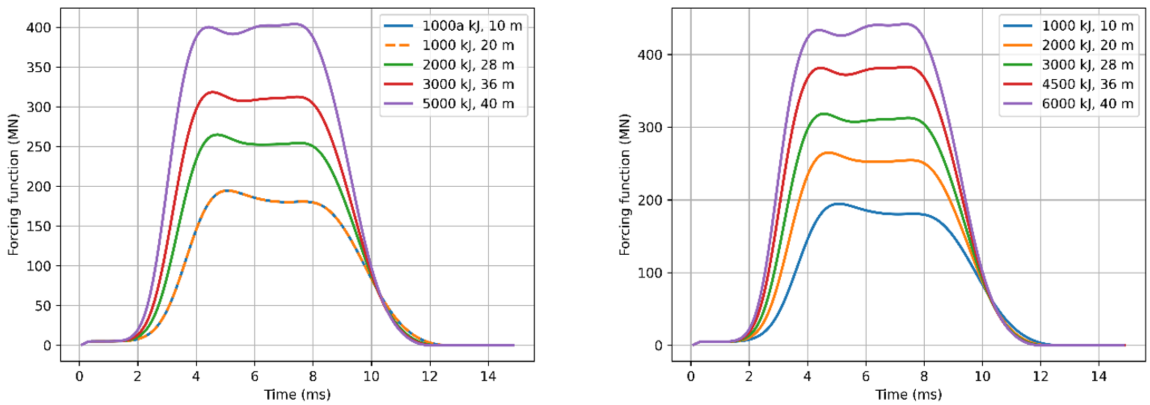

Figure 14. Modeled forcing functions versus time for a 12 m monopile as a function of hammer energy (left) MHU5000 kJ and (right) MHU6000 kJ hammer.

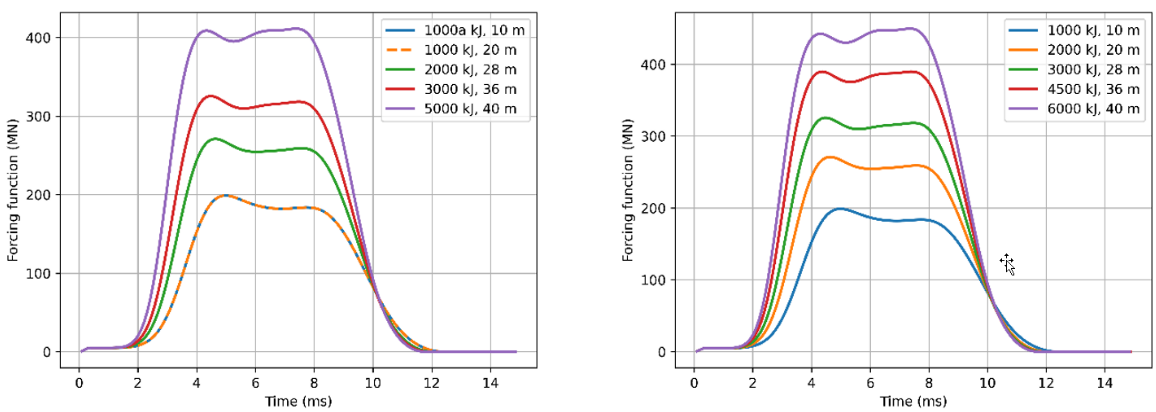

Figure 15. Modeled forcing functions versus time for a 13 m monopile as a function of hammer energy using a (left) MHU 5000 kJ and (right) MHU 6000 kJ hammer.

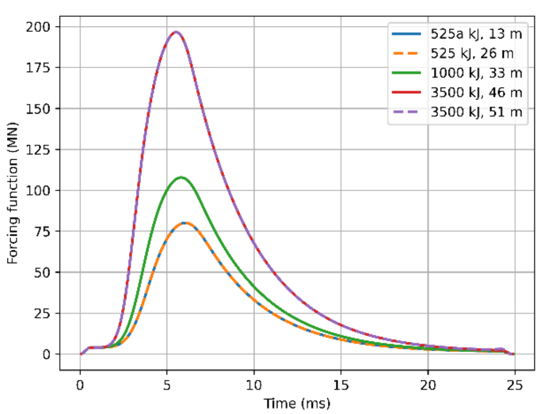

Figure 16. Modeled forcing functions versus time for a 4 m jacket as a function of hammer energy (MHU 3500).

3.5.1.2. Vibratory Pile-Setting Followed by Impact Pile Driving

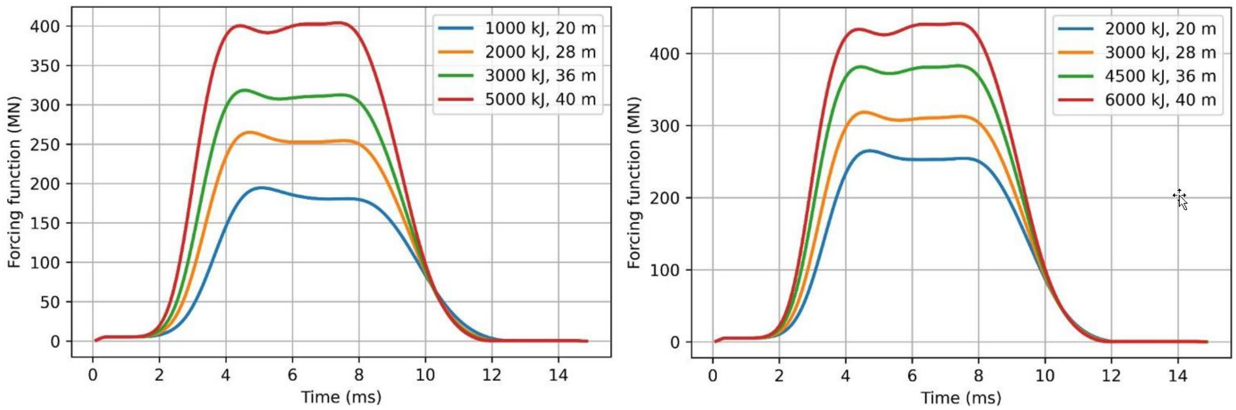

Figure 17. Modeled forcing functions versus time for a 12 m monopile as a function of hammer energy (left) MHU5000 kJ and (right) MHU6000 kJ hammer.

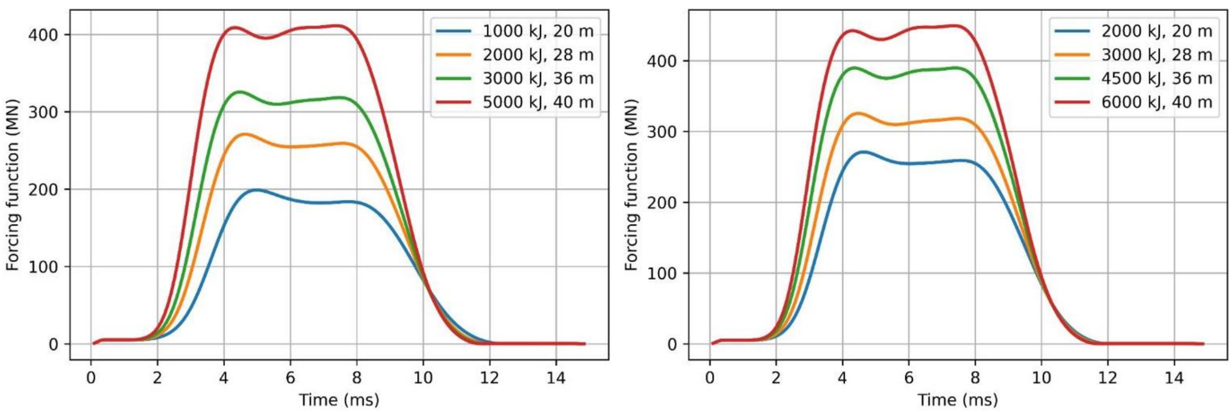

Figure 18. Modeled forcing functions versus time for a 13 m monopile as a function of hammer energy using a (left) MHU 5000 kJ and (right) MHU 6000 kJ hammer.

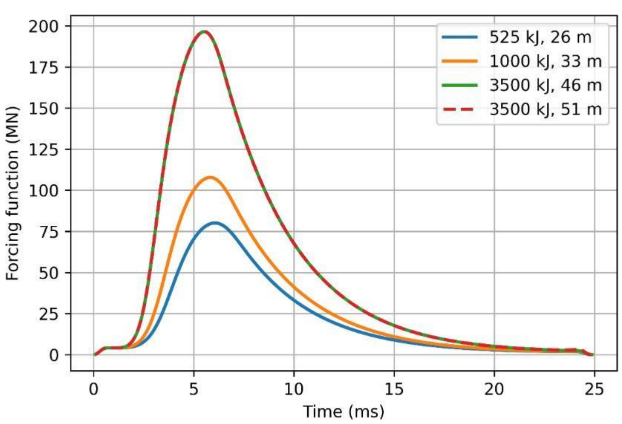

Figure 19. Modeled forcing functions versus time for a 4 m jacket as a function of hammer energy (MHU 3500).

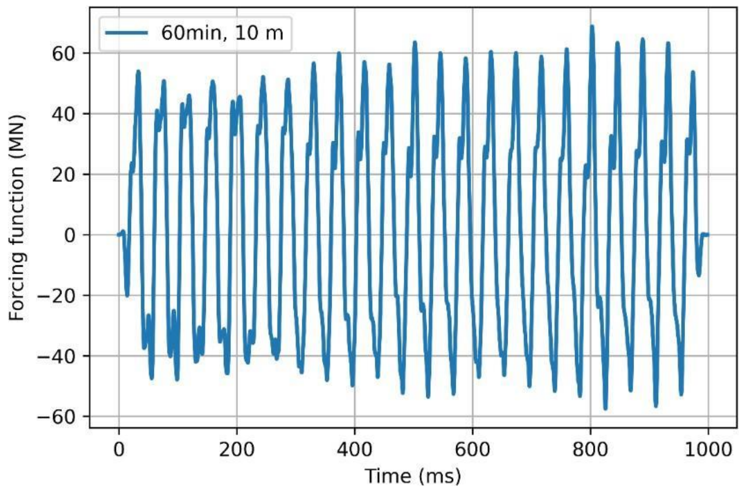

Figure 20. Modeled forcing functions versus time for a 12 m monopile (TR-CV640).

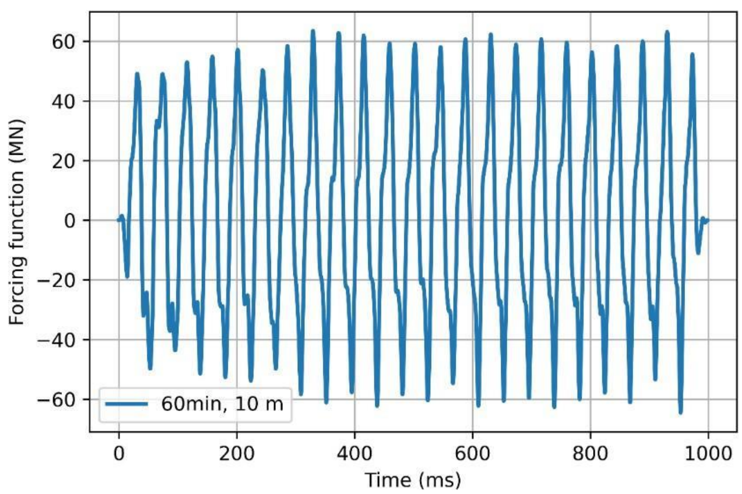

Figure 21. Modeled forcing functions versus time for a 13 m monopile (TR-CV640).

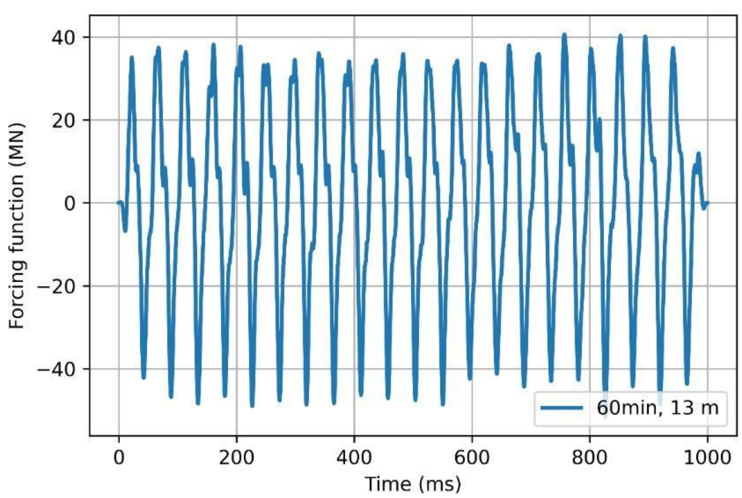

Figure 22. Modeled forcing functions versus time for a 4 m jacket (TR-CV640).

3.5.2. Decidecade band levels

3.5.2.1. Impact-Only Pile Driving

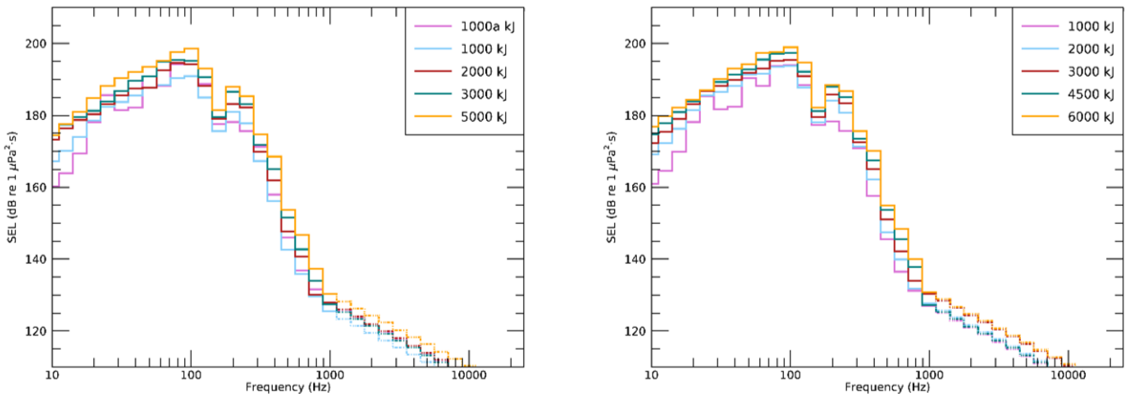

Figure 23. Decidecade band levels at 10 m from location M1 for a 12 m monopile assuming an installation scenario with (left) a MHU5000 kJ and (right) a MHU6000 kJ hammer with average sound speed profiles from May to December.

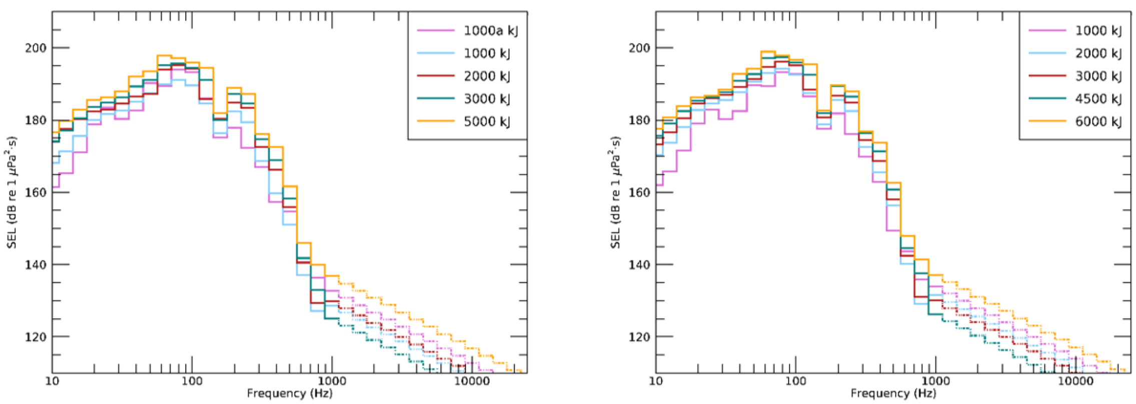

Figure 24. Decidecade band levels at 10 m from location M2 for a 13 m monopile assuming an installation scenario with (left) a MHU5000 kJ and (right) a MHU6000 kJ hammer with average sound speed profiles from May to December.

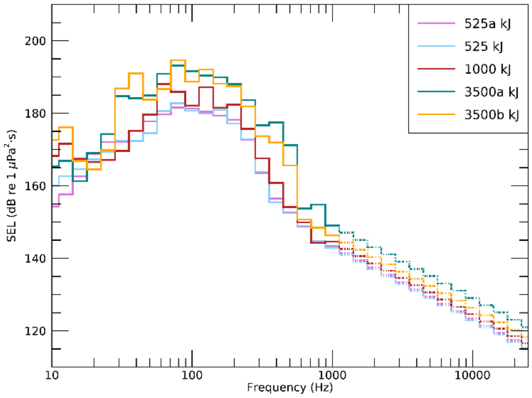

Figure 25. Decidecade band levels at 10 m from location J1 for a 4 m jacket assuming an installation scenario with a MHU 3500 kJ hammer with average sound speed profiles from May to December.

3.5.2.2. Vibratory Pile-Setting Followed by Impact Pile Driving

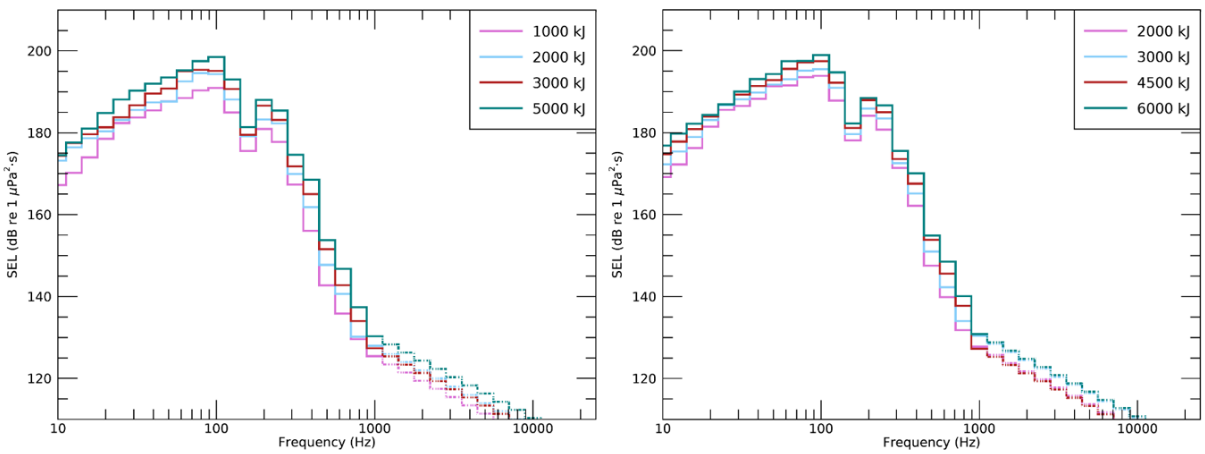

Figure 26. Decidecade band levels at 10 m from location M1 for a 12 m monopile assuming an installation scenario with (left) a MHU5000 kJ and (right) a MHU6000 kJ hammer with average sound speed profiles from May to December.

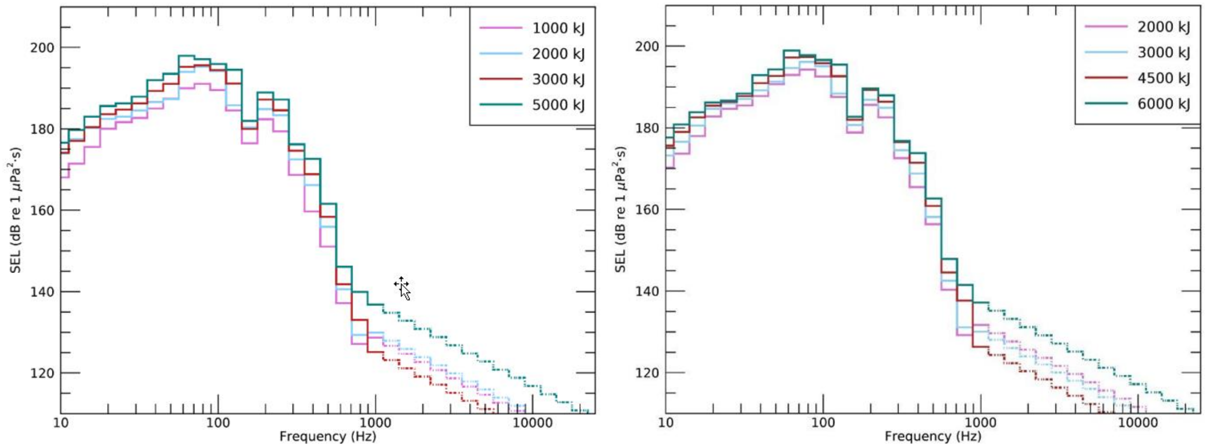

Figure 27. Decidecade band levels at 10 m from location M2 for a 13 m monopile assuming an installation scenario with (left) a MHU5000 kJ and (right) a MHU6000 kJ hammer with average sound speed profiles from May to December.

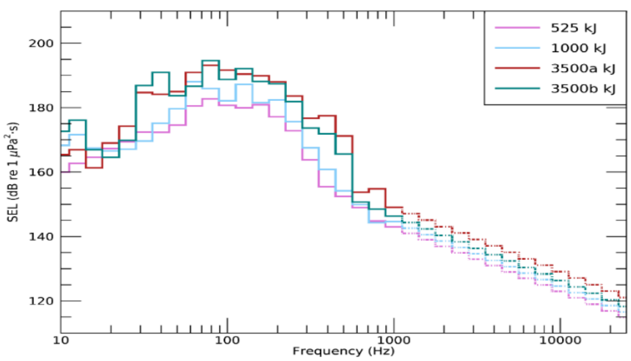

Figure 28. Decidecade band levels at 10 m from location J1 for a 4 m jacket assuming an installation scenario with a MHU 3500 kJ hammer with average sound speed profiles from May to December.

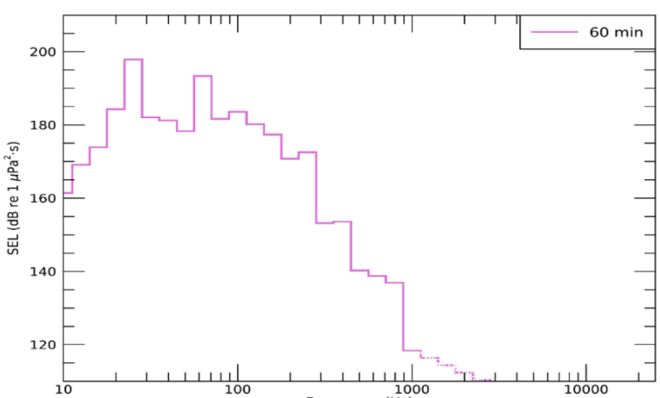

Figure 29. Decidecade band levels at 10 m from location M1 for a 12 m monopile assuming an installation scenario with a TR-CV640 vibratory hammer with average sound speed profiles from May to December.

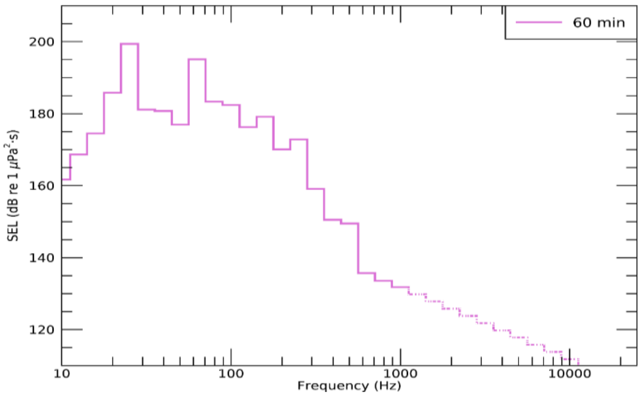

Figure 30. Decidecade band levels at 10 m from location M2 for a 13 m monopile assuming an installation scenario with a TR-CV640 vibratory hammer with average sound speed profiles from May to December.

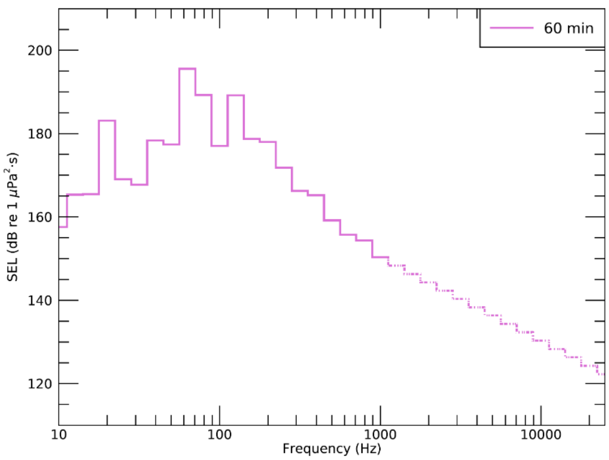

Figure 31. Decidecade band levels at 10 m from location J1 for a 4 m jacket assuming an installation scenario with a TR-CV640 vibratory hammer with average sound speed profiles from May to December.

3.5.3. Broadband levels

3.5.3.1. Impact-Only Pile Driving

Table 23. Broadband source level at 10 m (SEL dB re 1 µPa^2·s) for the 12 m monopile at location M1 for average conditions between May to December.

Scenario	Location	Hammer duration/ Energy (kJ)	Impact
WTG (12 m monopile)	M1	**Drivability 1**	
		1000a	199.5
		1000	197.0
		2000	200.2
		3000	201.8
		5000	204.0
		Drivability 2	
		1000	199.2
		2000	200.1
		3000	201.7
		4500	203.5
		6000	204.8

Table 24. Broadband source level at 10 m (SEL dB re 1 µPa^2·s) for the 13 m monopile at location M2 for average conditions between May to December.

Scenario	Location	Hammer duration/ Energy (kJ)	Impact
WTG (13 m monopile)	M2	**Drivability 1**	
		1000a	198.8
		1000	197.1
		2000	200.6
		3000	201.9
		5000	204.0
		Drivability 2	
		1000	198.5
		2000	200.2
		3000	201.9
		4500	203.6
		6000	204.8

Table 25. Broadband source level at 10 m (SEL dB re 1 µPa²·s) for a 4 m jacket pin pile at location J1 for average conditions between May to December.

Scenario	Location	Hammer duration/ Energy (kJ)	Impact
OSS (4 m jacket)	J1	Drivability 1	
		525a	189.0
		525	189.0
		1000	193.5
		3500a	199.4
		3500b	199.6

3.5.3.2. Vibratory Pile-Setting Followed by Impact Pile Driving

Table 26. Broadband source level at 10 m (SEL dB re 1 µPa²·s) for the 12 m monopile at location M1 for average conditions between May to December.

Scenario	Location	Hammer duration/ Energy (kJ)	Impact	Vibratory
WTG (12 m monopile)	M1	Vibratory pile setting		
		60 min	-	200.1
		Impact pile driving impact drivability 1		
		1000	197.0	-
		2000	200.2	-
		3000	201.8	-
		5000	204.0	-
		Impact Pile Driving		
		2000	200.1	-
		3000	201.7	-
		4500	203.5	-
		6000	204.8	-

Table 27. Broadband source level at 10 m (SEL dB re 1 µPa²·s) for the 13 m monopile at location M2 for average conditions between May to December.

Scenario	Location	Hammer duration/ Energy (kJ)	Impact	Vibratory
WTG (13 m monopile)	M2	Vibratory pile setting		
		60 min	-	201.2
		Impact pile driving		
		1000	197.1	-
		2000	200.6	-
		3000	201.9	-
		5000	204.0	-
		Impact pile driving		
		2000	200.2	-
		3000	201.9	-
		4500	203.6	-
		6000	204.8	-

Table 28. Broadband source level at 10 m (SEL dB re 1 μPa^2·s) for a 4 m jacket pin pile at location J1 for average conditions between May to December.

Scenario	Location	Hammer duration/ Energy (kJ)	Impact	Vibratory
Jacket (4 m pin pile)	J1	**Vibratory pile setting**		
		60 min	-	197.7
		Impact drivability		
		525	189.0	-
		1000	193.5	-
		3500 (a)	199.4	-
		3500 (b)	199.6	-

3.6. Modeled Ranges to Acoustic Thresholds Relevant for Impact-Only 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 E.4.

Tables 29 to 34 show the maximum 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. The $R_{95\%}$ for SEL is inclusive of all the hammer energy levels, while the $R_{95\%}$ for PK and SPL is from the hammer energy level that produces the longest range. The distances to SEL are calculated using the representative hammer energy schedules (Table 1) for driving one monopile or 4 pin piles.

Table 29. Maximum ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for marine mammals and sea turtles, and physical injury for fish for the 12 m monopile foundation driven with impact pile driving (MHU 6000). Ranges to SEL thresholds represent the cumulative sound level for one 12 m monopile foundation with varying levels of noise attenuation.

Faunal group	Metric	Threshold	Attenuation level (dB)		
			0	10	12
Low-frequency (LF) cetaceans	L_E	183	7,227	3,546	2,942
Mid-frequency (MF) cetaceans	L_E	185	-	-	-
High-frequency (HF) cetaceans	L_E	155	144	20	-
Phocid seals in water (PW)	L_E	185	1,532	400	260
Sea turtles (TUW)	L_E	204	2,206	679	519
Fish without swim bladder	L_{pk}	213	184	45	20
	L_E	216	680	128	108
Tables	L_{pk}	207	449	100	80
	L_E	203	2,843	1,032	787
Fish with swim bladder involved in hearing	L_{pk}	207	449	100	80
	L_E	203	2,843	1,032	787
Fish greater than or equal to 2 g	L_{pk}	206	469	108	89
	L_E	187	9,260	4,704	4,043
Fish less than 2 g	L_{pk}	206	469	108	89
	L_E	183	12,093	6,295	5,467

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s) for marine mammals and sea turtles, unweighted for fish.
A dash (-) indicates the threshold was not reached. Thresholds are taken from Tables 15 to 17.

Table 30. Maximum ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for marine mammals and sea turtles, and physical injury for fish for the 13 m monopile foundation driven with impact pile driving (MHU 6000). Ranges to SEL thresholds represent the cumulative sound level for one 13 m monopile foundation with varying levels of noise attenuation.

Faunal group	Metric	Threshold	Attenuation level (dB)		
			0	10	12
Low-frequency (LF) cetaceans	L_E	183	7,820	4,041	3,427
Mid-frequency (MF) cetaceans	L_E	185	-	-	-
High-frequency (HF) cetaceans	L_E	155	609	108	85
Phocid seals in water (PW)	L_E	185	1,683	451	286
Sea turtles (TUW)	L_E	204	2,518	789	553
Fish without swim bladder	L_{pk}	213	241	28	-
	L_E	216	796	146	126
Fish with swim bladder not involved in hearing	L_{pk}	207	488	113	89
	L_E	203	3,390	1,188	888
Fish with swim bladder involved in hearing	L_{pk}	207	488	113	89
	L_E	203	3,390	1,188	888
Fish greater than or equal to 2 g	L_{pk}	206	549	126	102
	L_E	187	10,652	5,362	4,656
Fish less than 2 g	L_{pk}	206	549	126	102
	L_E	183	13,767	7,013	6,121

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s) for marine mammals and sea turtles, unweighted for fish.
A dash (-) indicates the threshold was not reached. Thresholds are taken from Tables 15 to 17.

Table 31. Maximum ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for marine mammals and sea turtles, and physical injury for fish for the 3500 kJ, 4 m jacket foundation driven with impact pile driving (MHU 3500). 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) (4 Piles)		
			0	10	12
Low-frequency (LF) cetaceans	L_E	183	11,812	6,822	6,141
Mid-frequency (MF) cetaceans	L_E	185	28	-	-
High-frequency (HF) cetaceans	L_E	155	1,521	428	402
Phocid seals in water (PW)	L_E	185	4,029	1,605	1,271
Sea turtles (TUW)	L_E	204	4,872	2,131	1,726
Fish without swim bladder	L_{pk}	213	161	-	-
	L_E	216	2,053	560	422
Fish with swim bladder not involved in hearing	L_{pk}	207	443	117	89
	L_E	203	5,805	2,744	2,300
Fish with swim bladder involved in hearing	L_{pk}	207	443	117	89
	L_E	203	5,805	2,744	2,300
Fish greater than or equal to 2 g	L_{pk}	206	460	128	102
	L_E	187	14,170	8,200	7,324
Fish less than 2 g	L_{pk}	206	460	128	102
	L_E	183	17,157	10,251	9,065

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s) for marine mammals and sea turtles, unweighted for fish.
Thresholds are taken from Tables 15 to 17. A dash (-) indicates the threshold was not reached.

Table 32. Maximum SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 12 m monopile foundation (MHU 6000).

Faunal group	L_p (dB re 1 µPa)	Impact		
		Attenuation level (dB)		
		0	10	12
Marine Mammals	160	10,789	5,456	4,677
Sea turtles	175	3,715	1,537	1,229
Fish	150	18,051	10,789	9,304

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 15 to 17.

Table 33. Maximum SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 13 m monopile foundation (MHU 6000).

Faunal group	L_p (dB re 1 µPa)	Impact		
		Attenuation level (dB)		
		0	10	12
Marine Mammals	160	11,431	5,716	4,943
Sea turtles	175	4,007	1,659	1,322
Fish	150	21,289	11,431	9,773

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 15 to 17.

Table 34. Maximum SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 4 m jacket foundation (MHU 3500).

Faunal group	L_p (dB re 1 µPa)	Impact		
		Attenuation level (dB)		
		0	10	12
Marine Mammals	160	8,656	5,016	4,429
Sea turtles	175	3,579	1,387	1,059
Fish	150	14,918	8,656	7,749

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 15 to 17.

3.7. Modeled Ranges to Acoustic Thresholds Relevant for Vibratory Pile-Setting Followed by Impact Pile Driving

Like the prior section (Section 3.6), acoustic ranges are not used for exposure estimates but are reported here for vibratory setting followed by impact pile driving. For each sound level threshold, the maximum range (R_{max}) and the 95% range ($R_{95\%}$) were calculated (Tables 35 – 40). 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 E.4.

Table 35. Maximum ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for marine mammals and sea turtles, and physical injury for fish for the 12 m monopile foundation driven with 60 minutes of vibratory pile-setting followed by impact pile driving (MHU 6000, TR CV640). Ranges to SEL thresholds represent the cumulative sound level for one 12 m monopile foundation with varying levels of noise attenuation.

Faunal group	Metric	Threshold	Attenuation level (dB)		
			0	10	12
Low-frequency (LF) cetaceans	L_E	183	8,308	4,082	3,502
Mid-frequency (MF) cetaceans	L_E	185	-	-	-
High-frequency (HF) cetaceans	L_E	155	247	40	-
Phocid seals in water (PW)	L_E	185	1,811	487	397
Sea turtles	L_E	204	2,610	906	668
Fish without swim bladder	L_{pk}	213	184	45	20
	L_E	216	950	206	134
Fish with swim bladder not involved in hearing	L_{pk}	207	449	100	80
	L_E	203	3,567	1,397	104
Fish with swim bladder involved in hearing	L_{pk}	207	449	100	80
	L_E	203	3,567	1,397	104
Fish greater than or equal to 2 g	L_{pk}	206	469	108	89
	L_E	187	10,953	5,613	4,839
Fish less than 2 g	L_{pk}	206	469	108	89
	L_E	183	13,643	7,441	6,452

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s) for marine mammals and sea turtles, and unweighted for fish.
A dash (-) indicates the threshold was not reached. Thresholds are taken from Tables 15 to 17.

Table 36. Maximum ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for marine mammals and sea turtles, and physical injury for fish for the 13 m monopile foundation driven with 60 minutes of vibratory pile-setting followed by impact pile driving (MHU 6000, TR CV640). Ranges to SEL thresholds represent the cumulative sound level for one 13 m monopile foundation with varying levels of noise attenuation.

Faunal group	Metric	Threshold	Attenuation level (dB)		
			0	10	12
Low-frequency (LF) cetaceans	L_E	183	8,901	4,577	3,953
Mid-frequency (MF) cetaceans	L_E	185	-	-	-
High-frequency (HF) cetaceans	L_E	155	699	108	89
Phocid seals in water (PW)	L_E	185	1,965	528	432
Sea turtles	L_{pk}	232	-	-	-
	L_E	204	2,912	943	757
Fish without swim bladder	L_{pk}	213	241	28	-
	L_E	216	1,052	241	146
Fish with swim bladder not involved in hearing	L_{pk}	207	488	113	89
	L_E	203	4,116	1,556	1,234
Fish with swim bladder involved in hearing	L_{pk}	207	488	113	89
	L_E	203	4,116	1,556	1,234
Fish greater than or equal to 2 g	L_{pk}	206	549	126	102
	L_E	187	12,543	6,283	5,499
Fish less than 2 g	L_{pk}	206	549	126	102
	L_E	183	15,990	8,280	7,233

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s) for marine mammals and seat turtles, and unweighted for fish.
A dash (-) indicates the threshold was not reached. Thresholds are taken from Tables 15 to 17.

Table 37. Maximum ranges ($R_{95\%}$ in meters) to marine fauna auditory injury thresholds for marine mammals and sea turtles, and physical injury for fish for the 3500 kJ, 4 m jacket foundation driven with 60 minutes of vibratory pile-setting followed by impact pile driving (MHU 3500, TR CV640). 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) (4 Piles)		
			0	10	12
Low-frequency (LF) cetaceans	L_E	183	13,005	7,405	6,575
Mid-frequency (MF) cetaceans	L_E	185	45	-	-
High-frequency (HF) cetaceans	L_E	155	1,649	440	422
Phocid seals in water (PW)	L_E	185	4,284	1,735	1,393
Sea turtles	L_{pk}	232	-	-	-
	L_E	204	5,361	2,441	1.935
Fish without swim bladder	L_{pk}	213	161	-	-
	L_E	216	2,407	661	506
Fish with swim bladder not involved in hearing	L_{pk}	207	443	117	89
	L_E	203	6,480	3,132	2,606
Fish with swim bladder involved in hearing	L_{pk}	207	443	117	89
	L_E	203	6,480	3,132	2.606
Fish greater than or equal to 2 g	L_{pk}	206	460	128	102
	L_E	187	16,219	9,268	8,332
Fish less than 2 g	L_{pk}	206	460	128	102
	L_E	183	19,422	12,021	10,657

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = frequency-weighted sound exposure level (dB re 1 µPa^2·s), for marine mammals and sea turtles, and unweighted for fish.

Thresholds are taken from Tables 15 to 17. A dash (-) indicates the threshold was not reached.Table 38. Maximum SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 12 m monopile foundation (MHU 6000, TR CV640).

Faunal group	L_p (dB re 1 µPa)	Impact			L_p (dB re 1 µPa)	Vibratory		
		Attenuation level (dB)				Attenuation level (dB)		
		0	10	12		0	10	12
Marine Mammals	160	10,789	5,456	4,677	120	32,545	22,521	20,412
Sea turtles	175	3,715	1,537	1,229	175	888	190	144
Fish	150	18,051	10,789	9,304	150	7,944	3,963	3,396

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 15 to 17.

Table 39. Maximum SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 13 m monopile foundation (MHU 6000, TR CV640).

Faunal group	L_p (dB re 1 µPa)	Impact			L_p (dB re 1 µPa)	Vibratory		
		Attenuation level (dB)				Attenuation level (dB)		
		0	10	12		0	10	12
Marine Mammals	160	11,431	5,716	4,943	120	44,832	28,900	26,448
Sea turtles	175	4,007	1,659	1,322	175	863	171	117
Fish	150	21,289	11,431	9,773	150	9,083	4,491	3,864

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 15 to 17.

Table 40. Maximum SPL ranges ($R_{95\%}$ in meters) to marine fauna auditory behavioral thresholds for the 4 m jacket foundation (MHU 3500, TR CV640).

Faunal group	L_p (dB re 1 µPa)	Impact			L_p (dB re 1 µPa)	Vibratory		
		Attenuation level (dB)				Attenuation level (dB)		
		0	10	12		0	10	12
Marine Mammals	160	8,656	5,016	4,429	120	39,681	27,896	25,916
Sea turtles	175	3,579	1,387	1,059	175	1,211	272	161
Fish	150	14,918	8,656	7,749	150	10,791	5,358	4,596

L_p = unweighted sound pressure level (dB re 1 µPa)
Thresholds are taken from Tables 15 to 17.

3.8. Exposure Estimates

Exposure estimates were calculated for marine mammals and sea turtles using each of the proposed construction schedules (see Section 1.2.7). Each construction schedule includes a combination of foundations installed with vibratory setting of piles followed by impact pile driving and foundations installed with impact pile driving alone. For full results, including all modeled attenuation levels (0,10, and 12 dB), see Appendix H.

3.8.1. Marine Mammal Exposure Estimates

Table 41. Construction Schedule A, Total. Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	13.33	0.02	260.87	37.41
	Minke whale (migrating)	46.43	0.09	637.91	640.28
	Humpback whale	13.62	0.05	174.03	33.66
	North Atlantic right whale [c]	2.69	0	50.08	9.89
	Sei whale [c] (migrating)	1.79	<0.01	30.63	34.86
MF	Atlantic white-sided dolphin	0	0	2239.68	222.62
	Atlantic spotted dolphin	0	0	217.30	5.71
	Common dolphin	0	0	36917.57	3204.79
	Bottlenose dolphin, offshore	0	0	2560.58	165.39
	Risso's dolphin	0	0	568.94	16.66
	Long-finned pilot whale	0	0	269.65	21.71
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	76.04	4.50
HF	Harbor porpoise (sensitive)	0	7.11	1202.72	1548.37
PW	Gray seal	0.37	0	1465.82	69.76
	Harbor seal	0.07	0.04	794.75	100.43
	Harp seal	0.34	0.02	1927.81	101.52

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

Table 42. Construction Schedule B, Total. Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	31.35	0.07	347.50	55.16
	Minke whale (migrating)	138.78	0.39	1007.39	1065.90
	Humpback whale	27.60	0.12	245.91	47.56
	North Atlantic right whale [c]	4.95	0	71.88	11.24
	Sei whale [c] (migrating)	3.92	<0.01	48.74	45.65
MF	Atlantic white-sided dolphin	0	0	3425.59	401.24
	Atlantic spotted dolphin	0	0	224.87	6.35
	Common dolphin	0	0	48805.44	5125.28
	Bottlenose dolphin, offshore	0	0	3620.53	317.82
	Risso's dolphin	0	0	696.11	26.25
	Long-finned pilot whale	0	0	368.00	38.68
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	95.27	7.03
HF	Harbor porpoise (sensitive)	0	15.51	1592.22	1779.99
PW	Gray seal	1.01	0	2034.39	53.12
	Harbor seal	0.20	0	1070.90	108.70
	Harp seal	0.88	0.08	2839.51	98.93

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

Table 43. Construction Schedule A, Year 1 and 2. Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7

		Injury		Behavior		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]	L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	5.57	<0.01	108.46	22.43	7.75	0.02	152.41	14.98
	Minke whale (migrating)	16.88	<0.01	284.57	367.74	29.55	0.08	353.33	272.53
	Humpback whale	5.58	0.02	75.24	19.02	8.04	0.03	98.79	14.64
	North Atlantic right whale [c]	0.98	0	19.36	5.39	1.71	0	30.72	4.49
	Sei whale [c] (migrating)	0.54	<0.01	12.02	19.08	1.25	<0.01	18.61	15.77
MF	Atlantic white-sided dolphin	0	0	951.70	100.09	0	0	1287.99	122.53
	Atlantic spotted dolphin	0	0	81.79	2.30	0	0	135.51	3.41
	Common dolphin	0	0	13739.47	1348.86	0	0	23178.10	1855.93
	Bottlenose dolphin, offshore	0	0	897.08	67.63	0	0	1663.50	97.76
	Risso's dolphin	0	0	168.60	6.97	0	0	400.34	9.69
	Long-finned pilot whale	0	0	105.51	9.65	0	0	164.14	12.06
	Short-finned pilot whale	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	28.33	2.04	0	0	47.71	2.47
HF	Harbor porpoise (sensitive)	0	1.58	485.64	882.22	0	5.52	717.07	666.15
	Gray seal	0.01	0	593.10	43.61	0.36	0	872.72	26.15
	Harbor seal	<0.01	0.04	333.67	54.23	0.07	0	461.08	46.20

PW	Harp seal	<0.01	<0.01	715.48	57.82	0.33	0.02	1212.34	43.70

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

Table 44. Construction Schedule B, Year 1, 2, and 3. Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

		Injury		Behavior		Injury		Behavior		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]	L_E	L_{pk}	L_p [a]	L_p [b]	L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	4.24	0.01	91.43	16.37	19.32	0.04	188.88	27.57	7.79	0.02	67.19	11.22
	Minke whale (migrating)	15.02	0.01	259.13	306.23	85.85	0.26	517.67	526.86	37.91	0.12	230.59	232.81
	Humpback whale	3.99	<0.01	62.63	13.50	16.51	0.08	127.85	23.79	7.10	0.03	55.43	10.26
	North Atlantic right whale [c]	0.75	0	13.21	3.45	2.88	0	40.53	5.33	1.32	0	18.14	2.46
	Sei whale [c] (migrating)	0.41	<0.01	8.99	12.10	2.36	<0.01	26.18	22.69	1.14	<0.01	13.57	10.86
MF	Atlantic white-sided dolphin	0	0	754.22	70.41	0	0	1838.83	231.05	0	0	832.54	99.77
	Atlantic spotted dolphin	0	0	45.03	1.15	0	0	137.43	3.60	0	0	42.41	1.60
	Common dolphin	0	0	9842.10	835.28	0	0	28373.15	2995.08	0	0	10590.19	1294.92
	Bottlenose dolphin, offshore	0	0	656.25	45.81	0	0	2164.30	192.70	0	0	799.98	79.31
	Risso's dolphin	0	0	94.69	4.12	0	0	458.24	15.49	0	0	143.19	6.64
	Long-finned pilot whale	0	0	79.13	6.52	0	0	210.13	22.71	0	0	78.75	9.44
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	23.63	1.33	0	0	54.21	4.04	0	0	17.44	1.65
HF	Harbor porpoise (sensitive)	0	1.06	391.52	574.76	0	10.03	863.37	844.18	0	4.42	337.33	361.05
PW	Gray seal	0.02	0	297.91	28.40	0.67	0	1181.15	16.89	0.32	0	555.33	7.83
	Harbor seal	<0.01	0	268.75	34.57	0.13	0	529.17	50.65	0.06	0	272.98	23.49
	Harp seal	0.03	<0.01	378.60	37.32	0.57	0.06	1674.77	42.10	0.28	0.02	786.14	19.51

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

3.8.1.1. Effect of Aversion

The mean exposure estimates reported in Section 3.8.1 do not consider animals avoiding loud sounds (aversion) or implementation of mitigation measures other than sound attenuation using NAS. Some marine mammals are well known for their aversive responses to anthropogenic sound (e.g., harbor porpoise), although it is assumed that most species will avert from noise. The Wood et al. (2012) step function includes a probability of response that is based primarily on observed aversive behavior in field studies. Additional exposure estimates with aversion based on the Wood et al. (2012) response probabilities were calculated for NARW and harbor porpoise in this study. For comparative purposes only, the results are shown with and without aversion for one sample year of one construction schedule (Table 45). Aversion was not applied to exposure estimates and only presented here for comparison.

Table 45. Comparison of mean exposure estimates modeled for Construction Schedule A, year 2 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	1.67	<0.01	19.13	6.98	0.28	<0.01	16.16	5.58
Harbor porpoise	52.13	3.71	529.84	4165.36	0.46	0	305.06	3291.01

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

3.8.2. Sea Turtle Exposure Estimates

As was done for marine mammals, the numbers of individual sea turtles predicted to receive sound levels above threshold criteria were determined using animal movement modeling. The construction schedules described in Section 1.2.7 were used to calculate the total number of real-world individual turtles predicted to receive sound levels above injury and behavior thresholds (Finneran et al. 2017). These results are assuming broadband attenuation of 10 dB, calculated in the same way as the marine mammal exposures.

Table 46. Construction schedule A, Total. Mean number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7

	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	<0.01	0	0.12
Leatherback turtle [a]	2.05	0	5.20
Loggerhead turtle	0.58	0	7.02
Green turtle	0.04	0	0.35

[a] Listed as Endangered under the ESA.

Table 47. Construction schedule B, Total. Mean number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0.02	0	0.27
Leatherback turtle [a]	4.17	0	5.40
Loggerhead turtle	1.11	0	9.85
Green turtle	0.11	0	0.66

[a] Listed as Endangered under the ESA.

Table 48. Construction schedule A, Year 1 and 2. Mean number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

	Year 1			Year 2		
	Injury		Behavior	Injury		Behavior
	L_E	L_{pk}	L_p	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	<0.01	0	0.04	<0.01	0	0.08
Leatherback turtle [a]	0.55	0	3.41	1.50	0	1.79
Loggerhead turtle	0.04	0	2.98	0.54	0	4.04
Green turtle	<0.01	0	0.14	0.04	0	0.21

[a] Listed as Endangered under the ESA.

Table 49. Construction schedule B, Year 1, 2, and 3. Mean number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

	Year 1			Year 2			Year 3		
	Injury		Behavior	Injury		Behavior	Injury		Behavior
	L_E	L_{pk}	L_p	L_E	L_{pk}	L_p	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	<0.01	0	0.03	0.01	0	0.17	<0.01	0	0.07
Leatherback turtle [a]	0.43	0	2.05	2.65	0	2.36	1.09	0	0.99
Loggerhead turtle	0.07	0	1.65	0.73	0	5.67	0.31	0	2.53
Green turtle	<0.01	0	0.10	0.08	0	0.40	0.03	0	0.16

[a] Listed as Endangered under the ESA.

3.9. Exposure Range Estimates

Exposure ranges, or $ER_{95\%}$, are the horizontal distances that include 95% of the CPAs of animats exceeding a given impact threshold. These were calculated for marine mammals and sea turtles, and the results for vibratory pile setting followed by impact pile driving are summarized in Figure 32. Sections 3.9.1–3.9.2 include tabular results for each of the foundation types and installation schedules, assuming 10 dB attenuation. For full results including all modeled attenuation levels, see Appendix H.

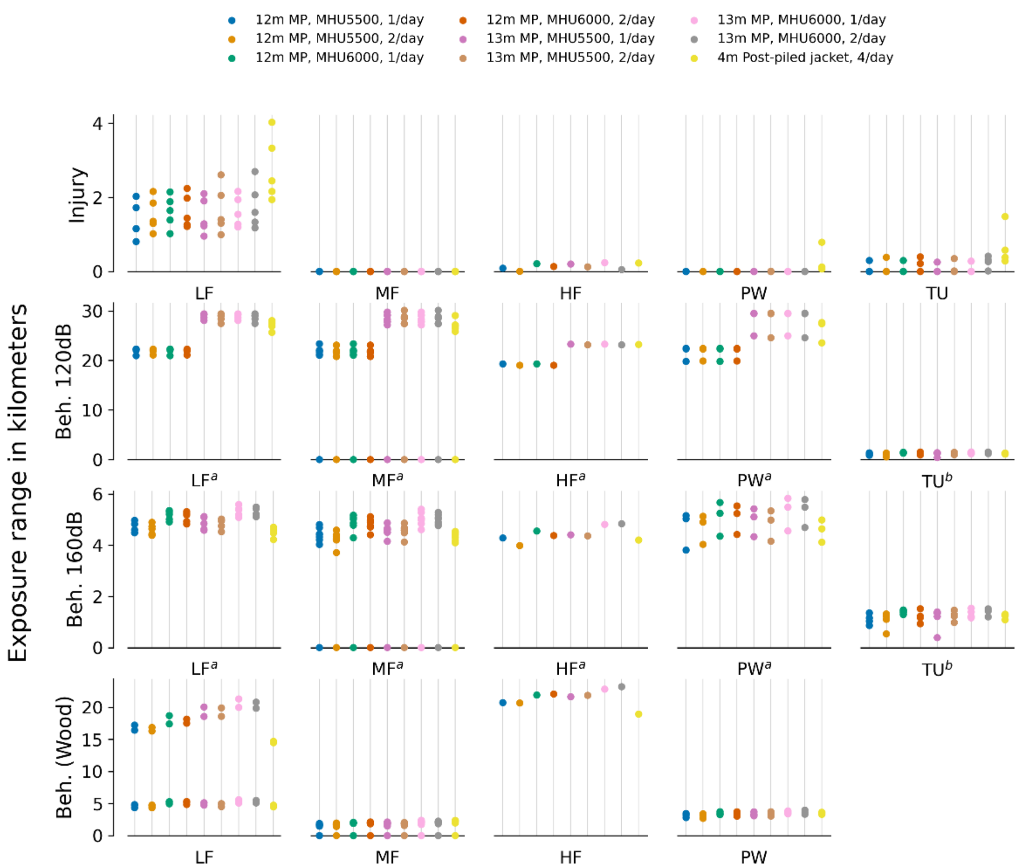

Figure 32. Maximum exposure ranges ($ER_{95\%}$) for injury and behavior thresholds, for vibratory pile setting followed by impact pile driving, shown for each hearing group, assuming an attenuation of 10 dB and summer sound speed profile. Each dot represents a species within the indicated hearing group (LF = low frequency cetacean, MF = mid-frequency cetacean, HF = high frequency cetacean, PW = phocid pinniped in water, and TU = turtle), and dot color represents a combination of foundation type (Monopile [MP] or jacket), size, and installation schedule (number of piles installed per day). Shown are all the different foundation type /installation schedule combinations used in the construction schedules for vibratory pile setting followed by impact pile driving. Jacket foundations were modeled as post-piled. Note the difference in y-axis scaling between the injury and behavior plots. Arrows indicate NARWs. Superscript a indicates that the NOAA (2005) behavioral thresholds for marine mammals were used, and superscript b indicates that the Finneran et al. (2017) behavioral threshold for turtles was used.

3.9.1. Exposure Ranges – Impact Pile Driving Only

The exposure ranges, $ER_{95\%}$, to injury and behavior thresholds calculated for marine mammals and sea turtles are summarized in Tables 50–67, assuming 10 dB broadband attenuation. Exposure ranges reported in this section (Section 3.9.1) are foundations installed with impact pile driving alone. For full results, including all modeled attenuation levels (0,10, and 12 dB), see Appendix H.

3.9.1.1. Marine Mammals

Table 50. 12 m monopile, 5000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.00	<0.01	4.88	4.86
	Minke whale (migrating)	0.82	0	4.61	16.51
	Humpback whale	1.71	0	4.86	4.78
	North Atlantic right whale [c]	1.19	0	4.50	4.47
	Sei whale [c] (migrating)	0.94	0	4.72	17.26
MF	Atlantic white-sided dolphin	0	0	4.26	1.71
	Atlantic spotted dolphin	0	0	4.48	1.87
	Common dolphin	0	0	4.47	1.79
	Bottlenose dolphin	0	0	3.98	1.39
	Risso's dolphin	0	0	4.30	1.63
	Long-finned pilot whale	0	0	4.20	1.59
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	4.68	1.79
HF	Harbor porpoise (sensitive)	0	<0.01	4.23	20.61
PW	Gray seal	0	0	5.10	3.46
	Harbor seal	0	0	3.80	2.78
	Harp seal	0	0	4.86	3.14

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

Table 51. 12 m monopile, 5000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.13	0	4.92	4.82
	Minke whale (migrating)	0.96	0	4.32	16.18
	Humpback whale	1.78	0	4.65	4.60
	North Atlantic right whale [c]	1.41	0	4.39	4.36
	Sei whale [c] (migrating)	1.14	0	4.60	16.76
MF	Atlantic white-sided dolphin	0	0	4.31	1.69
	Atlantic spotted dolphin	0	0	4.18	1.75
	Common dolphin	0	0	4.34	1.70
	Bottlenose dolphin	0	0	3.79	1.45
	Risso's dolphin	0	0	4.20	1.74
	Long-finned pilot whale	0	0	4.09	1.60
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	4.51	1.88
HF	Harbor porpoise (sensitive)	0	0.21	3.94	20.67
PW	Gray seal	0	0	5.13	3.39
	Harbor seal	0	0	4.06	2.73
	Harp seal	0	0	4.84	3.13

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

Table 52. 12 m monopile, 6000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.05	<0.01	5.28	5.27
	Minke whale (migrating)	0.91	0	4.95	17.27
	Humpback whale	1.72	0	5.26	5.23
	North Atlantic right whale [c]	1.19	0	4.91	5.00
	Sei whale [c] (migrating)	1.36	0	5.19	18.72
MF	Atlantic white-sided dolphin	0	0	4.87	1.90
	Atlantic spotted dolphin	0	0	5.02	2.00
	Common dolphin	0	0	4.99	2.00
	Bottlenose dolphin	0	0	4.45	1.92
	Risso's dolphin	0	0	4.72	2.02
	Long-finned pilot whale	0	0	4.75	1.84
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	5.22	2.09
HF	Harbor porpoise (sensitive)	0	0.20	4.46	21.85
PW	Gray seal	0	0	5.58	3.73
	Harbor seal	0	0	4.45	2.97
	Harp seal	0	0	5.26	3.48

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

Table 53. 12 m monopile, 6000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.16	0	5.29	5.31
	Minke whale (migrating)	1.12	0	4.87	17.36
	Humpback whale	1.97	0	5.12	5.17
	North Atlantic right whale [c]	1.34	0	4.83	4.81
	Sei whale [c] (migrating)	1.27	0	5.17	18.19
MF	Atlantic white-sided dolphin	0	0	4.83	1.94
	Atlantic spotted dolphin	0	0	4.51	2.07
	Common dolphin	0	0	4.88	2.00
	Bottlenose dolphin	0	0	4.18	1.78
	Risso's dolphin	0	0	4.74	1.98
	Long-finned pilot whale	0	0	4.72	1.84
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	5.16	2.08
HF	Harbor porpoise (sensitive)	0	0.12	4.44	21.94
PW	Gray seal	0	0	5.53	3.72
	Harbor seal	0	0	4.41	2.96
	Harp seal	0	0	5.31	3.45

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

Table 54. 13 m monopile, 5000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.04	0	5.08	5.09
	Minke whale (migrating)	0.96	0	4.44	18.41
	Humpback whale	1.87	0	5.02	5.07
	North Atlantic right whale [c]	1.19	0	4.73	4.73
	Sei whale [c] (migrating)	1.17	0	4.96	19.90
MF	Atlantic white-sided dolphin	0	0	4.50	1.83
	Atlantic spotted dolphin	0	0	4.74	2.15
	Common dolphin	0	0	4.63	1.94
	Bottlenose dolphin	0	0	4.09	1.64
	Risso's dolphin	0	0	4.55	1.95
	Long-finned pilot whale	0	0	4.39	1.90
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	4.80	2.00
HF	Harbor porpoise (sensitive)	0	0.21	4.49	21.58
PW	Gray seal	0	0	5.42	3.70
	Harbor seal	0	0	4.33	3.01
	Harp seal	0	0	5.02	3.29

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

Table 55. 13 m monopile, 5000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.30	0	4.99	4.99
	Minke whale (migrating)	1.02	0	4.67	18.45
	Humpback whale	1.99	<0.01	4.93	4.94
	North Atlantic right whale [c]	1.37	0	4.51	4.49
	Sei whale [c] (migrating)	1.30	0	4.90	19.77
MF	Atlantic white-sided dolphin	0	0	4.47	1.67
	Atlantic spotted dolphin	0	0	4.58	1.99
	Common dolphin	0	0	4.55	1.83
	Bottlenose dolphin	0	0	4.12	1.64
	Risso's dolphin	0	0	4.50	1.89
	Long-finned pilot whale	0	0	4.38	1.79
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	4.84	2.02
HF	Harbor porpoise (sensitive)	0	0.24	4.41	21.68
PW	Gray seal	0	0	5.34	3.73
	Harbor seal	0	<0.01	4.18	3.02
	Harp seal	0	0	4.96	3.27

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

Table 56. 13 m monopile, 6000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.14	0	5.56	5.50
	Minke whale (migrating)	1.22	0	5.05	19.93
	Humpback whale	1.96	0	5.27	5.24
	North Atlantic right whale [c]	1.56	0	5.28	5.19
	Sei whale [c] (migrating)	1.32	0	5.44	20.99
MF	Atlantic white-sided dolphin	0	0	5.01	2.05
	Atlantic spotted dolphin	0	0	4.88	2.26
	Common dolphin	0	0	5.28	2.02
	Bottlenose dolphin	0	0	4.70	1.78
	Risso's dolphin	0	0	4.93	2.04
	Long-finned pilot whale	0	0	4.95	2.05
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	5.33	2.14
HF	Harbor porpoise (sensitive)	0	0.20	4.74	22.87
PW	Gray seal	0	0	5.85	3.81
	Harbor seal	0	0	4.43	3.30
	Harp seal	0	0	5.50	3.60

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

Table 57. 13 m monopile, 6000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	2.58	0	5.40	5.40
	Minke whale (migrating)	1.19	0	5.05	19.75
	Humpback whale	1.99	<0.01	5.40	5.38
	North Atlantic right whale [c]	1.62	0	5.18	5.13
	Sei whale [c] (migrating)	1.31	0	5.34	20.69
MF	Atlantic white-sided dolphin	0	0	4.98	2.08
	Atlantic spotted dolphin	0	0	4.84	2.18
	Common dolphin	0	0	5.10	2.07
	Bottlenose dolphin	0	0	4.65	1.82
	Risso's dolphin	0	0	5.05	2.02
	Long-finned pilot whale	0	0	4.76	2.00
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	5.27	2.24
HF	Harbor porpoise (sensitive)	0	0.23	4.75	23.22
PW	Gray seal	0	0	5.77	3.97
	Harbor seal	0	0	4.56	3.31
	Harp seal	0	0	5.45	3.63

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

Table 58. Jacket, 3500 kJ hammer, 4 piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	3.73	<0.01	4.66	4.68
	Minke whale (migrating)	1.76	<0.01	4.24	14.41
	Humpback whale	2.94	<0.01	4.65	4.66
	North Atlantic right whale [c]	2.35	0	4.54	4.55
	Sei whale [c] (migrating)	2.10	<0.01	4.52	14.78
MF	Atlantic white-sided dolphin	0	0	4.40	2.28
	Atlantic spotted dolphin	0	0	4.47	2.37
	Common dolphin	0	0	4.48	2.30
	Bottlenose dolphin	0	0	4.02	1.98
	Risso's dolphin	0	0	4.31	2.24
	Long-finned pilot whale	0	0	4.11	2.17
	Short-finned pilot whale	0	0	0	0
	Sperm whale [c]	0	0	4.52	2.28
HF	Harbor porpoise (sensitive)	0	0.23	4.20	18.88
PW	Gray seal	0.79	0	4.97	3.63
	Harbor seal	0.02	0	4.09	3.29
	Harp seal	0.11	<0.01	4.65	3.49

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

3.9.1.2. Sea Turtles

Table 59. 12 m monopile, 5000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	0.87
Leatherback turtle [a]	0.30	0	1.38
Loggerhead turtle	0	0	1.20
Green turtle	0	0	1.01

[a] Listed as Endangered under the ESA.

Table 60. 12 m monopile, 5000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	0.54
Leatherback turtle [a]	0.25	0	1.31
Loggerhead turtle	0	0	1.16
Green turtle	0	0	1.14

[a] Listed as Endangered under the ESA.

Table 61. 12 m monopile, 6000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	1.19
Leatherback turtle [a]	0.30	0	1.46
Loggerhead turtle	0	0	1.39
Green turtle	0	0	1.29

[a] Listed as Endangered under the ESA.

Table 62. 12 m monopile, 6000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	0.94
Leatherback turtle [a]	0.26	0	1.47
Loggerhead turtle	0	0	1.41
Green turtle	0	0	1.25

[a] Listed as Endangered under the ESA.

Table 63. 13 m monopile, 5000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	0.23
Leatherback turtle [a]	0.25	0	1.34
Loggerhead turtle	0	0	1.36
Green turtle	0	0	1.28

[a] Listed as Endangered under the ESA.

Table 64. 13 m monopile, 5000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	0.89
Leatherback turtle [a]	0.26	0	1.38
Loggerhead turtle	0	0	1.21
Green turtle	0.01	0	1.27

[a] Listed as Endangered under the ESA.

Table 65. 13 m monopile, 6000 kJ hammer, one pile per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	0.87
Leatherback turtle [a]	0.25	0	1.37
Loggerhead turtle	0	0	1.48
Green turtle	0.19	0	1.31

[a] Listed as Endangered under the ESA.

Table 66. 13 m monopile, 6000 kJ hammer, two piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0	0	0.99
Leatherback turtle [a]	0.29	0	1.50
Loggerhead turtle	0	0	1.32
Green turtle	0.01	0	1.47

[a] Listed as Endangered under the ESA.

Table 67. Jacket, 3500 kJ hammer, 4 piles per day: Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	Injury		Behavior
	L_E	L_{pk}	L_p
Kemp's ridley turtle [a]	0.42	0	1.12
Leatherback turtle [a]	1.28	0	1.28
Loggerhead turtle	0.48	0	1.29
Green turtle	0.24	0	1.20

[a] Listed as Endangered under the ESA.

3.9.2. Exposure Range Estimates – Vibratory Setting Followed by Impact Piling

The exposure ranges, $ER_{95\%}$, to injury and behavior thresholds calculated for marine mammals and sea turtles are summarized in Tables 68 – 85, assuming 10 dB broadband attenuation. Exposure ranges reported in this section (Section 3.9.2) are foundations installed with vibratory setting of piles followed by impact pile driving. For full results, including all modeled attenuation levels (0,10, and 12 dB), see Appendix H.

3.9.2.1. Marine Mammals

Table 68. Monopile foundation (12 m diameter, 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

	Species	Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.02	<0.01	0.02	4.97	4.83	22.22
LF	Minke whale (migrating)	0.81	0	0	4.49	16.41	22.06
LF	Humpback whale	1.72	0	0	4.83	4.73	22.26
LF	North Atlantic right whale [c]	1.15	0	0	4.49	4.35	20.96
LF	Sei whale [c] (migrating)	1.15	0	0	4.60	17.21	22.30
MF	Atlantic white-sided dolphin	0	0	0	4.32	1.67	22.07
MF	Atlantic spotted dolphin	0	0	0	4.80	1.62	23.35
MF	Common dolphin	0	0	0	4.44	1.89	21.97
MF	Bottlenose dolphin	0	0	0	4.03	1.46	21.21
MF	Risso's dolphin	0	0	0	4.42	1.69	21.05
MF	Long-finned pilot whale	0	0	0	4.21	1.62	21.72
MF	Short-finned pilot whale	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	4.68	1.76	21.97
HF	Harbor porpoise (sensitive)	0	0.09	0	4.29	20.75	19.32
PW	Gray seal	0	0	0	5.16	3.45	22.32
PW	Harbor seal	0	0	0	3.81	2.80	19.80
PW	Harp seal	0	0	0	5.03	3.20	22.45

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

Table 69. Monopile foundation (12 m diameter, 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.16	0	0	4.89	4.76	22.14
	Minke whale (migrating)	1.02	0	0	4.43	16.29	21.93
	Humpback whale	1.84	0	0	4.73	4.67	22.28
	North Atlantic right whale [c]	1.35	0	0	4.38	4.34	21.10
	Sei whale [c] (migrating)	1.29	0	0	4.63	16.85	22.08
MF	Atlantic white-sided dolphin	0	0	0	4.40	1.76	21.72
	Atlantic spotted dolphin	0	0	0	4.22	1.82	23.10
	Common dolphin	0	0	0	4.34	1.69	21.89
	Bottlenose dolphin	0	0	0	3.71	1.42	20.81
	Risso's dolphin	0	0	0	4.27	1.76	20.79
	Long-finned pilot whale	0	0	0	4.20	1.62	21.59
	Short-finned pilot whale	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	4.59	1.96	21.95
HF	Harbor porpoise (sensitive)	0	<0.01	0	3.99	20.68	19.03
PW	Gray seal	0	0	0	5.13	3.40	22.29
	Harbor seal	0	0	0	4.03	2.69	19.89
	Harp seal	0	0	0	4.90	3.16	22.43

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

Table 70. Monopile foundation (12 m diameter, 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.14	<0.01	0.02	5.30	5.29	22.22
	Minke whale (migrating)	1.02	0	0	5.01	17.40	22.06
	Humpback whale	1.88	0	0	5.35	5.25	22.26
	North Atlantic right whale [c]	1.39	<0.01	0	4.91	4.95	20.96
	Sei whale [c] (migrating)	1.64	0	0	5.21	18.69	22.30
MF	Atlantic white-sided dolphin	0	0	0	5.08	1.97	22.07
	Atlantic spotted dolphin	0	0	0	5.17	1.98	23.35
	Common dolphin	0	0	0	5.02	2.05	21.97
	Bottlenose dolphin	0	0	0	4.29	1.94	21.21
	Risso's dolphin	0	0	0	4.78	2.04	21.05
	Long-finned pilot whale	0	0	0	4.86	1.90	21.72
	Short-finned pilot whale	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	5.17	2.05	21.97
HF	Harbor porpoise (sensitive)	0	0.21	0	4.56	21.94	19.32
PW	Gray seal	0	0	0	5.67	3.73	22.32
	Harbor seal	0	0	0	4.35	3.27	19.80
	Harp seal	0	0	0	5.25	3.44	22.45

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

Table 71. Monopile foundation (12 m diameter, 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.24	0	0	5.31	5.31	22.14
	Minke whale (migrating)	1.21	0	0	4.92	17.50	21.93
	Humpback whale	1.98	0	0	5.18	5.19	22.28
	North Atlantic right whale [c]	1.44	0	0	4.83	4.84	21.10
	Sei whale [c] (migrating)	1.26	0	0	5.24	18.14	22.08
MF	Atlantic white-sided dolphin	0	0	0	4.97	2.00	21.72
	Atlantic spotted dolphin	0	0	0	4.71	2.05	23.10
	Common dolphin	0	0	0	4.90	2.08	21.89
	Bottlenose dolphin	0	0	0	4.41	1.84	20.81
	Risso's dolphin	0	0	0	4.71	2.04	20.79
	Long-finned pilot whale	0	0	0	4.76	1.87	21.59
	Short-finned pilot whale	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	5.11	2.13	21.95
HF	Harbor porpoise (sensitive)	0	0.14	0	4.38	22.08	19.03
PW	Gray seal	0	0	0	5.53	3.72	22.29
	Harbor seal	0	0	0	4.42	3.03	19.89
	Harp seal	0	0	0	5.24	3.40	22.43

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

Table 72. Monopile foundation (13 m diameter, 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.10	0	0	5.12	5.12	29.40
	Minke whale (migrating)	0.95	0	0	4.62	18.55	28.66
	Humpback whale	1.90	0	0	5.09	5.10	29.27
	North Atlantic right whale [c]	1.29	0	0	4.58	4.75	28.07
	Sei whale [c] (migrating)	1.23	0	0	4.85	20.03	29.29
MF	Atlantic white-sided dolphin	0	0	0	4.50	1.76	28.30
	Atlantic spotted dolphin	0	0	0	4.66	2.12	29.75
	Common dolphin	0	0	0	4.61	1.92	29.10
	Bottlenose dolphin	0	0	0	4.15	1.50	27.88
	Risso's dolphin	0	0	0	4.60	1.86	27.16
	Long-finned pilot whale	0	0	0	4.50	1.95	27.77
	Short-finned pilot whale	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	4.87	2.03	29.15
HF	Harbor porpoise (sensitive)	0	0.21	0	4.41	21.67	23.33
PW	Gray seal	0	0	0	5.42	3.70	29.51
	Harbor seal	0	0	0	4.33	3.08	24.96
	Harp seal	0	0	0	5.11	3.32	29.45

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

Table 73. Monopile foundation (13 m diameter, 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.61	0	0	4.97	4.98	29.41
LF	Minke whale (migrating)	0.99	0	0	4.75	18.57	28.38
LF	Humpback whale	2.05	<0.01	0	4.95	4.98	29.03
LF	North Atlantic right whale [c]	1.40	0	0	4.52	4.51	27.45
LF	Sei whale [c] (migrating)	1.30	0	0	5.02	19.89	29.02
MF	Atlantic white-sided dolphin	0	0	0	4.57	1.80	28.64
MF	Atlantic spotted dolphin	0	0	0	4.68	1.99	30.12
MF	Common dolphin	0	0	0	4.64	1.94	28.53
MF	Bottlenose dolphin	0	0	0	4.12	1.57	27.42
MF	Risso's dolphin	0	0	0	4.59	1.84	27.41
MF	Long-finned pilot whale	0	0	0	4.48	1.80	27.45
MF	Short-finned pilot whale	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	4.86	2.05	28.87
HF	Harbor porpoise (sensitive)	0	0.13	0	4.37	21.85	23.20
PW	Gray seal	0	0	0	5.34	3.72	29.53
PW	Harbor seal	0	<0.01	0	4.15	3.04	24.58
PW	Harp seal	0	0	0	4.98	3.38	29.44

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

Table 74. Monopile foundation (13 m diameter, 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.16	0	0	5.59	5.59	29.40
	Minke whale (migrating)	1.20	0	0	5.19	19.97	28.66
	Humpback whale	1.94	0	0	5.42	5.39	29.27
	North Atlantic right whale [c]	1.54	0	0	5.08	5.07	28.07
	Sei whale [c] (migrating)	1.27	0	0	5.38	21.28	29.29
MF	Atlantic white-sided dolphin	0	0	0	5.04	2.09	28.30
	Atlantic spotted dolphin	0	0	0	5.05	2.38	29.75
	Common dolphin	0	0	0	5.28	2.16	29.10
	Bottlenose dolphin	0	0	0	4.61	1.73	27.88
	Risso's dolphin	0	0	0	4.99	2.11	27.16
	Long-finned pilot whale	0	0	0	4.84	1.94	27.77
	Short-finned pilot whale	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	5.40	2.17	29.15
HF	Harbor porpoise (sensitive)	0	0.24	0	4.82	22.86	23.33
PW	Gray seal	0	0	0	5.83	3.84	29.51
	Harbor seal	0	0	0	4.56	3.40	24.96
	Harp seal	0	0	0	5.49	3.61	29.45

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

Table 75. Monopile foundation (13 m diameter, 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	2.69	0	0	5.49	5.48	29.41
LF	Minke whale (migrating)	1.18	0	0	5.21	19.83	28.38
LF	Humpback whale	2.07	<0.01	0	5.43	5.43	29.03
LF	North Atlantic right whale [c]	1.59	0	0	5.11	5.09	27.45
LF	Sei whale [c] (migrating)	1.33	0	0	5.43	20.78	29.02
MF	Atlantic white-sided dolphin	0	0	0	5.03	2.11	28.64
MF	Atlantic spotted dolphin	0	0	0	4.90	2.22	30.12
MF	Common dolphin	0	0	0	5.19	2.09	28.53
MF	Bottlenose dolphin	0	0	0	4.76	1.85	27.42
MF	Risso's dolphin	0	0	0	5.08	2.08	27.41
MF	Long-finned pilot whale	0	0	0	4.83	2.03	27.45
MF	Short-finned pilot whale	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	5.28	2.25	28.87
HF	Harbor porpoise (sensitive)	0	0.06	0	4.84	23.24	23.20
PW	Gray seal	0	0	0	5.78	3.97	29.53
PW	Harbor seal	0	0	0	4.69	3.33	24.58
PW	Harp seal	0	0	0	5.48	3.61	29.44

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

Table 76. Jacket foundation (4 m diameter, 3500 kJ hammer, 4 per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Species		Injury			Behavior		
		Vibratory and Impact		Vibratory	Impact		Vibratory
		L_E	L_{pk}	L_E	L_p [a]	L_p [b]	L_p [a]
LF	Fin whale [c]	4.02	<0.01	0.04	4.63	4.65	27.74
	Minke whale (migrating)	1.94	<0.01	0	4.22	14.48	26.94
	Humpback whale	3.32	<0.01	0	4.70	4.74	27.43
	North Atlantic right whale [c]	2.44	0	0	4.47	4.48	25.66
	Sei whale [c] (migrating)	2.16	<0.01	0	4.56	14.68	28.05
MF	Atlantic white-sided dolphin	0	0	0	4.41	2.29	27.16
	Atlantic spotted dolphin	0	0	0	4.50	2.37	29.06
	Common dolphin	0	0	0	4.46	2.28	27.04
	Bottlenose dolphin	0	0	0	4.09	1.97	25.85
	Risso's dolphin	0	0	0	4.30	2.27	26.51
	Long-finned pilot whale	0	0	0	4.18	2.22	26.89
	Short-finned pilot whale	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	4.54	2.27	27.11
HF	Harbor porpoise (sensitive)	0	0.23	0	4.21	18.94	23.26
PW	Gray seal	0.79	0	0	4.98	3.63	27.41
	Harbor seal	0.07	0	0	4.11	3.31	23.55
	Harp seal	0.12	0	0	4.64	3.57	27.65

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

3.9.2.2. Sea Turtles

Table 77. Monopile foundation (12 m diameter 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0	0	0	0.86
Leatherback turtle [a]	0.30	0	0	1.35
Loggerhead turtle	0	0	0	1.15
Green turtle	0	0	0	1.03

[a] Listed as Endangered under the ESA.

Table 78. Monopile foundation (12 m diameter 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0	0	0	0.54
Leatherback turtle [a]	0.38	0	0	1.31
Loggerhead turtle	0	0	0	1.23
Green turtle	0	0	0	1.10

[a] Listed as Endangered under the ESA.

Table 79. Monopile foundation (12 m diameter 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0	0	0	1.37
Leatherback turtle [a]	0.30	0	0	1.47
Loggerhead turtle	0	0	0	1.43
Green turtle	0	0	0	1.29

[a] Listed as Endangered under the ESA.

Table 80. Monopile foundation (12 m diameter 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0	0	0	0.93
Leatherback turtle [a]	0.39	0	0	1.52
Loggerhead turtle	0.21	0	0	1.17
Green turtle	0	0	0	1.23

[a] Listed as Endangered under the ESA.

Table 81. Monopile foundation (13 m diameter 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0	0	0	0.39
Leatherback turtle [a]	0.25	0	0	1.34
Loggerhead turtle	0	0	0	1.39
Green turtle	0	0	0	1.21

[a] Listed as Endangered under the ESA.

Table 82. Monopile foundation (13 m diameter 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0	0	0	0.98
Leatherback turtle [a]	0.35	0	0	1.46
Loggerhead turtle	0	0	0	1.23
Green turtle	0.01	0	0	1.29

[a] Listed as Endangered under the ESA.

Table 83. Monopile foundation (13 m diameter 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0	0	0	1.16
Leatherback turtle [a]	0.28	0	0	1.54
Loggerhead turtle	0	0	0	1.39
Green turtle	0	0	0	1.22

[a] Listed as Endangered under the ESA.

Table 84. Monopile foundation (13 m diameter 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0.27	0	0	1.20
Leatherback turtle [a]	0.41	0	0	1.51
Loggerhead turtle	0.31	0	0	1.43
Green turtle	0.01	0	0	1.45

[a] Listed as Endangered under the ESA.

Table 85. Jacket foundation (4 m diameter, 3500 kJ hammer, 4 per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10dB attenuation

Species	Injury			Behavior
	Vibratory + Impact		Vibratory	Vibratory + Impact
	L_E	L_{pk}	L_E	L_p
Kemp's ridley turtle [a]	0.28	0	0	1.09
Leatherback turtle [a]	1.48	0	0	1.28
Loggerhead turtle	0.58	0	0	1.30
Green turtle	0.38	0	0	1.24

[a] Listed as Endangered under the ESA.

3.10. Acoustic Ranges for Fish

3.10.1. Acoustic Ranges for Fish Exposed to Impact-Only Pile Driving

Applying the thresholds for potential injury (see Section 2.4.2) 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 128 m, 108 m, and 126 m, respectively. Ranges from the piling source to regulatory-defined thresholds for large fish (≥ 2g) SEL (187 dB) are 8,200 m for four (4) 4-m jacket foundation piles, 4,704 m for 12 m monopiles, and 5,362 m for 13 m monopiles, all with 10 dB attenuation. For small fish (≤ 2g) the ranges to the regulatory threshold SEL (183 dB) are 10,251 m for four (4) 4-m jacket foundation piles, 6,295 m for 12 m monopiles, and 7,103 m for 13 m monopiles, all with 10 dB attenuation. These estimates do not account for any aversion that might occur as a result using of sound attenuation systems (e.g., bubble curtains). Popper et al. 2014 does not define quantitative acoustic thresholds for behavioral response in fish, but NMFS ESA Acoustic Thresholds (noaa.gov) uses a 150 dB SPL threshold for all fish. When the NMFS threshold is used, distances to potential behavioral disturbance for fish are 8,656 m from the 4 m jacket foundation piles, 10,789 m from the 12 m monopiles, and 11,431 m from the 13 m monopiles.

3.10.2. Acoustic Ranges for Fish Exposed to Vibratory Pile-Setting Followed by Impact Pile Driving

Applying the thresholds for potential injury (see Section 2.4.2) 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 128 m, 108 m, and 126 m, respectively. Ranges from the piling source to regulatory-defined thresholds for large fish (>2g) for SEL (187 dB) are 9,268 m for 4 m jacket foundation piles, 5,613 m for 12 m monopiles, and 6,283 m for 13 m monopiles all with 10 dB attenuation. And, the ranges from the piling source to regulatory thresholds for small fish (≤ 2g) SEL (183 dB) are 12,021 m for four (4) 4-m jacket foundation piles, 7,441 m for 12 m monopiles, and 8,280 m 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). NMFS ESA Acoustic Thresholds (noaa.gov) uses a 150 dB SPL threshold for all fish. When this criterion is used, distances to potential behavioral disturbance for fish are 8,656 m for the impact pile driving component and 5,358 m for the vibratory pile-setting component of the 4 m jacket foundation pile installation, 10,789 m for the impact pile driving component and 3,963 m for the vibratory pile-setting component of the 12 m monopile installation, and 11,431 m for the impact pile driving component and 4,491 m for the vibratory pile-setting component of the 13 m monopile installation, respectively.

4. Discussion

Sound 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) received 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 3.9) were determined with different broadband attenuation levels (0, 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 3.10).

4.1. 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. These thresholds are described in detail in Section 2.4. 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). This discussion summarizes the modeled injury and behavior exposure estimates, exposure ranges, and fish acoustic ranges presented in the main body of this report.

Table 86. Summary of exposure above injury and behavioral threshold for marine mammals for Construction Schedules A and B (all years summed), with 10 dB attenuation. Construction schedule assumptions are summarized in Section 1.2.7.

	Species	Schedule A				Schedule B			
		Injury		Behavior		Injury		Behavior	
		L_E	L_{pk}	L_p [a]	L_p [b]	L_E	L_{pk}	L_p [a]	L_p [b]
LF	Fin whale [c]	13.33	0.02	260.87	37.41	31.35	0.07	347.50	55.16
LF	Minke whale (migrating)	46.43	0.09	637.91	640.28	138.78	0.39	1007.39	1065.90
LF	Humpback whale	13.62	0.05	174.03	33.66	27.60	0.12	245.91	47.56
LF	North Atlantic right whale [c]	2.69	0	50.08	9.89	4.95	0	71.88	11.24
LF	Sei whale [c] (migrating)	1.79	<0.01	30.63	34.86	3.92	<0.01	48.74	45.65
MF	Atlantic white-sided dolphin	0	0	2239.68	222.62	0	0	3425.59	401.24
MF	Atlantic spotted dolphin	0	0	217.30	5.71	0	0	224.87	6.35
MF	Common dolphin	0	0	36917.57	3204.79	0	0	48805.44	5125.28
MF	Bottlenose dolphin, offshore	0	0	2560.58	165.39	0	0	3620.53	317.82
MF	Risso's dolphin	0	0	568.94	16.66	0	0	696.11	26.25
MF	Long-finned pilot whale	0	0	269.65	21.71	0	0	368.00	38.68
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	76.04	4.50	0	0	95.27	7.03
HF	Harbor porpoise (sensitive)	0	7.11	1202.72	1548.37	0	15.51	1592.22	1779.99
PW	Gray seal	0.37	0	1465.82	69.76	1.01	0	2034.39	53.12
PW	Harbor seal	0.07	0.04	794.75	100.43	0.20	0	1070.90	108.70
PW	Harp seal	0.34	0.02	1927.81	101.52	0.88	0.08	2839.51	98.93

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

Table 87. Summary of exposures above injury and behavioral 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	0.12	0.02	0	0.27
Leatherback turtle [a]	2.05	0	5.20	4.17	0	5.40
Loggerhead turtle	0.58	0	7.02	1.11	0	9.85
Green turtle	0.04	0	0.35	0.11	0	0.66

[a] Listed as Endangered under the ESA.

The endangered NARW is predicted to experience fewer than five injurious exposures during the combined installation of Phases 1 and 2, assuming 10 dB attenuation. However, it is important to note that the Proponent will implement several mitigation measures to prevent any injurious exposures to NARW. The number of exposures above SEL injury threshold for all low-frequency cetaceans, assuming 10 dB attenuation, varies from approximately 1 to 138 individuals. There are zero predicted injury-level acoustic exposures for mid-frequency cetacean species. Harbor porpoise, the only high frequency cetacean in the acoustic analysis, is predicted to experience up to 16 exposures above the SEL injury threshold, assuming 10 dB attenuation. For NARW, assuming 10 dB attenuation, up to 72 animals are predicted to experience sound levels exceeding the 160 dB SPL behavioral thresholds. Due to their relatively high local monthly densities, common dolphins have the highest predicted number of exposures above behavioral thresholds, assuming 10 dB attenuation, at approximately 48,805 animals.

Fewer than five sea turtles are predicted to be exposed to sound levels exceeding injury threshold. Up to 10 exposures above behavior threshold are predicted to occur.

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. The use of NAS and mitigation may reduce the number of marine mammal and sea turtle exposures.

4.2. Exposure Ranges for Marine Mammals and Sea Turtles

Tables 88 – 91 summarize the minimum and maximum exposure ranges across all foundation types, pile installation schedules (e.g., piles per day), and pile installation methods (impact pile driving alone, and vibratory pile setting followed by impact pile driving) 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.

Table 88. Summary of the predicted minimum and maximum marine mammal exposure ranges to injury and behavioral thresholds from impact pile driving alone assuming 10 dB of broadband attenuation.

Species		Injury		Behavior			
		Max (L_E, L_{pk})		L_p [a]		L_p [b]	
		Min	Max	Min	Max	Min	Max
LF	Fin whale [c]	2.00	3.73	4.66	5.56	4.68	5.50
	Minke whale (migrating)	0.82	1.76	4.24	5.05	14.41	19.93
	Humpback whale	1.71	2.94	4.65	5.40	4.60	5.38
	North Atlantic right whale [c]	1.19	2.35	4.39	5.28	4.36	5.19
	Sei whale [c] (migrating)	0.94	2.10	4.52	5.44	14.78	20.99
MF	Atlantic white-sided dolphin	0	0	4.26	5.01	1.67	2.28
	Atlantic spotted dolphin	0	0	4.18	5.02	1.75	2.37
	Common dolphin	0	0	4.34	5.28	1.70	2.30
	Bottlenose dolphin	0	0	3.79	4.70	1.39	1.98
	Risso's dolphin	0	0	4.20	5.05	1.63	2.24
	Long-finned pilot whale	0	0	4.09	4.95	1.59	2.17
	Short-finned pilot whale	0	0	0	0	0	0
	Sperm whale [c]	0	0	4.51	5.33	1.79	2.28
HF	Harbor porpoise (sensitive)	<0.01	0.24	3.94	4.75	18.88	23.22
PW	Gray seal	0	0.79	4.97	5.85	3.39	3.97
	Harbor seal	0	0.02	3.80	4.56	2.73	3.31
	Harp seal	0	0.11	4.65	5.50	3.13	3.63

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

Table 89. Summary of the predicted minimum and maximum sea turtle exposure ranges to injury and behavioral thresholds from impact pile driving alone assuming 10 dB of broadband attenuation.

Species	Injury		Behavior	
	Max (L_E, L_{pk})		L_p	
	Min	Max	Min	Max
Kemp's ridley turtle [a]	0	0.42	0.23	1.19
Leatherback turtle [a]	0.25	1.28	1.28	1.50
Loggerhead turtle	0	0.48	1.16	1.48
Green turtle	0	0.24	1.01	1.47

[a] Listed as Endangered under the ESA.

Table 90. Summary of the predicted minimum and maximum marine mammal exposure ranges to injury and behavioral thresholds from vibratory pile setting followed by impact pile driving assuming 10 dB of broadband attenuation.

	Species	Injury				Behavior					
		Vibratory and Impact		Vibratory		Impact				Vibratory	
		Max (L_E, L_{pk})		L_E		L_p [a]		L_p [b]		L_p [a]	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
LF	Fin whale [c]	2.02	4.02	0	0.04	4.63	5.59	4.65	5.59	22.14	29.41
	Minke whale (migrating)	0.81	1.94	0	0	4.22	5.21	14.48	19.97	21.93	28.66
	Humpback whale	1.72	3.32	0	0	4.70	5.43	4.67	5.43	22.26	29.27
	North Atlantic right whale [c]	1.15	2.44	0	0	4.38	5.11	4.34	5.09	20.96	28.07
	Sei whale [c] (migrating)	1.15	2.16	0	0	4.56	5.43	14.68	21.28	22.08	29.29
MF	Atlantic white-sided dolphin	0	0	0	0	4.32	5.08	1.67	2.29	21.72	28.64
	Atlantic spotted dolphin	0	0	0	0	4.22	5.17	1.62	2.38	23.10	30.12
	Common dolphin	0	0	0	0	4.34	5.28	1.69	2.28	21.89	29.10
	Bottlenose dolphin	0	0	0	0	3.71	4.76	1.42	1.97	20.81	27.88
	Risso's dolphin	0	0	0	0	4.27	5.08	1.69	2.27	20.79	27.41
	Long-finned pilot whale	0	0	0	0	4.18	4.86	1.62	2.22	21.59	27.77
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	4.54	5.40	1.76	2.27	21.95	29.15
HF	Harbor porpoise (sensitive)	<0.01	0.24	0	0	3.99	4.84	18.94	23.24	19.03	23.33
PW	Gray seal	0	0.79	0	0	4.98	5.83	3.40	3.97	22.29	29.53
	Harbor seal	0	0.07	0	0	3.81	4.69	2.69	3.40	19.80	24.96
	Harp seal	0	0.12	0	0	4.64	5.49	3.16	3.61	22.43	29.45

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

Table 91. Summary of the predicted minimum and maximum sea turtle exposure ranges to injury and behavioral thresholds from vibratory pile setting followed by impact pile driving assuming 10 dB of broadband attenuation.

Species	Injury				Behavior	
	Vibratory + Impact		Vibratory		Vibratory + Impact	
	Max (L_E, L_{pk})		L_E		L_p	
	Min	Max	Min	Max	Min	Max
Kemp's ridley turtle [a]	0	0.28	0	0	0.39	1.37
Leatherback turtle [a]	0.25	1.48	0	0	1.28	1.54
Loggerhead turtle	0	0.58	0	0	1.15	1.43
Green turtle	0	0.38	0	0	1.03	1.45

[a] Listed as Endangered under the ESA.

The maximum $ER_{95\%}$ NARW exposure range across all foundation types to injury thresholds for any source with 10 dB attenuation is 2.44 km. The maximum NARW $ER_{95\%}$ for potential behavioral disruption is 5.28 km for impact pile driving only and 28.07 km for vibratory pile setting. For low frequency cetaceans, the maximum $ER_{95\%}$ to injury thresholds for all low frequency cetaceans is between 0–4.02 km and 4.22–29.41 km for behavioral thresholds. Exposure ranges ($ER_{95\%}$) are not expected to exceed injury thresholds for mid-frequency cetaceans. For harbor porpoise, the exposure range to injury thresholds is up to 0.24 km. The gray seal has the largest behavioral $ER_{95\%}$ at approximately 29.53 km.

The maximum exposure range for sea turtle injury for any foundation type is 1.48 km. Sea turtle maximum exposure range for behavioral disruption is approximately 1.54 km.

4.3. Acoustic Ranges for Fish

For potential injury, the maximum range predicted for fish was 12,021 m for small fish (< 2 g) exposed to four 4-m piles during the installation of a jacket foundation using vibratory pile setting followed by impact pile driving with 10 dB attenuation. (For comparison, the maximum range predicted for small fish (<2 g) exposed to four 4-m piles during the installation of a jacket foundation using impact-only pile driving was 10,251 m.) The maximum range for potential behavioral response of impact-only pile driving with 10 dB was 11,431 m, which was predicted to be the same for the impact pile driving component of vibratory-pile setting followed by impact pile driving or impact-only pile driving of a 13 m monopile at 6000 kJ.

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Glossary of Acoustic Terms

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).

1/3-octave-band

Frequency band whose bandwidth is one 1/3-octave. *Note*: The bandwidth of a 1/3-octave-band increases with increasing center frequency.

absorption

The reduction of sound amplitude due to sound pressure energy converting to heat in the propagation medium.

acoustic noise

Sound that interferes with an acoustic process.

agent-based modeling

A computer simulation of autonomous agents (sometimes called animats) acting in an environment, used to assess the agents' experience of the environment and/or their effect on the environment. See also animal movement modeling.

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 modeling

Simulation of animal movement based on behavioral rules for the purpose of predicting an animal's experience of an environment. A type of agent-based modeling.

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 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.

A-weighting

Frequency-selective weighting for human hearing in air that is derived from the inverse of the idealized 40-phon equal loudness hearing function across frequencies.

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

A range within a continuous band of frequencies. Unit: hertz (Hz).

boxcar averaging

A signal smoothing technique that returns the averages of consecutive segments of a specified width.

broadband level

The total level measured over a specified frequency range.

cetacean

An animal in the order Cetacea. Cetaceans 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. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

continuous sound

A sound whose sound pressure level remains above the background noise during the observation period. A sound that gradually varies in intensity with time, e.g., sound from a marine vessel.

decade

Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 80000-3:2006).

decibel (dB)

Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale.

decidecade

One tenth of a decade. Approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct), and for this reason is sometimes referred to as a 1/3-octave.

decidecade band

Frequency band whose bandwidth is one decidecade. *Note*: The bandwidth of a decidecade band increases with increasing center frequency.

delphinid

Member of the family of oceanic dolphins, or Delphinidae, composed of approximately 30 extant species, including dolphins, porpoises, and killer whales.

energy source level

A property of a sound source equal to the sound exposure level measured in the far field plus the propagation loss from the acoustic center of the source to the receiver position. Unit: decibel (dB). reference value: 1 µPa^2 m^2 s.

ensonified

Exposed to sound.

far field

The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point.

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 recording system, typically consisting of a hydrophone, one or more amplifiers, and an analog-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 their 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).

hearing threshold

For a given species or hearing group, the sound pressure level for a given frequency that is barely audible (i.e., that would be barely audible for a given individual for specified background noise during a specific percentage of experimental trials).

hertz (Hz)

A unit of frequency defined as one cycle per second.

high-frequency (HF) cetaceans

See hearing group.

intermittent sound

A sound whose level abruptly drops below the background noise level several times during an observation period.

impulsive sound

Qualitative term meaning sounds that are typically transient, brief (less than 1 s), 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.

isopleth

A line drawn on a map through all points having the same value of some quantity.

level

A measure of a quantity expressed as the logarithm of the ratio of the quantity to a specified reference value of that quantity. For example, a value of sound pressure level with reference to 1 μPa^2 can be written in the form *x* dB re 1 μPa^2.

low-frequency (LF) cetaceans

See hearing group.

mid-frequency (MF) cetacean

See hearing group.

Monte Carlo simulation

A method of investigating the distribution of a non-linear multi-variate function by random sampling of all of its input variable distributions.

multiple linear regression

A statistical method that seeks to explain the response of a dependent variable using multiple explanatory variables.

M-weighting

A set of auditory frequency-weighting functions proposed by Southall et al. (2007).

mysticete

A suborder of cetaceans that use baleen plates to filter food from water. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound

Sound that is not an impulsive sound. A non-impulsive sound is not necessarily a continuous sound.

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.

odontocete

Whales that have teeth rather than baleen. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The skulls of toothed whales are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid

A common term used to describe members of the Otariidae, eared seals, commonly called sea lions and fur seals. Otariids are adapted to a semi-aquatic life; they use their large fore flippers for propulsion. Their ears distinguish them from phocids. Otariids are one of the three main groups in the superfamily Pinnipedia; the other two groups are phocids and walrus.

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.

particle acceleration

See sound particle acceleration.

particle velocity

See sound particle velocity.

peak sound pressure level (PK), zero-to-peak sound pressure level

The level (L_{pk}) of the squared maximum magnitude of the sound pressure (p_{pk}^2) in a stated frequency band and time window. Defined as $L_{pk} = 10\log_{10}(p_{\mathrm{pk}}^2/p_0^2) = 20\log_{10}(p_{pk}/p_0)$. Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 μPa^2.

permanent threshold shift (PTS)

An irreversible loss of hearing sensitivity caused by excessive noise exposure. Considered auditory injury. Compare to temporary threshold shift.

phocid

A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.

pinniped

A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source

A source that radiates sound as if from a single point.

power spectral density

Generic term, formally defined as power in a unit frequency band. Unit: watt per hertz (W/Hz). The term is sometimes loosely used to refer to the spectral density of other parameters such as squared sound pressure. Ratio of energy spectral density, E_f, to time duration, Δt, in a specified temporal observation window. In equation form, the power spectral density P_f is given by $P_f = E_f/\Delta t$. Power spectral density can be expressed in terms of various field variables (e.g., **sound pressure**).

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, $\mathrm{PL}(x) = \mathrm{SL} - \mathrm{L}(x)$.
Unit: decibel (dB). See also transmission loss.

received level

The level of a given field variable measured (or that would be measured) at a defined location.

reference value

Standard value of a quantity used for calculating underwater sound level. The reference value depends on the quantity for which the level is being calculated:

Quantity	Reference value
Sound pressure	$p_0{}^2$ = 1 μPa^2 or p_0 = 1 μPa
Sound exposure	E_0 = 1 μPa^2 s
Sound particle displacement	$\delta_0{}^2$ = 1 pm^2
Sound particle velocity	$u_0{}^2$ = 1 nm^2/s^2
Sound particle acceleration	$a_0{}^2$ = 1 μm^2/s^4

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 h) or from start to end of a specified event (e.g., a pile strike, an airgun pulse, a construction operation). Unit: pascal squared second (Pa^2 s). Symbol: E.

sound exposure level (SEL)

The level (L_E) of the sound exposure (E) in a stated frequency band and time window: $L_E = 10\log_{10}(E/E_0)$. Unit: decibel (dB). **Reference value** (E_0) for sound in water: 1 μPa^2 s.

sound field

Region containing sound waves.

sound particle acceleration

The rate of change of sound particle velocity. Unit: meter per second squared (m/s^2). Symbol: a.

sound particle velocity

The velocity of a particle in a material moving back and forth in the direction of the pressure wave. Unit: meter per second (m/s). Symbol: u.

sound pressure

The contribution to total pressure caused by the action of sound (ISO 18405:2017). Unit: pascal (Pa). Symbol: p.

sound pressure level (SPL), rms sound pressure level

The level (L_p) of the time-mean-square **sound pressure** (p^2_{rms}) in a stated frequency band and time window: $L_p = 10\log_{10}(p^2_{\mathrm{rms}}/p^2_0) = 20\log_{10}(p_{rms}/p_0)$, where rms is the abbreviation for root-mean-square. Unit: decibel (dB). **Reference value** (p^2_0) for sound in water: 1 μPa^2.

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 equal to the sound pressure level measured in the far field plus the propagation loss from the acoustic center of the source to the receiver position. Unit: decibel (dB). **Reference value**: 1 μPa^2 m^2.

spectrum

An acoustic signal represented in terms of its power, energy, mean-square **sound pressure**, or sound exposure distribution with frequency.

temporary threshold shift (TTS)

Reversible loss of hearing sensitivity caused by noise exposure. Compare with permanent threshold shift.

transmission loss (TL)

The difference between a specified level at one location and that at a different location: $\mathrm{TL}(x_1,x_2) = L(x_1) - L(x_2)$. Unit: decibel (dB). See also propagation loss.

unweighted

Term indicating that no frequency-weighting function is applied.

Appendix A. 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 and 6000 kJ).
- Helmet weight: 2351 kN
- Ram weight: 2726 kN
- One or two piles installed per day

A.1. Detailed Modeling Technical Inputs

Table A-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 B. Underwater Acoustics Metrics

This section provides a detailed description of the acoustic metrics relevant to the modeling study and the modeling methodology.

B.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, $\mathrm{p(t)}$:

$$L_{pk} = 10\log_{10}\frac{\max|\mathrm{p}^2(\mathrm{t})|}{\mathrm{p}_0^2} = 20\log_{10}\frac{\max|\mathrm{p(t)}|}{\mathrm{p}_0} \quad \text{(B-1)}$$

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:

$$L_p = 10\log_{10}\left(\frac{1}{\mathrm{T}}\int_{\mathrm{T}} \mathrm{g(t)}\,\mathrm{p}^2(\mathrm{t})\,\mathrm{dt} \Big/ \mathrm{p}_0^2\right)\,\mathrm{dB} \quad \text{(B-2)}$$

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):

$$L_E = 10\log_{10}\left(\int_T \mathrm{p}^2(\mathrm{t})\,\mathrm{dt} \Big/ \mathrm{T_0 p_0^2}\right)\ \mathrm{dB} \tag{B-3}$$

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:

$$L_{E,\mathrm{N}} = 10\log_{10}\left(\sum_{\mathrm{i}=1}^{\mathrm{N}} 10^{\frac{\mathrm{L_{E,i}}}{10}}\right)\ \mathrm{dB} \tag{B-4}$$

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:

$$L_p = L_E - 10\log_{10}(T) \tag{B-5}$$

$$L_{p90} = L_E - 10\log_{10}(T_{90}) - 0.458 \tag{B-6}$$

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, $\mathrm{p(t)}$, over the same time period, T:

$$L_{eq} = 10\log_{10}\left(\frac{1}{T}\int_T \mathrm{p}^2(\mathrm{t})\,\mathrm{dt} \Big/ \mathrm{p_0^2}\right) \tag{B-7}$$

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 0) 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.

B.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, $f_c(\mathrm{i})$, is defined as:

$$f_c(\mathrm{i}) = 10^{\frac{\mathrm{i}}{10}} \tag{B-8}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith band are defined as:

$$f_{\text{lo,i}} = 10^{\frac{-1}{20}} \mathrm{f_c(i)} \quad \text{and} \quad f_{\text{hi,i}} = 10^{\frac{1}{20}} \mathrm{f_c(i)}\,. \tag{B-9}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure B-1). The acoustic modeling spans from band 10 (f_c (10) = 10 Hz) to band 44 ($\mathrm{f_c}(44)$ = 25 kHz).

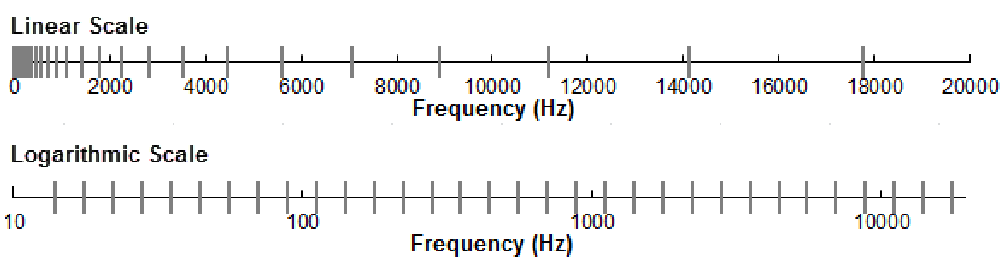

Figure B-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band $(L_{p,i})$ is computed from the spectrum $S(\mathrm{f})$ between $f_{\text{lo,i}}$ and $f_{\text{hi,i}}$:

$$\mathrm{L_{p,i}} = 10 \log_{10} \int_{f_{\text{lo,i}}}^{f_{\text{hi,i}}} \mathrm{S(f)\,df}\,. \tag{B-10}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband Lp} = 10 \log_{10} \sum_{\mathrm{i}} 10^{\frac{\mathrm{L_{p,i}}}{10}}\,. \tag{B-11}$$

Figure B-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.

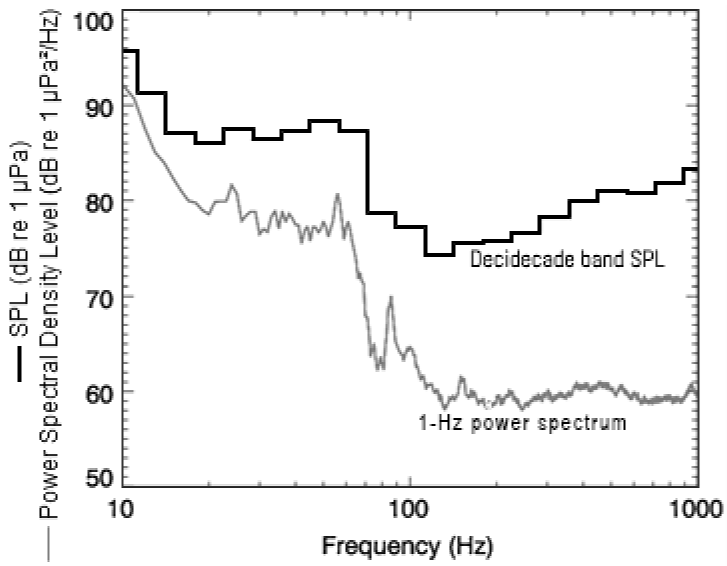

Figure B-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient sound shown on a logarithmic frequency scale. Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the power spectrum.

Appendix C. 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).

C.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:

$$G(f) = K + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}. \quad \text{(C-1)}$$

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 C-1 lists the frequency-weighting parameters for each hearing group; Figure C-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 C-1). Parameters are provided in Table C-1.

Table C-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.

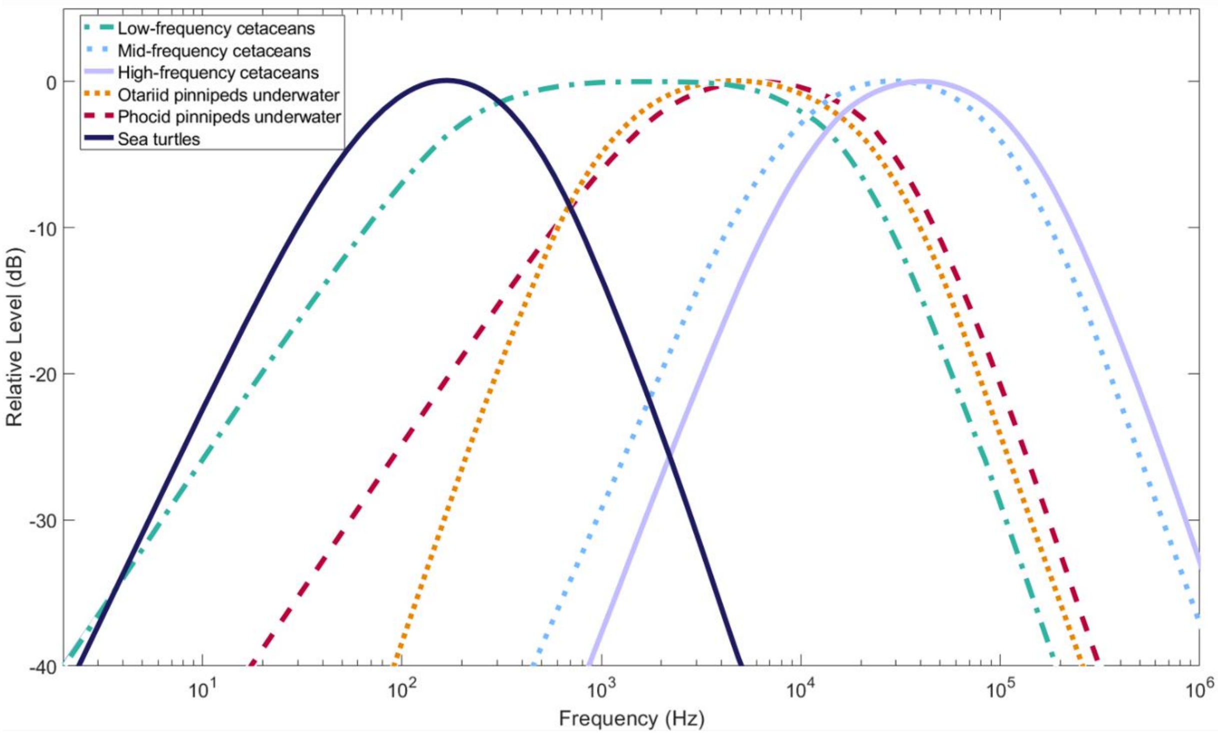

Figure C-1. Auditory weighting functions for functional marine mammal hearing groups included in NMFS (2018).

C.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:

$$G(f) = -20\log_{10}\left[\left(1+\frac{\mathrm{a}^2}{\mathrm{f}^2}\right)\left(1+\frac{\mathrm{f}^2}{\mathrm{b}^2}\right)\right] \quad \text{(C-2)}$$

where $G(\mathrm{f})$ 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 C-2). shows the auditory weighting functions.

Table C-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

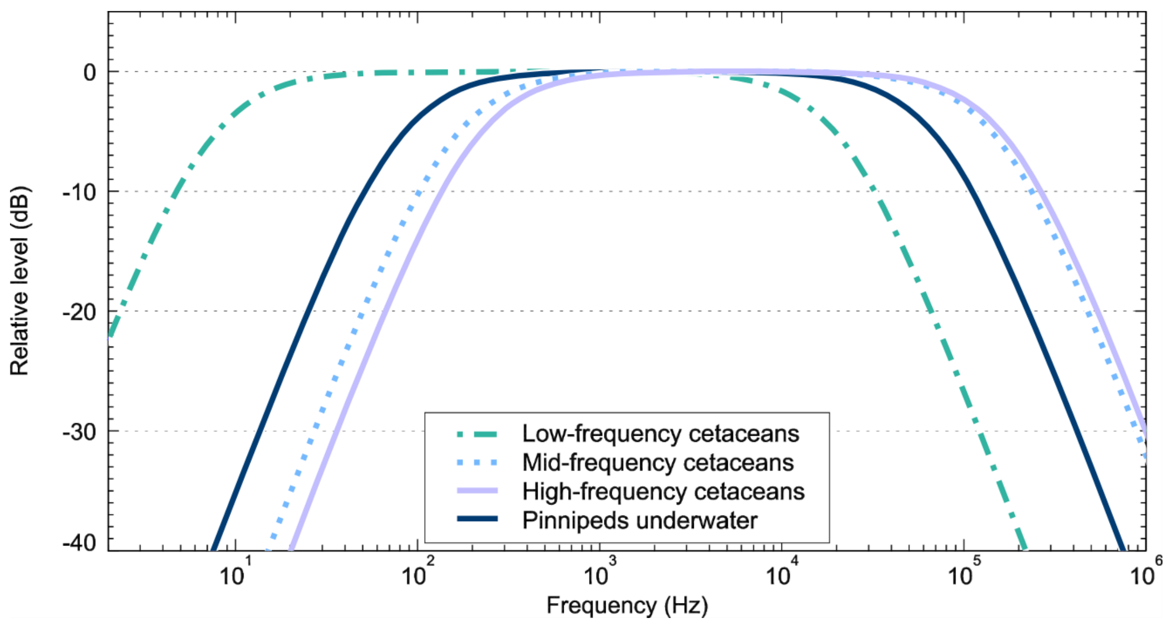

Figure C-2. Auditory weighting functions for the functional marine mammal hearing groups as recommended by Southall et al. (2007).

Appendix D. 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 D-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 2010b), 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 E). MacGillivray (2014) describes the theory behind the physical model in more detail.

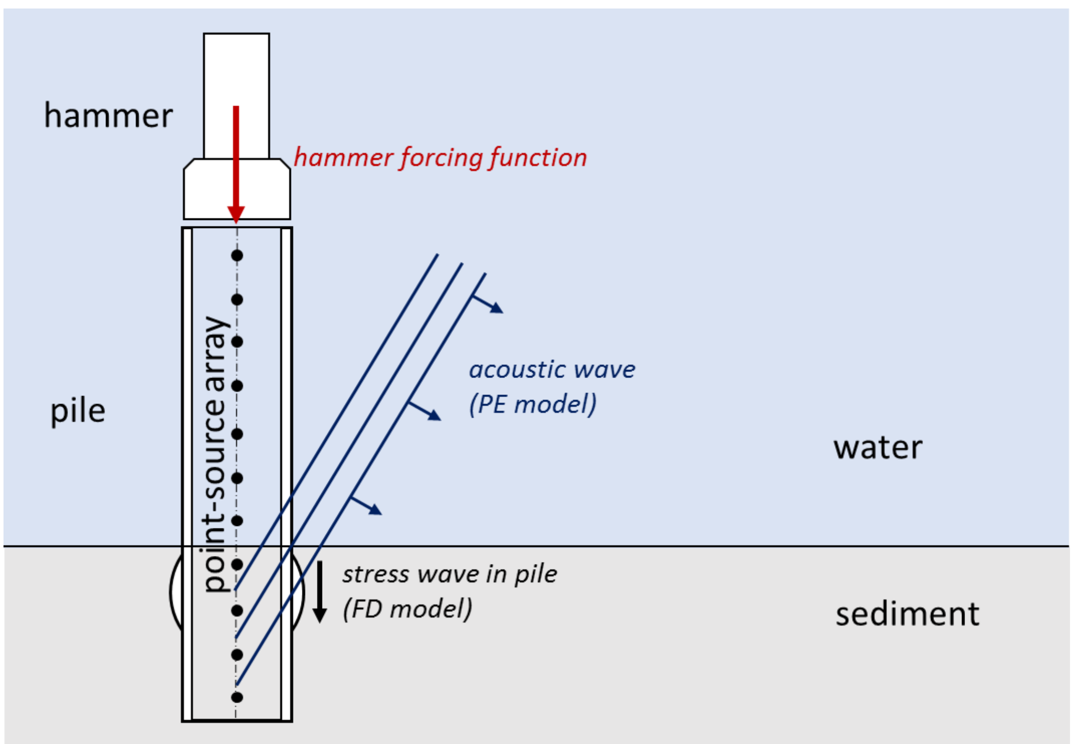

Figure D-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical array of point sources is used with the parabolic equation (PE) model to compute the acoustic waves that the pile wall radiates.

Appendix E. Sound Propagation Modeling

E.1. Environmental Parameters

E.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).

E.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 E-1 shows the sediment layer geoacoustic property profile based on the model presented by Ainslie (2010), which gives the geoacoustic properties by sediment type derived from measurements of geoacoustic parameters and determined empirical relationships between them.

Table E-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		

E.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 E-1). An average profile, obtained by calculating the mean of all profiles shown in Figure E-1 was assumed representative of the area for modeling purposes.

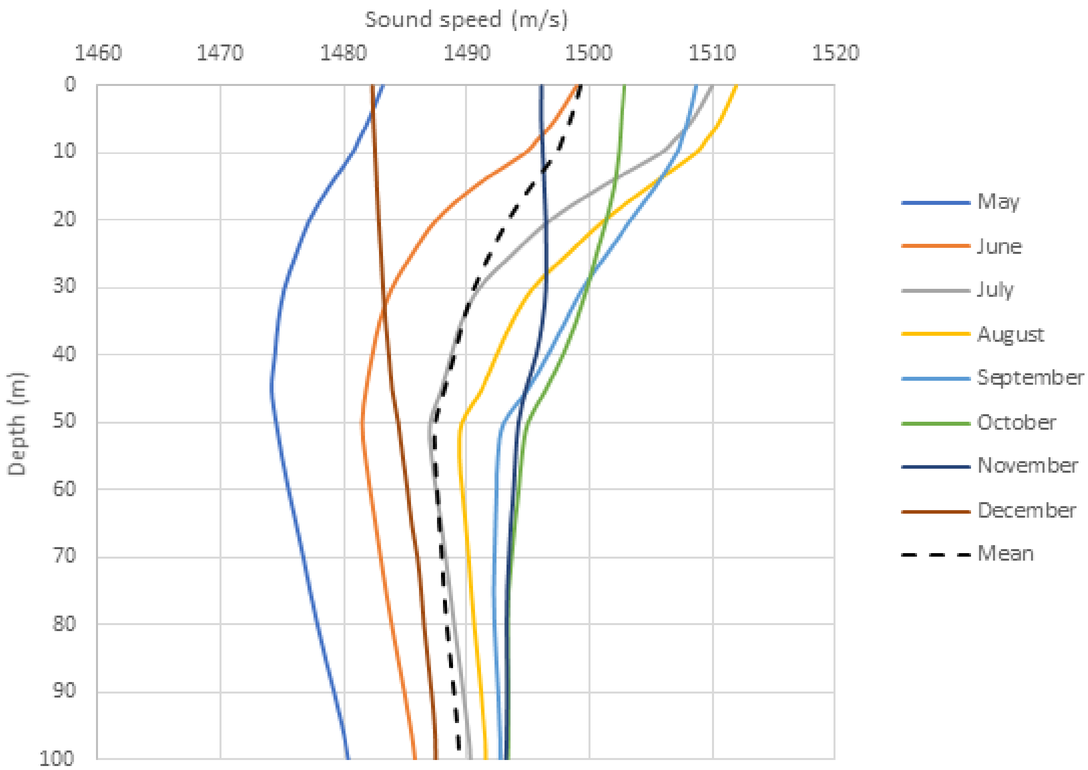

Figure E-1. Sound speed profiles up to 100 m depth for the months of May through December for Southern Wind Development Area (SWDA), and the mean profile used in the modeling and obtained by taking the average of all profiles.

E.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:

$$\mathrm{RL} = \mathrm{SL} - \mathrm{PL} \tag{E-1}$$

E.3. Sound Propagation with FWRAM

For impulsive sounds from impact pile driving, as well as non-impulsive sounds from vibratory piling, 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 a wide-angle parabolic equation (PE). FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments and takes environmental inputs (bathymetry, water sound speed profile, and seabed geoacoustic profile). 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 E-2). 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.

The modeled acoustic far-field source levels are extrapolated in the frequency domain to higher frequencies (up to 32,000 Hz) by applying a 20 dB/decade decay rate to match peer-reviewed acoustic measurements of impact pile driving (Illingworth & Rodkin 2007, Matuschek and Betke 2009). The same decay rate is used for vibratory pile driving due to the lack of publicly available data from acoustic measurements made from vibratory piling of large piles.

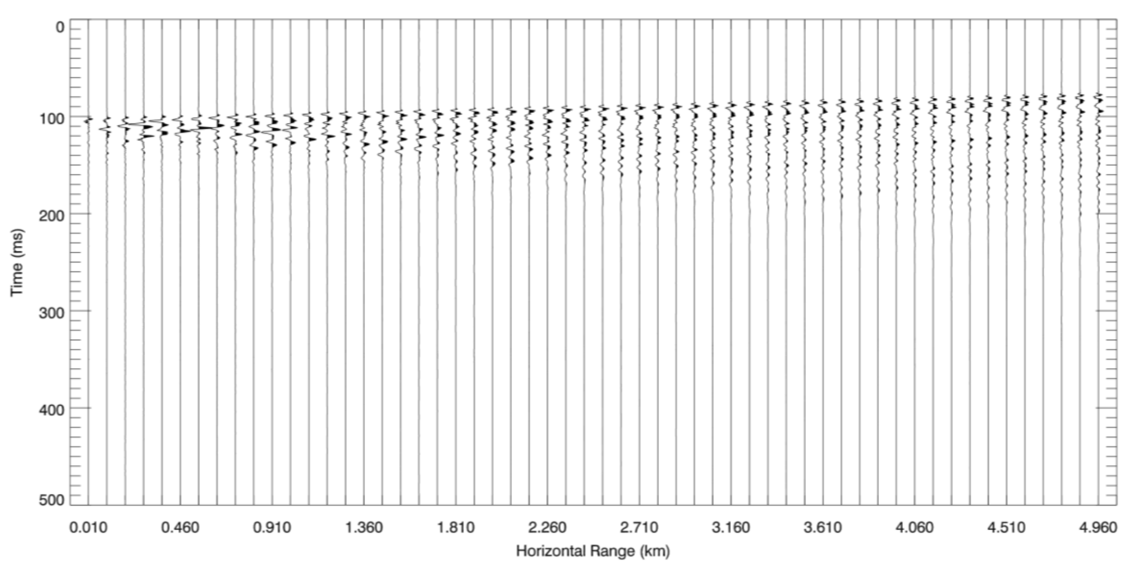

Figure E-2. Example of synthetic pressure waveforms computed by FWRAM at multiple range offsets. Receiver depth is 35 m and the amplitudes of the pressure traces have been normalised for display purposes.

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 E-3). These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ planes.

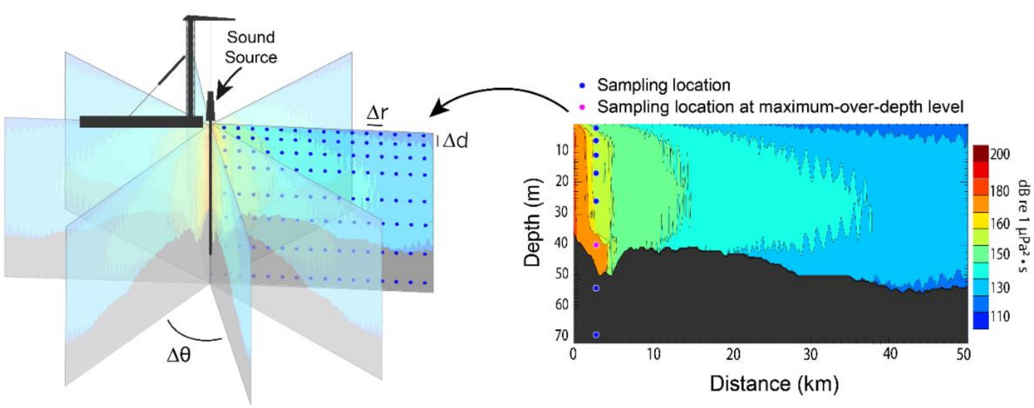

Figure E-3. Modeled three-dimensional sound field (N×2-D method) and maximum-over-depth modeling approach. Sampling locations are shown as blue dots on both figures. On the right panel, the pink dot represents the sampling location where the sound level is maximum over the water column. This maximum-over-depth level is used in calculating distances to sound level thresholds for some marine animals.

E.4. 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 E-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.

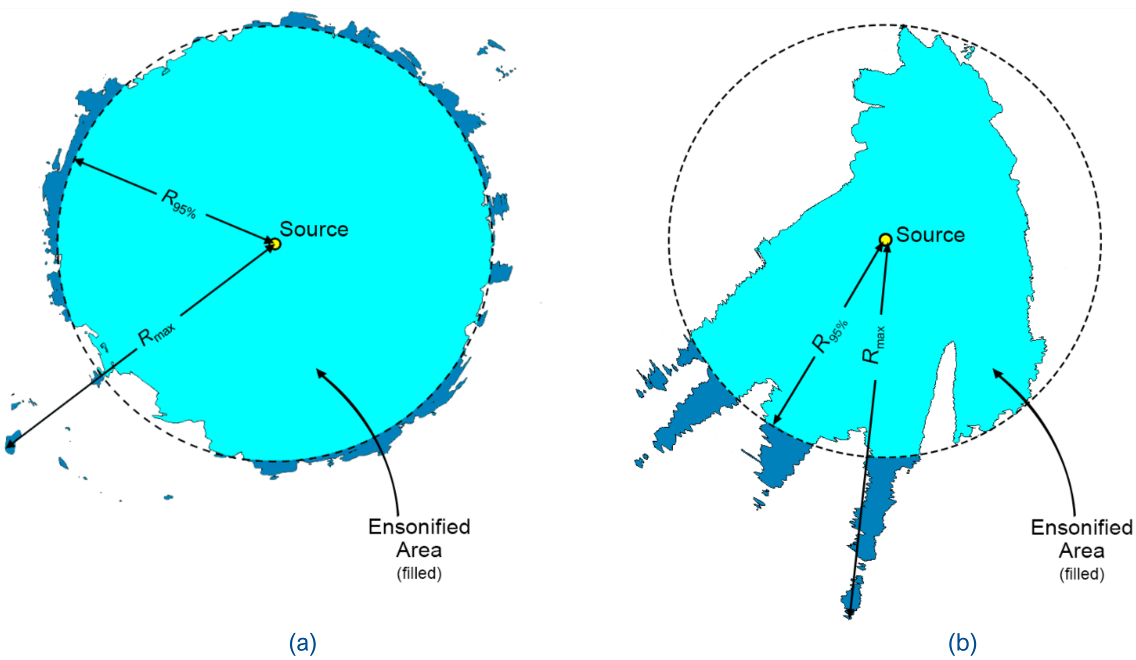

Figure E-4. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

E.5. Model Validation Information

Predictions from JASCO's propagation model (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 F. Acoustic Ranges to Regulatory Thresholds for Impact-Only Pile Driving

The following subsections contain tables of ranges to injury and behavior thresholds described in Sections 2.4 and 2.4.2. Results are presented for pile driving operations assuming a 0, 10, 12, and 15 dB broadband attenuation achieved using noise attenuation systems.

F.1. Decidecade and Broadband Levels at 750 m

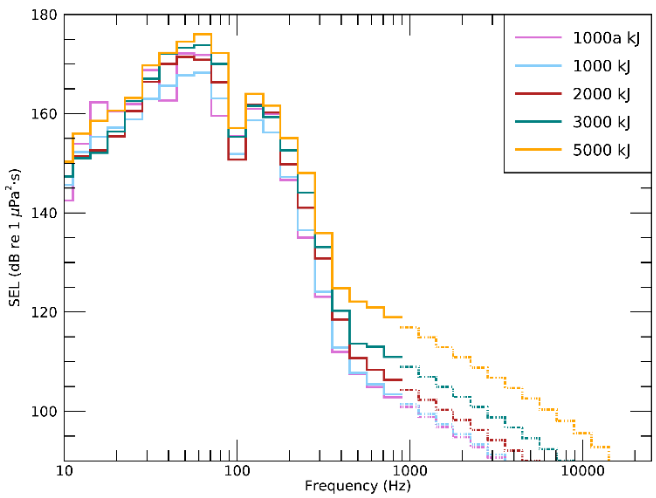

Figure F-1. Decidecade band levels at 750 m from location M1 for a 12 m monopile assuming an installation scenario with a MHU5000 kJ hammer with average sound speed profiles from May to December.

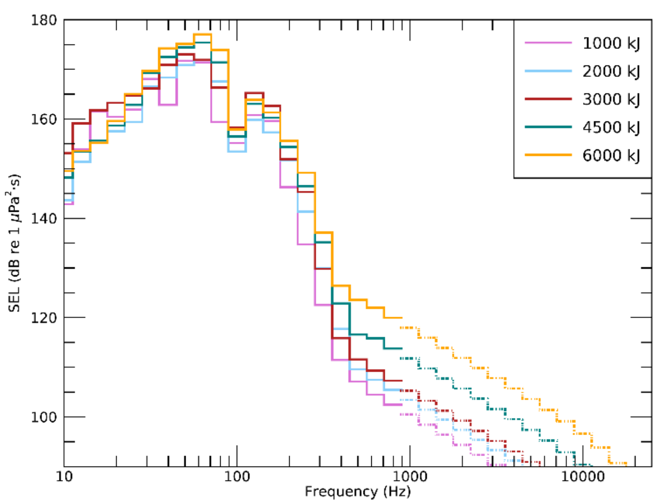

Figure F-2. Decidecade band levels at 750 m from location M1 for a 12 m monopile assuming an installation scenario with a MHU6000 kJ hammer with average sound speed profiles from May to December.

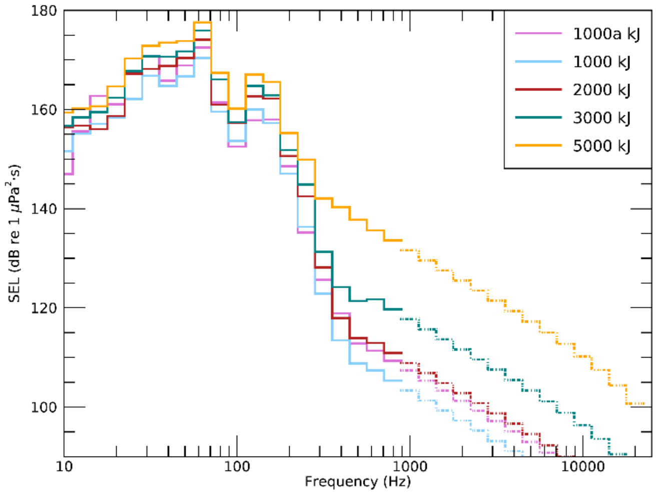

Figure F-3. Decidecade band levels at 750 m from location M2 for a 13 m monopile assuming an installation scenario with a MHU5000 kJ hammer with average sound speed profiles from May to December.

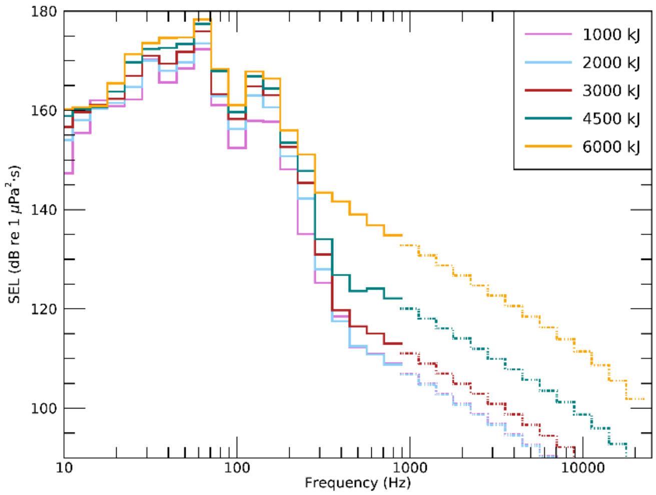

Figure F-4. Decidecade band levels at 750 m from location M2 for a 13 m monopile assuming an installation scenario with a MHU6000 kJ hammer with average sound speed profiles from May to December.

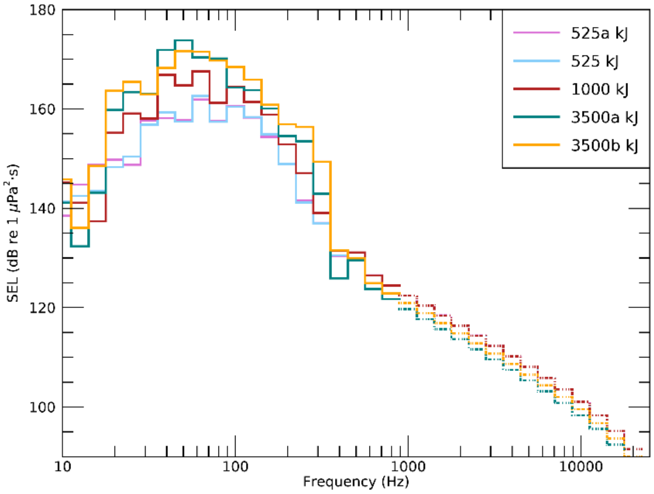

Figure F-5. Decidecade band levels at 750 m from location J1 for a 4 m jacket assuming an installation scenario with a MHU3500 kJ hammer with average sound speed profiles from May to December.

Table F-1. Broadband level at 750 m (SEL dB re 1 µPa) for the 12 m monopile at location M1 for average conditions between May to December.

Scenario	Drivability	Hammer Duration/ Energy	Single Strike SEL
WTG (12 m monopile)	MHU 5000	Impact-only pile driving	
		1000 (a) kJ	176.9
		1000 kJ	173.7
		2000 kJ	177.0
		3000 kJ	179.2
		5000 kJ	180.8
	MHU 6000	Impact-only pile driving	
		1000 kJ	176.5
		2000 kJ	176.9
		3000 kJ	178.4
		4500 kJ	180.4
		6000 kJ	181.9

Table F-2. Broadband level at 750 m (SEL dB re 1 µPa) for the 13 m monopile at location M2 for average conditions between May to December.

Scenario	Drivability	Hammer Duration/ Energy	Single Strike SEL
WTG (13 m monopile)	MHU 5000	Impact-only pile driving	
		1000 (a) kJ	176.9
		1000 kJ	174.6
		2000 kJ	177.9
		3000 kJ	179.7
		5000 kJ	181.8
	MHU 6000	Impact-only pile driving	
		1000 kJ	176.6
		2000 kJ	177.6
		3000 kJ	179.6
		4500 kJ	181.4
		6000 kJ	182.7

Table F-3. Broadband level at 750 m (SEL dB re 1 uPa) for a 4 m jacket pin pile at location J1 for average conditions between May to December.

Scenario	Drivability	Hammer duration/ Energy	Single Strike SEL
		Impact-only pile driving	
Jacket (4 m pin pile)	MHU 3500	525 (a) kJ	168.2
		525 kJ	168.4
		1000 kJ	173.6
		3500 (a) kJ	178.5
		3500 (b) kJ	178.2

F.2. Single-strike PK Acoustic Ranges

Table 92. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		525 (a)	525	1000	3500 (a)	3500 (b)
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	0.09	0.09
PPW	218	-	-	-	0.10	0.09
HF	202	0.26	0.26	0.41	0.76	0.72

Table 93. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		525 (a)	525	1000	3500 (a)	3500 (b)
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.09	0.09	0.12	0.17	0.17

Table 94. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		525 (a)	525	1000	3500 (a)	3500 (b)
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.03	0.03	0.09	0.15	0.14

Table 95. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		525 (a)	525	1000	3500 (a)	3500 (b)
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	-	-	0.02	0.12	0.11

Table 96. Monopile foundation (12 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	0.04	0.05	0.06
PPW	218	0.02	-	0.05	0.06	0.09
HF	202	0.37	0.33	0.44	0.50	0.62

Table 97. Monopile foundation (12 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.06	0.06	0.10	0.12	0.20

Table 98. Monopile foundation (12 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.06	0.05	0.07	0.10	0.13

Table 99. Monopile foundation (12 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.03	0.02	0.05	0.06	0.09

Table 100. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	0.04	0.05	0.06	0.08
PPW	218	-	0.05	0.06	0.06	0.09
HF	202	0.36	0.44	0.52	0.61	0.67

Table 101. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.06	0.09	0.12	0.14	0.24

Table 102. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.06	0.07	0.09	0.12	0.13

Table 103. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.03	0.05	0.06	0.09	0.10

Table 104. Monopile foundation (13 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	0.02	0.06	0.07
PPW	218	-	-	0.03	0.06	0.10
HF	202	0.40	0.38	0.49	0.61	0.72

Table 105. Monopile foundation (13 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.07	0.06	0.11	0.14	0.25

Table 106. Monopile foundation (13 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.06	0.06	0.09	0.12	0.15

Table 107. Monopile foundation (13 m typical monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000 (a)	1000	2000	3000	5000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.02	-	0.06	0.07	0.11

Table 108. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	0.02	0.06	0.07	0.09
PPW	218	-	0.03	0.06	0.08	0.10
HF	202	0.39	0.48	0.60	0.67	0.79

Table 109. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.07	0.11	0.13	0.17	0.28

Table 110. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.06	0.08	0.11	0.13	0.16

Table 111. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)				
		Annual				
		1000	2000	3000	4500	6000
TUW	232	-	-	-	-	-
MF	230	-	-	-	-	-
LF	219	-	-	-	-	-
PPW	218	-	-	-	-	-
HF	202	0.02	0.06	0.07	0.10	0.11

F.3. Per-pile SEL Acoustic Ranges to Injury Threshold

Table 112. Jacket with 4 legs (post-piled 4 m diameter typical, MHU 3500) foundation SEL acoustic ranges (*R*95% in km) with attenuation (Finneran et al. 2017, NMFS 2018) for location J1.

Hearing group	Threshold (dB)	Attenuation Level (dB) Annual			
		0	10	12	15
LF	183	11.81	6.82	6.14	5.18
MF	185	0.03	-	-	-
HF	155	1.52	0.43	0.40	0.23
PPW	185	4.03	1.61	1.27	0.85

Table 113. Monopile foundation (12 m diameter typical, MHU 5500 hammer, annual) acoustic ranges (*R*95% in km) with attenuation (Finneran et al. 2017, NMFS 2018) for location M1.

Hearing group	Threshold (dB)	Attenuation Level (dB) Annual			
		0	10	12	15
LF	183	7.15	3.50	2.90	2.30
MF	185	-	-	-	-
HF	155	0.14	-	-	-
PPW	185	1.50	0.40	0.25	0.14

Table 114. Monopile foundation (12 m diameter typical, MHU 6000 hammer, annual) acoustic ranges (*R*95% in km) with attenuation (Finneran et al. 2017, NMFS 2018) for location M1.

Hearing group	Threshold (dB)	Attenuation Level (dB) Annual			
		0	10	12	15
LF	183	7.23	3.55	2.94	2.33
MF	185	-	-	-	-
HF	155	0.14	0.02	-	-
PPW	185	1.53	0.40	0.26	0.14

Table 115. Monopile foundation (13 m diameter typical, MHU 5500 hammer, annual) acoustic ranges ($R_{95\%}$ in km) with attenuation (Finneran et al. 2017, NMFS 2018) for location M2.

Hearing group	Threshold (dB)	Attenuation Level (dB) Annual			
		0	10	12	15
LF	183	7.74	4.00	3.38	2.57
MF	185	-	-	-	-
HF	155	0.52	0.09	0.07	0.05
PPW	185	1.65	0.44	0.28	0.16

Table 116. Monopile foundation (13 m diameter typical, MHU 6000 hammer, annual) acoustic ranges ($R_{95\%}$ in km) with attenuation (Finneran et al. 2017, NMFS 2018) for location M2.

Hearing group	Threshold (dB)	Attenuation Level (dB) Annual			
		0	10	12	15
LF	183	7.82	4.04	3.43	2.60
MF	185	-	-	-	-
HF	155	0.61	0.11	0.09	0.06
PPW	185	1.68	0.45	0.29	0.16

F.4. Fish and Sea Turtle Acoustic Distances to Threshold

Table 117. Typical jacket foundation with 4 pin piles (post-piled 4 m diameter, MHU 3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			525 (a)	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	14.17				
	L_{pk} [a]	206	0.14	0.14	0.17	0.46	0.46
	L_p [b]	150	8.43	8.58	11.58	14.83	14.92
Fish ≤ 2 g	L_E [a]	183	17.16				
	L_{pk} [a]	206	0.14	0.14	0.17	0.46	0.46
	L_p [b]	150	8.43	8.58	11.58	14.83	14.92
Fish without swim bladder	L_E [c]	216	2.05				
	L_{pk} [c]	213	0.07	0.06	0.10	0.16	0.15
Fish with swim bladder involved in hearing	L_E [c]	203	5.81				
	L_{pk} [c]	207	0.13	0.13	0.16	0.44	0.44
Fish with swim bladder not involved in hearing	L_E [c]	203	5.81				
	L_{pk} [c]	207	0.13	0.13	0.16	0.44	0.44
Sea turtles	L_E [d]	204	5.47				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	1.26	1.27	2.00	3.43	3.58

Table 118. Typical jacket foundation with 4 pin piles (post-piled 4 m diameter, MHU 3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			525 (a)	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	8.20				
	L_{pk} [a]	206	-	-	0.06	0.13	0.12
	L_p [b]	150	4.62	4.67	6.17	8.24	8.66
Fish ≤ 2 g	L_E [a]	183	10.25				
	L_{pk} [a]	206	-	-	0.06	0.13	0.12
	L_p [b]	150	4.62	4.67	6.17	8.24	8.66
Fish without swim bladder	L_E [c]	216	0.56				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	2.74				
	L_{pk} [c]	207	-	-	0.02	0.12	0.11
Fish with swim bladder not involved in hearing	L_E [c]	203	2.74				
	L_{pk} [c]	207	-	-	0.02	0.12	0.11
Sea turtles	L_E [d]	204	2.53				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.27	0.27	0.56	1.39	1.35

Table 119. Typical jacket foundation with 4 pin piles (post-piled 4 m diameter, MHU 3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			525 (a)	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	7.32				
	L_{pk} [a]	206	-	-	-	0.10	0.09
	L_p [b]	150	4.09	4.12	5.44	7.31	7.75
Fish ≤ 2 g	L_E [a]	183	9.07				
	L_{pk} [a]	206	-	-	-	0.10	0.09
	L_p [b]	150	4.09	4.12	5.44	7.31	7.75
Fish without swim bladder	L_E [c]	216	0.42				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	2.30				
	L_{pk} [c]	207	-	-	-	0.09	0.09
Fish with swim bladder not involved in hearing	L_E [c]	203	2.30				
	L_{pk} [c]	207	-	-	-	0.09	0.09
Sea turtles	L_E [d]	204	2.05				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.16	0.20	0.43	1.06	0.98

Table 120. Typical jacket foundation with 4 pin piles (post-piled 4 m diameter, MHU 3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			525 (a)	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	6.16				
	L_{pk} [a]	206	-	-	-	0.06	0.03
	L_p [b]	150	3.27	3.28	4.51	6.23	6.56
Fish ≤ 2 g	L_E [a]	183	7.76				
	L_{pk} [a]	206	-	-	-	0.06	0.03
	L_p [b]	150	3.27	3.28	4.51	6.23	6.56
Fish without swim bladder	L_E [c]	216	0.22				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	1.68				
	L_{pk} [c]	207	-	-	-	0.02	0.02
Fish with swim bladder not involved in hearing	L_E [c]	203	1.68				
	L_{pk} [c]	207	-	-	-	0.02	0.02
Sea turtles	L_E [d]	204	1.47				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.13	0.13	0.25	0.66	0.63

Table 121. Typical monopile foundation (12 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	9.21				
	L_{pk} [a]	206	0.18	0.13	0.26	0.38	0.46
	L_p [b]	150	12.52	12.13	14.38	15.86	17.39
Fish ≤ 2 g	L_E [a]	183	12.03				
	L_{pk} [a]	206	0.18	0.13	0.26	0.38	0.46
	L_p [b]	150	12.52	12.13	14.38	15.86	17.39
Fish without swim bladder	L_E [c]	216	0.67				
	L_p [kc]	213	0.06	0.06	0.09	0.11	0.14
Fish with swim bladder involved in hearing	L_E [c]	203	2.82				
	L_{pk} [c]	207	0.15	0.12	0.23	0.35	0.43
Fish with swim bladder not involved in hearing	L_E [c]	203	2.82				
	L_{pk} [c]	207	0.15	0.12	0.23	0.35	0.43
Sea turtles	L_E [d]	204	2.62				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	2.43	1.84	2.50	2.83	3.44

Table 122. Typical monopile foundation (12 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	4.67				
	L_{pk} [a]	206	0.04	0.04	0.06	0.08	0.10
	L_p [b]	150	7.27	6.28	7.99	8.89	10.13
Fish ≤ 2 g	L_E [a]	183	6.26				
	L_{pk} [a]	206	0.04	0.04	0.06	0.08	0.10
	L_p [b]	150	7.27	6.28	7.99	8.89	10.13
Fish without swim bladder	L_E [c]	216	0.13				
	L_p [kc]	213	-	-	-	-	0.04
Fish with swim bladder involved in hearing	L_E [c]	203	1.02				
	L_{pk} [c]	207	0.03	0.02	0.05	0.06	0.09
Fish with swim bladder not involved in hearing	L_E [c]	203	1.02				
	L_{pk} [c]	207	0.03	0.02	0.05	0.06	0.09
Sea turtles	L_E [d]	204	0.91				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.77	0.56	0.86	1.08	1.39

Table 123. Typical monopile foundation (12 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	4.01				
	L_{pk} [a]	206	0.02	-	0.05	0.06	0.09
	L_p [b]	150	6.36	5.43	6.95	7.89	8.86
Fish ≤ 2 g	L_E [a]	183	5.43				
	L_{pk} [a]	206	0.02	-	0.05	0.06	0.09
	L_p [b]	150	6.36	5.43	6.95	7.89	8.86
Fish without swim bladder	L_E [c]	216	0.11				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.74				
	L_{pk} [c]	207	-	-	0.04	0.05	0.06
Fish with swim bladder not involved in hearing	L_E [c]	203	0.74				
	L_{pk} [c]	207	-	-	0.04	0.05	0.06
Sea turtles	L_E [d]	204	0.67				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.58	0.39	0.66	0.87	1.10

Table 124. Typical monopile foundation (12 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	3.10				
	L_{pk} [a]	206	-	-	-	0.03	0.05
	L_p [b]	150	5.22	4.30	5.57	6.37	7.32
Fish ≤ 2 g	L_E [a]	183	4.32				
	L_{pk} [a]	206	-	-	-	0.03	0.05
	L_p [b]	150	5.22	4.30	5.57	6.37	7.32
Fish without swim bladder	L_E [c]	216	0.07				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.48				
	L_{pk} [c]	207	-	-	-	0.02	0.05
Fish with swim bladder not involved in hearing	L_E [c]	203	0.48				
	L_{pk} [c]	207	-	-	-	0.02	0.05
Sea turtles	L_E [d]	204	0.41				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.35	0.23	0.40	0.56	0.72

Table 125. Typical monopile foundation (12 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	9.26				
	L_{pk} [a]	206	0.17	0.24	0.37	0.44	0.47
	L_p [b]	150	12.39	14.22	15.49	16.99	18.05
Fish ≤ 2 g	L_E [a]	183	12.09				
	L_{pk} [a]	206	0.17	0.24	0.37	0.44	0.47
	L_p [b]	150	12.39	14.22	15.49	16.99	18.05
Fish without swim bladder	L_E [c]	216	0.68				
	L_p [kc]	213	0.06	0.09	0.11	0.13	0.18
Fish with swim bladder involved in hearing	L_E [c]	203	2.84				
	L_{pk} [c]	207	0.12	0.20	0.34	0.39	0.45
Fish with swim bladder not involved in hearing	L_E [c]	203	2.84				
	L_{pk} [c]	207	0.12	0.20	0.34	0.39	0.45
Sea turtles	L_E [d]	204	2.65				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	2.35	2.45	2.78	3.28	3.72

Table 126. Typical monopile foundation (12 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	4.70				
	L_{pk} [a]	206	0.04	0.06	0.07	0.09	0.11
	L_p [b]	150	7.10	7.79	8.70	9.77	10.79
Fish ≤ 2 g	L_E [a]	183	6.30				
	L_{pk} [a]	206	0.04	0.06	0.07	0.09	0.11
	L_p [b]	150	7.10	7.79	8.70	9.77	10.79
Fish without swim bladder	L_E [c]	216	0.13				
	L_p [kc]	213	-	-	-	0.03	0.05
Fish with swim bladder involved in hearing	L_E [c]	203	1.03				
	L_{pk} [c]	207	0.03	0.05	0.06	0.09	0.10
Fish with swim bladder not involved in hearing	L_E [c]	203	1.03				
	L_{pk} [c]	207	0.03	0.05	0.06	0.09	0.10
Sea turtles	L_E [d]	204	0.92				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.74	0.86	1.04	1.31	1.54

Table 127. Typical monopile foundation (12 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	4.04				
	L_{pk} [a]	206	-	0.05	0.06	0.06	0.09
	L_p [b]	150	6.21	6.74	7.68	8.65	9.30
Fish ≤ 2 g	L_E [a]	183	5.47				
	L_{pk} [a]	206	-	0.05	0.06	0.06	0.09
	L_p [b]	150	6.21	6.74	7.68	8.65	9.30
Fish without swim bladder	L_E [c]	216	0.11				
	L_p [kc]	213	-	-	-	-	0.02
Fish with swim bladder involved in hearing	L_E [c]	203	0.79				
	L_{pk} [c]	207	-	0.04	0.05	0.06	0.08
Fish with swim bladder not involved in hearing	L_E [c]	203	0.79				
	L_{pk} [c]	207	-	0.04	0.05	0.06	0.08
Sea turtles	L_E [d]	204	0.68				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.55	0.64	0.80	1.02	1.23

Table 128. Typical monopile foundation (12 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	3.14				
	L_{pk} [a]	206	-	-	0.03	0.05	0.06
	L_p [b]	150	5.09	5.43	6.18	7.10	7.78
Fish ≤ 2 g	L_E [a]	183	4.36				
	L_{pk} [a]	206	-	-	0.03	0.05	0.06
	L_p [b]	150	5.09	5.43	6.18	7.10	7.78
Fish without swim bladder	L_E [c]	216	0.08				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.51				
	L_{pk} [c]	207	-	-	0.02	0.04	0.05
Fish with swim bladder not involved in hearing	L_E [c]	203	0.51				
	L_{pk} [c]	207	-	-	0.02	0.04	0.05
Sea turtles	L_E [d]	204	0.42				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.34	0.40	0.52	0.67	0.86

Table 129. Typical monopile foundation (13 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	10.57				
	L_{pk} [a]	206	0.17	0.15	0.31	0.43	0.50
	L_p [b]	150	14.16	13.26	16.30	17.68	20.12
Fish ≤ 2 g	L_E [a]	183	13.68				
	L_{pk} [a]	206	0.17	0.15	0.31	0.43	0.50
	L_p [b]	150	14.16	13.26	16.30	17.68	20.12
Fish without swim bladder	L_E [c]	216	0.78				
	L_p [kc]	213	0.06	0.06	0.10	0.13	0.16
Fish with swim bladder involved in hearing	L_E [c]	203	3.35				
	L_{pk} [c]	207	0.13	0.13	0.27	0.40	0.46
Fish with swim bladder not involved in hearing	L_E [c]	203	3.35				
	L_{pk} [c]	207	0.13	0.13	0.27	0.40	0.46
Sea turtles	L_E [d]	204	3.02				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	2.54	2.00	2.74	3.16	3.78

Table 130. Typical monopile foundation (13 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	5.32				
	L_{pk} [a]	206	0.03	0.02	0.06	0.09	0.12
	L_p [b]	150	7.61	6.58	8.42	9.21	10.80
Fish ≤ 2 g	L_E [a]	183	6.96				
	L_{pk} [a]	206	0.03	0.02	0.06	0.09	0.12
	L_p [b]	150	7.61	6.58	8.42	9.21	10.80
Fish without swim bladder	L_E [c]	216	0.15				
	L_p [kc]	213	-	-	-	-	0.02
Fish with swim bladder involved in hearing	L_E [c]	203	1.16				
	L_{pk} [c]	207	0.02	-	0.06	0.07	0.11
Fish with swim bladder not involved in hearing	L_E [c]	203	1.16				
	L_{pk} [c]	207	0.02	-	0.06	0.07	0.11
Sea turtles	L_E [d]	204	0.99				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.78	0.57	0.93	1.18	1.52

Table 131. Typical monopile foundation (13 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E[a]	187	4.62				
	L_{pk}[a]	206	-	-	0.03	0.06	0.10
	L_p[b]	150	6.65	5.75	7.30	8.16	9.21
Fish ≤ 2 g	L_E[a]	183	6.08				
	L_{pk}[a]	206	-	-	0.03	0.06	0.10
	L_p[b]	150	6.65	5.75	7.30	8.16	9.21
Fish without swim bladder	L_E[c]	216	0.13				
	L_p[kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E[c]	203	0.88				
	L_{pk}[c]	207	-	-	0.02	0.06	0.07
Fish with swim bladder not involved in hearing	L_E[c]	203	0.88				
	L_{pk}[c]	207	-	-	0.02	0.06	0.07
Sea turtles	L_E[d]	204	0.78				
	L_{pk}[d]	232	-	-	-	-	-
	L_p[e]	175	0.52	0.43	0.71	0.89	1.20

Table 132. Typical monopile foundation (13 m diameter, MHU 5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000 (a)	1000	2000	3000	5000
Fish ≥ 2g	L_E[a]	187	3.68				
	L_{pk}[a]	206	-	-	-	0.02	0.06
	L_p[b]	150	5.50	4.65	5.89	6.62	7.63
Fish ≤ 2 g	L_E[a]	183	4.96				
	L_{pk}[a]	206	-	-	-	0.02	0.06
	L_p[b]	150	5.50	4.65	5.89	6.62	7.63
Fish without swim bladder	L_E[c]	216	0.09				
	L_p[kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E[c]	203	0.55				
	L_{pk}[c]	207	-	-	-	-	0.04
Fish with swim bladder not involved in hearing	L_E[c]	203	0.55				
	L_{pk}[c]	207	-	-	-	-	0.04
Sea turtles	L_E[d]	204	0.48				
	L_{pk}[d]	232	-	-	-	-	-
	L_p[e]	175	0.39	0.26	0.44	0.57	0.79

Table 133. Typical monopile foundation (13 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	10.65				
	L_{pk} [a]	206	0.15	0.28	0.42	0.47	0.55
	L_p [b]	150	13.95	15.78	17.56	19.69	21.29
Fish ≤ 2 g	L_E [a]	183	13.77				
	L_{pk} [a]	206	0.15	0.28	0.42	0.47	0.55
	L_p [b]	150	13.95	15.78	17.56	19.69	21.29
Fish without swim bladder	L_E [c]	216	0.80				
	L_p [kc]	213	0.06	0.10	0.12	0.15	0.24
Fish with swim bladder involved in hearing	L_E [c]	203	3.39				
	L_{pk} [c]	207	0.13	0.20	0.39	0.45	0.49
Fish with swim bladder not involved in hearing	L_E [c]	203	3.39				
	L_{pk} [c]	207	0.13	0.20	0.39	0.45	0.49
Sea turtles	L_E [d]	204	3.06				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	2.47	2.64	3.09	3.66	4.01

Table 134. Typical monopile foundation (13 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	5.36				
	L_{pk} [a]	206	0.02	0.06	0.08	0.11	0.13
	L_p [b]	150	7.43	8.11	9.15	10.49	11.43
Fish ≤ 2 g	L_E [a]	183	7.01				
	L_{pk} [a]	206	0.02	0.06	0.08	0.11	0.13
	L_p [b]	150	7.43	8.11	9.15	10.49	11.43
Fish without swim bladder	L_E [c]	216	0.15				
	L_p [kc]	213	-	-	-	0.02	0.03
Fish with swim bladder involved in hearing	L_E [c]	203	1.19				
	L_{pk} [c]	207	0.02	0.06	0.07	0.10	0.11
Fish with swim bladder not involved in hearing	L_E [c]	203	1.19				
	L_{pk} [c]	207	0.02	0.06	0.07	0.10	0.11
Sea turtles	L_E [d]	204	1.00				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.75	0.88	1.15	1.45	1.66

Table 135. Typical monopile foundation (13 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	4.66				
	L_{pk} [a]	206	-	0.03	0.06	0.08	0.10
	L_p [b]	150	6.49	7.05	8.06	9.01	9.77
Fish ≤ 2 g	L_E [a]	183	6.12				
	L_{pk} [a]	206	-	0.03	0.06	0.08	0.10
	L_p [b]	150	6.49	7.05	8.06	9.01	9.77
Fish without swim bladder	L_E [c]	216	0.13				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.89				
	L_{pk} [c]	207	-	0.02	0.06	0.07	0.09
Fish with swim bladder not involved in hearing	L_E [c]	203	0.89				
	L_{pk} [c]	207	-	0.02	0.06	0.07	0.09
Sea turtles	L_E [d]	204	0.80				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.50	0.67	0.87	1.11	1.32

Table 136. Typical monopile foundation (13 m diameter, MHU 6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			1000	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	3.72				
	L_{pk} [a]	206	-	-	0.02	0.06	0.06
	L_p [b]	150	5.37	5.71	6.50	7.44	8.05
Fish ≤ 2 g	L_E [a]	183	5.00				
	L_{pk} [a]	206	-	-	0.02	0.06	0.06
	L_p [b]	150	5.37	5.71	6.50	7.44	8.05
Fish without swim bladder	L_E [c]	216	0.09				
	L_p [kc]	213	-	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.57				
	L_{pk} [c]	207	-	-	-	0.03	0.06
Fish with swim bladder not involved in hearing	L_E [c]	203	0.57				
	L_{pk} [c]	207	-	-	-	0.03	0.06
Sea turtles	L_E [d]	204	0.48				
	L_{pk} [d]	232	-	-	-	-	-
	L_p [e]	175	0.38	0.43	0.55	0.77	0.86

F.5. Single-strike SPL Acoustic Ranges

Table 137. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 525a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
180	0.65	0.62	0.64	0.61	0.23	0.22	0.13	0.13	0.42	0.41
175	1.32	1.26	1.30	1.25	0.46	0.44	0.29	0.28	0.82	0.78
170	2.26	2.15	2.24	2.13	0.91	0.87	0.60	0.58	1.56	1.50
160	4.86	4.62	4.84	4.59	2.72	2.60	2.18	2.06	3.89	3.66
150	9.17	8.43	9.11	8.38	5.38	5.10	4.68	4.43	6.97	6.49
140	16.67	14.93	16.60	14.86	9.38	8.58	8.14	7.45	12.97	11.63
130	28.38	24.93	28.25	24.83	16.47	14.77	14.05	12.62	22.53	20.02
120	45.94	38.60	45.68	38.40	30.07	26.20	25.22	22.28	39.25	33.35

Table 138. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 525a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
175	0.28	0.27	0.27	0.26	0.11	0.10	0.08	0.08	0.15	0.14
170	0.65	0.62	0.64	0.61	0.23	0.22	0.13	0.13	0.42	0.41
160	2.26	2.15	2.24	2.13	0.91	0.87	0.60	0.58	1.56	1.50
150	4.86	4.62	4.84	4.59	2.72	2.60	2.18	2.06	3.89	3.66
140	9.17	8.43	9.11	8.38	5.38	5.10	4.68	4.43	6.97	6.49
130	16.67	14.93	16.60	14.86	9.38	8.58	8.14	7.45	12.97	11.63
120	28.38	24.93	28.25	24.83	16.47	14.77	14.05	12.62	22.53	20.02

Table 139. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 525a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.11	0.11	0.11	0.11	-	-	-	-	0.07	0.07
175	0.20	0.16	0.16	0.16	0.09	0.09	0.02	0.02	0.13	0.13
170	0.48	0.46	0.47	0.45	0.14	0.13	0.11	0.11	0.28	0.27
160	1.84	1.76	1.83	1.75	0.67	0.64	0.47	0.45	1.24	1.19
150	4.32	4.09	4.30	4.07	2.32	2.19	1.80	1.70	3.27	3.10
140	8.08	7.47	8.03	7.43	4.82	4.58	4.16	3.95	6.21	5.83
130	15.05	13.45	14.98	13.38	8.47	7.76	7.24	6.68	11.53	10.24
120	25.64	22.76	25.52	22.66	14.81	13.26	12.78	11.42	19.73	17.82

Table 140. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 525a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.08	0.08	0.08	0.08	-	-	-	-	-	-
175	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
170	0.28	0.27	0.27	0.26	0.11	0.10	0.08	0.08	0.15	0.14
160	1.32	1.26	1.30	1.25	0.46	0.44	0.29	0.28	0.82	0.78
150	3.47	3.27	3.44	3.25	1.71	1.62	1.27	1.21	2.57	2.45
140	6.60	6.21	6.56	6.17	4.07	3.84	3.30	3.13	5.22	4.94
130	12.82	11.49	12.75	11.43	7.12	6.59	6.14	5.77	9.37	8.59
120	21.52	19.09	21.41	18.99	12.76	11.40	10.69	9.49	16.95	15.21

Table 141. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 0525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
180	0.63	0.60	0.61	0.59	0.23	0.23	0.13	0.13	0.42	0.41
175	1.33	1.27	1.31	1.26	0.45	0.44	0.29	0.28	0.84	0.80
170	2.25	2.13	2.23	2.12	0.91	0.87	0.60	0.58	1.57	1.50
160	4.92	4.67	4.90	4.64	2.72	2.60	2.16	2.04	3.92	3.69
150	9.35	8.58	9.29	8.53	5.42	5.13	4.70	4.45	7.01	6.51
140	16.92	15.15	16.85	15.09	9.43	8.61	8.16	7.46	13.14	11.74
130	28.36	24.86	28.22	24.76	16.45	14.75	14.17	12.67	22.06	19.58
120	45.70	38.30	45.42	38.11	29.81	25.87	24.72	21.80	38.81	32.88

Table 142. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 0525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
175	0.28	0.27	0.28	0.27	0.11	0.10	0.08	0.08	0.15	0.14
170	0.63	0.60	0.61	0.59	0.23	0.23	0.13	0.13	0.42	0.41
160	2.25	2.13	2.23	2.12	0.91	0.87	0.60	0.58	1.57	1.50
150	4.92	4.67	4.90	4.64	2.72	2.60	2.16	2.04	3.92	3.69
140	9.35	8.58	9.29	8.53	5.42	5.13	4.70	4.45	7.01	6.51
130	16.92	15.15	16.85	15.09	9.43	8.61	8.16	7.46	13.14	11.74
120	28.36	24.86	28.22	24.76	16.45	14.75	14.17	12.67	22.06	19.58

Table 143. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 0525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.11	0.11	0.11	0.11	-	-	-	-	0.07	0.07
175	0.22	0.20	0.22	0.19	0.09	0.09	0.02	0.02	0.13	0.13
170	0.48	0.45	0.47	0.45	0.14	0.13	0.11	0.11	0.28	0.27
160	1.84	1.75	1.82	1.74	0.68	0.64	0.46	0.45	1.24	1.18
150	4.36	4.12	4.34	4.10	2.30	2.17	1.79	1.70	3.30	3.12
140	8.23	7.61	8.19	7.56	4.85	4.60	4.18	3.96	6.25	5.86
130	15.39	13.74	15.32	13.68	8.49	7.78	7.25	6.69	11.67	10.34
120	25.53	22.64	25.41	22.54	14.89	13.31	12.88	11.46	19.52	17.63

Table 144. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 0525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.08	0.08	0.08	0.08	-	-	-	-	-	-
175	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
170	0.28	0.27	0.28	0.27	0.11	0.10	0.08	0.08	0.15	0.14
160	1.33	1.27	1.31	1.26	0.45	0.44	0.29	0.28	0.84	0.80
150	3.48	3.28	3.46	3.26	1.71	1.61	1.27	1.21	2.60	2.48
140	6.67	6.27	6.65	6.24	4.09	3.86	3.32	3.14	5.28	4.99
130	13.15	11.78	13.07	11.72	7.13	6.59	6.15	5.78	9.48	8.66
120	21.43	19.02	21.31	18.92	12.84	11.44	10.81	9.53	16.99	15.24

Table 145. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.06	0.06	0.06	0.06	-	-	-	-	-	-
190	0.26	0.25	0.26	0.25	0.09	0.09	0.02	0.02	0.13	0.13
180	1.26	1.21	1.25	1.19	0.41	0.40	0.26	0.26	0.74	0.72
175	2.10	2.00	2.08	1.98	0.80	0.77	0.50	0.48	1.41	1.35
170	3.27	3.08	3.24	3.05	1.48	1.40	1.04	0.99	2.33	2.22
160	6.54	6.17	6.50	6.13	3.74	3.53	2.93	2.80	5.03	4.77
150	13.01	11.58	12.93	11.51	6.75	6.32	5.82	5.49	9.18	8.43
140	21.65	19.12	21.54	19.02	12.17	10.79	9.93	9.06	16.95	15.08
130	35.15	30.08	35.00	29.99	20.76	18.31	17.65	15.70	28.78	25.18
120	54.29	45.10	53.88	44.82	36.60	31.01	31.44	26.95	45.79	38.46

Table 146. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.26	0.25	0.26	0.25	0.09	0.09	0.02	0.02	0.13	0.13
175	0.58	0.56	0.58	0.56	0.14	0.14	0.12	0.12	0.36	0.33
170	1.26	1.21	1.25	1.19	0.41	0.40	0.26	0.26	0.74	0.72
160	3.27	3.08	3.24	3.05	1.48	1.40	1.04	0.99	2.33	2.22
150	6.54	6.17	6.50	6.13	3.74	3.53	2.93	2.80	5.03	4.77
140	13.01	11.58	12.93	11.51	6.75	6.32	5.82	5.49	9.18	8.43
130	21.65	19.12	21.54	19.02	12.17	10.79	9.93	9.06	16.95	15.08
120	35.15	30.08	35.00	29.99	20.76	18.31	17.65	15.70	28.78	25.18

Table 147. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	-	-	-	-	-	-	-	-
180	0.16	0.15	0.15	0.15	0.03	0.03	-	-	0.11	0.11
175	0.45	0.43	0.44	0.43	0.12	0.12	0.10	0.09	0.25	0.24
170	0.90	0.86	0.89	0.85	0.27	0.27	0.15	0.14	0.51	0.49
160	2.75	2.62	2.73	2.61	1.15	1.09	0.83	0.80	1.90	1.81
150	5.74	5.44	5.71	5.41	3.10	2.93	2.53	2.41	4.45	4.21
140	11.35	10.03	11.26	9.95	6.06	5.71	5.20	4.93	8.19	7.56
130	19.41	17.47	19.35	17.40	10.70	9.48	9.07	8.29	15.29	13.56
120	32.22	27.85	32.08	27.74	18.71	16.70	15.92	14.12	25.90	22.99

Table 148. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.12	0.12	0.12	0.12	-	-	-	-	0.09	0.09
175	0.26	0.25	0.26	0.25	0.09	0.09	0.02	0.02	0.13	0.13
170	0.58	0.56	0.58	0.56	0.14	0.14	0.12	0.12	0.36	0.33
160	2.10	2.00	2.08	1.98	0.80	0.77	0.50	0.48	1.41	1.35
150	4.74	4.51	4.72	4.49	2.45	2.33	1.88	1.78	3.61	3.40
140	9.14	8.40	9.07	8.36	5.12	4.86	4.37	4.14	6.74	6.32
130	16.97	15.15	16.91	15.09	9.02	8.27	7.71	7.10	12.85	11.40
120	28.03	24.67	27.91	24.58	16.08	14.27	13.59	12.05	21.95	19.32

Table 149. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.14	0.13	0.13	0.13	-	-	-	-	0.09	0.09
190	0.69	0.66	0.68	0.65	0.15	0.15	0.13	0.13	0.42	0.40
180	2.39	2.29	2.38	2.26	0.88	0.84	0.54	0.52	1.54	1.47
175	3.61	3.43	3.58	3.40	1.64	1.53	1.18	1.12	2.55	2.44
170	4.99	4.74	4.96	4.71	2.63	2.51	2.07	1.95	3.82	3.63
160	8.95	8.24	8.88	8.17	5.22	4.94	4.50	4.27	6.77	6.30
150	16.39	14.83	16.30	14.75	8.81	8.03	7.69	7.05	12.27	11.01
140	28.06	24.54	27.92	24.46	15.54	14.11	13.27	11.93	21.74	19.28
130	45.14	37.80	44.88	37.60	28.75	25.05	23.90	21.08	37.93	32.18
120	80.58	66.62	79.43	65.69	51.97	42.74	43.47	36.20	68.02	55.72

Table 150. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.14	0.13	0.13	0.13	-	-	-	-	0.09	0.09
180	0.69	0.66	0.68	0.65	0.15	0.15	0.13	0.13	0.42	0.40
175	1.45	1.39	1.43	1.37	0.45	0.44	0.28	0.27	0.84	0.80
170	2.39	2.29	2.38	2.26	0.88	0.84	0.54	0.52	1.54	1.47
160	4.99	4.74	4.96	4.71	2.63	2.51	2.07	1.95	3.82	3.63
150	8.95	8.24	8.88	8.17	5.22	4.94	4.50	4.27	6.77	6.30
140	16.39	14.83	16.30	14.75	8.81	8.03	7.69	7.05	12.27	11.01
130	28.06	24.54	27.92	24.46	15.54	14.11	13.27	11.93	21.74	19.28
120	45.14	37.80	44.88	37.60	28.75	25.05	23.90	21.08	37.93	32.18

Table 151. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.10	-	-	-	-	0.03	0.03
180	0.53	0.51	0.52	0.50	0.13	0.13	0.10	0.10	0.28	0.27
175	1.11	1.06	1.10	1.05	0.29	0.28	0.16	0.16	0.58	0.57
170	1.93	1.85	1.91	1.83	0.62	0.59	0.46	0.45	1.21	1.16
160	4.44	4.22	4.40	4.19	2.23	2.10	1.73	1.63	3.20	3.05
150	7.93	7.31	7.88	7.26	4.68	4.43	4.00	3.80	6.08	5.72
140	14.77	13.32	14.68	13.25	8.01	7.31	6.92	6.42	10.65	9.51
130	25.43	22.41	25.31	22.31	14.01	12.63	11.90	10.57	19.23	17.40
120	40.90	34.50	40.72	34.36	25.57	22.53	20.46	18.42	34.29	29.30

Table 152. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.31	0.30	0.30	0.29	0.10	0.10	0.03	0.03	0.15	0.15
175	0.69	0.66	0.68	0.65	0.15	0.15	0.13	0.13	0.42	0.40
170	1.45	1.39	1.43	1.37	0.45	0.44	0.28	0.27	0.84	0.80
160	3.61	3.43	3.58	3.40	1.64	1.53	1.18	1.12	2.55	2.44
150	6.66	6.23	6.61	6.19	3.90	3.71	3.12	2.96	5.14	4.88
140	12.54	11.30	12.45	11.22	6.82	6.34	5.91	5.57	8.88	8.10
130	21.19	18.83	21.05	18.72	11.89	10.58	9.70	8.84	16.37	14.78
120	35.63	30.35	35.47	30.24	20.63	18.51	17.31	15.76	29.26	25.47

Table 153. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.12	0.12	0.12	-	-	-	-	0.09	0.09
190	0.65	0.63	0.65	0.62	0.15	0.14	0.12	0.12	0.35	0.32
180	2.39	2.29	2.36	2.26	0.87	0.84	0.55	0.53	1.52	1.44
175	3.79	3.58	3.75	3.55	1.64	1.56	1.12	1.07	2.57	2.45
170	5.29	5.02	5.26	4.98	2.65	2.52	2.07	1.94	3.98	3.75
160	9.46	8.66	9.40	8.60	5.46	5.17	4.67	4.42	7.17	6.62
150	16.73	14.92	16.65	14.84	9.25	8.43	8.12	7.40	12.71	11.32
140	27.13	24.10	26.98	24.00	15.90	14.19	13.73	12.25	21.19	18.67
130	45.42	38.05	45.09	37.83	28.40	25.06	24.03	21.06	38.14	32.44
120	82.26	66.82	80.73	65.69	55.14	44.98	46.74	38.46	69.75	56.53

Table 154. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.12	0.12	0.12	-	-	-	-	0.09	0.09
180	0.65	0.63	0.65	0.62	0.15	0.14	0.12	0.12	0.35	0.32
175	1.41	1.35	1.40	1.33	0.41	0.39	0.26	0.26	0.83	0.78
170	2.39	2.29	2.36	2.26	0.87	0.84	0.55	0.53	1.52	1.44
160	5.29	5.02	5.26	4.98	2.65	2.52	2.07	1.94	3.98	3.75
150	9.46	8.66	9.40	8.60	5.46	5.17	4.67	4.42	7.17	6.62
140	16.73	14.92	16.65	14.84	9.25	8.43	8.12	7.40	12.71	11.32
130	27.13	24.10	26.98	24.00	15.90	14.19	13.73	12.25	21.19	18.67
120	45.42	38.05	45.09	37.83	28.40	25.06	24.03	21.06	38.14	32.44

Table 155. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.09	0.10	0.09	-	-	-	-	0.03	0.03
180	0.53	0.51	0.52	0.50	0.13	0.13	0.10	0.09	0.26	0.24
175	1.04	0.98	1.03	0.97	0.28	0.27	0.15	0.15	0.58	0.56
170	1.94	1.86	1.92	1.84	0.60	0.58	0.44	0.42	1.14	1.09
160	4.67	4.43	4.64	4.40	2.18	2.05	1.70	1.61	3.32	3.14
150	8.42	7.75	8.38	7.70	4.87	4.61	4.12	3.90	6.45	6.02
140	15.24	13.55	15.15	13.47	8.42	7.68	7.32	6.70	11.33	9.94
130	24.59	21.94	24.48	21.83	14.37	12.83	12.47	11.04	19.01	17.08
120	40.87	34.61	40.64	34.44	25.24	22.28	20.83	18.40	34.05	29.28

Table 156. Jacket foundation (post-piled 4 m typical jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.26	0.25	0.26	0.25	0.09	0.09	0.03	0.03	0.14	0.13
175	0.65	0.63	0.65	0.62	0.15	0.14	0.12	0.12	0.35	0.32
170	1.41	1.35	1.40	1.33	0.41	0.39	0.26	0.26	0.83	0.78
160	3.79	3.58	3.75	3.55	1.64	1.56	1.12	1.07	2.57	2.45
150	7.06	6.56	6.99	6.52	4.05	3.82	3.17	3.01	5.43	5.13
140	13.10	11.69	13.01	11.62	7.19	6.62	6.23	5.83	9.33	8.53
130	20.89	18.51	20.78	18.43	12.41	11.00	10.33	9.24	16.45	14.69
120	35.29	30.24	35.09	30.11	20.67	18.31	17.75	15.85	28.26	25.00

Table 157. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.07	0.07	0.07	0.07	-	-	-	-	-	-
190	0.36	0.35	0.36	0.35	0.07	0.07	0.02	0.02	0.12	0.12
180	1.54	1.47	1.52	1.45	0.33	0.32	0.16	0.16	0.77	0.75
175	2.56	2.43	2.52	2.41	0.72	0.69	0.43	0.41	1.45	1.39
170	3.86	3.65	3.82	3.61	1.35	1.29	0.89	0.85	2.40	2.29
160	8.23	7.27	8.17	7.20	3.38	3.16	2.68	2.53	5.52	4.79
150	14.07	12.52	13.99	12.46	7.11	6.16	6.01	5.13	9.90	8.88
140	22.31	19.52	22.19	19.41	13.21	11.49	10.74	9.31	17.85	15.52
130	34.59	30.26	34.41	30.13	23.86	20.57	19.75	16.99	29.91	26.36
120	58.10	48.59	57.56	48.16	42.43	35.10	35.93	30.62	52.28	43.37

Table 158. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.07	0.07	0.07	0.07	-	-	-	-	-	-
180	0.36	0.35	0.36	0.35	0.07	0.07	0.02	0.02	0.12	0.12
175	0.81	0.77	0.80	0.76	0.12	0.12	0.09	0.09	0.35	0.34
170	1.54	1.47	1.52	1.45	0.33	0.32	0.16	0.16	0.77	0.75
160	3.86	3.65	3.82	3.61	1.35	1.29	0.89	0.85	2.40	2.29
150	8.23	7.27	8.17	7.20	3.38	3.16	2.68	2.53	5.52	4.79
140	14.07	12.52	13.99	12.46	7.11	6.16	6.01	5.13	9.90	8.88
130	22.31	19.52	22.19	19.41	13.21	11.49	10.74	9.31	17.85	15.52
120	34.59	30.26	34.41	30.13	23.86	20.57	19.75	16.99	29.91	26.36

Table 159. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.29	0.28	0.28	0.28	0.04	0.04	-	-	0.11	0.11
175	0.60	0.58	0.59	0.57	0.10	0.10	0.07	0.07	0.22	0.22
170	1.23	1.18	1.22	1.17	0.20	0.20	0.13	0.12	0.57	0.54
160	3.25	3.06	3.20	3.02	1.06	1.00	0.73	0.69	1.97	1.88
150	7.28	6.36	7.21	6.30	2.86	2.71	2.25	2.13	4.54	4.18
140	12.78	11.43	12.71	11.36	6.32	5.48	4.84	4.49	8.95	7.94
130	19.83	17.58	19.76	17.51	11.63	10.05	9.38	8.31	16.14	14.03
120	31.65	27.96	31.52	27.85	20.81	17.82	17.75	15.16	27.26	24.11

Table 160. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	0.02	0.02	-	-	-	-	-	-
180	0.12	0.12	0.12	0.12	-	-	-	-	0.07	0.07
175	0.36	0.35	0.36	0.35	0.07	0.07	0.02	0.02	0.12	0.12
170	0.81	0.77	0.80	0.76	0.12	0.12	0.09	0.09	0.35	0.34
160	2.56	2.43	2.52	2.41	0.72	0.69	0.43	0.41	1.45	1.39
150	6.03	5.22	5.97	5.17	2.24	2.13	1.69	1.61	3.62	3.40
140	10.79	9.53	10.69	9.47	4.95	4.51	3.94	3.68	7.54	6.53
130	17.60	15.51	17.53	15.44	9.39	8.34	8.02	6.94	13.77	12.09
120	27.94	24.85	27.84	24.76	17.60	15.11	14.92	12.83	23.56	20.49

Table 161. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.06	0.06	0.06	0.06	-	-	-	-	-	-
190	0.24	0.23	0.23	0.23	0.05	0.05	-	-	0.12	0.12
180	1.13	1.08	1.10	1.06	0.23	0.23	0.13	0.13	0.57	0.56
175	1.92	1.84	1.90	1.82	0.48	0.47	0.37	0.36	1.13	1.09
170	2.96	2.82	2.94	2.80	1.09	1.03	0.72	0.69	1.92	1.83
160	7.18	6.28	7.13	6.23	2.84	2.69	2.26	2.14	4.48	4.16
150	13.48	12.13	13.42	12.07	6.46	5.63	4.96	4.56	9.63	8.63
140	22.56	20.18	22.46	20.09	12.88	11.33	10.01	8.88	18.12	16.04
130	35.61	31.21	35.46	31.09	23.28	20.37	19.24	16.79	30.33	26.82
120	54.56	46.24	54.21	45.98	39.37	33.40	34.07	29.24	48.46	40.94

Table 162. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.24	0.23	0.23	0.23	0.05	0.05	-	-	0.12	0.12
175	0.58	0.56	0.57	0.54	0.12	0.12	0.09	0.09	0.24	0.23
170	1.13	1.08	1.10	1.06	0.23	0.23	0.13	0.13	0.57	0.56
160	2.96	2.82	2.94	2.80	1.09	1.03	0.72	0.69	1.92	1.83
150	7.18	6.28	7.13	6.23	2.84	2.69	2.26	2.14	4.48	4.16
140	13.48	12.13	13.42	12.07	6.46	5.63	4.96	4.56	9.63	8.63
130	22.56	20.18	22.46	20.09	12.88	11.33	10.01	8.88	18.12	16.04
120	35.61	31.21	35.46	31.09	23.28	20.37	19.24	16.79	30.33	26.82

Table 163. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.03	0.03	0.03	0.03	-	-	-	-	-	-
180	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
175	0.41	0.39	0.40	0.39	0.09	0.09	0.05	0.05	0.15	0.14
170	0.89	0.85	0.87	0.83	0.14	0.14	0.12	0.12	0.41	0.39
160	2.58	2.45	2.54	2.43	0.78	0.75	0.48	0.47	1.60	1.53
150	6.25	5.43	6.19	5.39	2.46	2.33	1.87	1.78	3.80	3.59
140	12.06	10.75	11.99	10.68	5.61	4.90	4.24	3.98	8.53	7.53
130	19.92	17.94	19.86	17.88	11.11	9.70	8.88	7.85	16.26	14.41
120	32.58	28.80	32.44	28.69	20.34	17.85	17.36	15.00	27.58	24.57

Table 164. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
175	0.24	0.23	0.23	0.23	0.05	0.05	-	-	0.12	0.12
170	0.58	0.56	0.57	0.54	0.12	0.12	0.09	0.09	0.24	0.23
160	1.92	1.84	1.90	1.82	0.48	0.47	0.37	0.36	1.13	1.09
150	4.63	4.30	4.57	4.26	1.85	1.77	1.39	1.32	2.92	2.78
140	9.79	8.79	9.73	8.75	4.21	3.97	3.38	3.16	6.90	6.02
130	17.54	15.65	17.48	15.59	9.02	7.99	7.33	6.36	13.62	12.17
120	28.57	25.54	28.45	25.46	17.49	15.24	14.48	12.59	23.82	21.20

Table 165. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
190	0.42	0.40	0.41	0.40	0.10	0.09	0.06	0.06	0.17	0.17
180	1.63	1.57	1.61	1.55	0.42	0.41	0.26	0.25	0.94	0.89
175	2.63	2.50	2.60	2.49	0.81	0.78	0.54	0.51	1.67	1.59
170	4.01	3.79	3.97	3.75	1.60	1.52	1.17	1.11	2.62	2.50
160	8.95	7.99	8.90	7.94	3.74	3.52	2.94	2.78	6.07	5.27
150	16.19	14.38	16.12	14.32	8.12	7.09	6.53	5.70	12.34	10.89
140	26.27	23.57	26.17	23.49	16.03	13.86	13.24	11.40	21.49	18.83
130	41.54	35.66	41.33	35.51	27.92	24.36	23.93	20.58	35.81	30.91
120	64.56	54.16	63.86	53.74	48.08	39.74	41.96	34.71	57.59	48.21

Table 166. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.42	0.40	0.41	0.40	0.10	0.09	0.06	0.06	0.17	0.17
175	0.92	0.86	0.90	0.83	0.15	0.14	0.12	0.12	0.43	0.42
170	1.63	1.57	1.61	1.55	0.42	0.41	0.26	0.25	0.94	0.89
160	4.01	3.79	3.97	3.75	1.60	1.52	1.17	1.11	2.62	2.50
150	8.95	7.99	8.90	7.94	3.74	3.52	2.94	2.78	6.07	5.27
140	16.19	14.38	16.12	14.32	8.12	7.09	6.53	5.70	12.34	10.89
130	26.27	23.57	26.17	23.49	16.03	13.86	13.24	11.40	21.49	18.83
120	41.54	35.66	41.33	35.51	27.92	24.36	23.93	20.58	35.81	30.91

Table 167. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.07	0.07	0.07	0.07	-	-	-	-	-	-
180	0.31	0.31	0.31	0.30	0.08	0.08	0.02	0.02	0.13	0.13
175	0.68	0.66	0.68	0.65	0.13	0.13	0.10	0.10	0.32	0.31
170	1.31	1.25	1.29	1.24	0.27	0.26	0.15	0.14	0.70	0.68
160	3.35	3.18	3.32	3.14	1.28	1.23	0.84	0.80	2.20	2.09
150	7.89	6.95	7.84	6.89	3.16	2.97	2.57	2.44	5.07	4.55
140	14.56	13.01	14.49	12.95	7.03	6.12	5.70	4.97	10.52	9.32
130	24.01	21.47	23.92	21.38	14.20	12.33	11.52	9.79	19.23	17.02
120	37.87	32.81	37.70	32.69	25.09	21.97	20.96	18.02	32.33	28.24

Table 168. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.03	0.03	0.03	0.03	-	-	-	-	-	-
180	0.17	0.17	0.16	0.16	0.02	0.02	-	-	0.09	0.09
175	0.42	0.40	0.41	0.40	0.10	0.09	0.06	0.06	0.17	0.17
170	0.92	0.86	0.90	0.83	0.15	0.14	0.12	0.12	0.43	0.42
160	2.63	2.50	2.60	2.49	0.81	0.78	0.54	0.51	1.67	1.59
150	6.35	5.57	6.31	5.52	2.55	2.42	1.94	1.84	3.91	3.69
140	12.30	11.02	12.25	10.95	5.70	4.97	4.36	4.07	8.68	7.70
130	20.23	18.05	20.12	17.98	11.61	9.99	9.20	8.06	16.63	14.60
120	32.98	28.96	32.85	28.85	20.94	18.13	17.91	15.36	27.92	24.71

Table 169. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
190	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.24	0.24
180	1.93	1.85	1.91	1.83	0.49	0.46	0.38	0.37	1.15	1.10
175	2.98	2.83	2.96	2.81	1.10	1.05	0.72	0.69	1.94	1.85
170	4.71	4.34	4.64	4.31	1.87	1.79	1.42	1.35	2.94	2.80
160	9.87	8.89	9.83	8.84	4.27	4.02	3.44	3.21	7.04	6.15
150	17.77	15.86	17.71	15.79	9.16	8.13	7.50	6.52	13.88	12.38
140	28.97	25.81	28.87	25.72	17.74	15.46	14.75	12.80	24.12	21.46
130	44.80	38.43	44.59	38.26	30.67	26.67	26.31	23.01	39.00	33.54
120	67.34	56.78	66.54	56.29	50.24	42.40	44.92	37.70	59.21	50.49

Table 170. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
180	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.24	0.24
175	1.13	1.08	1.11	1.07	0.24	0.23	0.14	0.13	0.59	0.57
170	1.93	1.85	1.91	1.83	0.49	0.46	0.38	0.37	1.15	1.10
160	4.71	4.34	4.64	4.31	1.87	1.79	1.42	1.35	2.94	2.80
150	9.87	8.89	9.83	8.84	4.27	4.02	3.44	3.21	7.04	6.15
140	17.77	15.86	17.71	15.79	9.16	8.13	7.50	6.52	13.88	12.38
130	28.97	25.81	28.87	25.72	17.74	15.46	14.75	12.80	24.12	21.46
120	44.80	38.43	44.59	38.26	30.67	26.67	26.31	23.01	39.00	33.54

Table 171. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.40	0.39	0.40	0.38	0.09	0.09	0.05	0.05	0.15	0.14
175	0.91	0.87	0.90	0.85	0.14	0.14	0.12	0.12	0.41	0.39
170	1.60	1.53	1.58	1.52	0.40	0.39	0.26	0.24	0.92	0.88
160	3.94	3.73	3.90	3.69	1.54	1.47	1.12	1.07	2.58	2.45
150	8.88	7.89	8.83	7.84	3.68	3.47	2.88	2.74	6.12	5.30
140	16.06	14.37	15.99	14.31	8.10	7.07	6.58	5.73	12.23	10.90
130	26.41	23.76	26.31	23.66	15.82	13.80	12.99	11.31	21.43	18.92
120	41.28	35.58	41.09	35.45	27.65	24.26	23.53	20.45	35.57	30.81

Table 172. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.24	0.23	0.24	0.23	0.06	0.06	-	-	0.12	0.12
175	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.24	0.24
170	1.13	1.08	1.11	1.07	0.24	0.23	0.14	0.13	0.59	0.57
160	2.98	2.83	2.96	2.81	1.10	1.05	0.72	0.69	1.94	1.85
150	7.30	6.37	7.24	6.32	2.86	2.72	2.30	2.18	4.57	4.22
140	13.66	12.30	13.59	12.24	6.62	5.74	5.15	4.63	9.76	8.76
130	22.84	20.46	22.75	20.37	13.14	11.54	10.30	9.02	18.36	16.26
120	36.26	31.59	36.11	31.48	23.54	20.62	19.41	17.00	30.77	27.07

Table 173. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
190	0.74	0.72	0.74	0.71	0.14	0.13	0.11	0.11	0.38	0.37
180	2.40	2.28	2.36	2.25	0.74	0.71	0.45	0.44	1.49	1.42
175	3.64	3.44	3.60	3.41	1.43	1.37	1.01	0.96	2.42	2.30
170	5.86	5.07	5.80	5.03	2.34	2.22	1.78	1.70	3.62	3.41
160	11.46	10.13	11.37	10.06	5.32	4.70	4.09	3.83	8.15	7.12
150	19.37	17.39	19.31	17.34	10.53	9.23	8.54	7.50	15.67	13.87
140	31.56	28.02	31.45	27.91	19.62	17.27	16.78	14.46	26.72	23.86
130	48.83	41.72	48.58	41.52	34.16	29.54	29.64	25.70	42.89	36.66
120	78.26	64.65	77.13	63.82	56.55	47.37	50.62	42.11	68.50	56.86

Table 174. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
180	0.74	0.72	0.74	0.71	0.14	0.13	0.11	0.11	0.38	0.37
175	1.45	1.39	1.43	1.38	0.38	0.37	0.23	0.23	0.75	0.72
170	2.40	2.28	2.36	2.25	0.74	0.71	0.45	0.44	1.49	1.42
160	5.86	5.07	5.80	5.03	2.34	2.22	1.78	1.70	3.62	3.41
150	11.46	10.13	11.37	10.06	5.32	4.70	4.09	3.83	8.15	7.12
140	19.37	17.39	19.31	17.34	10.53	9.23	8.54	7.50	15.67	13.87
130	31.56	28.02	31.45	27.91	19.62	17.27	16.78	14.46	26.72	23.86
120	48.83	41.72	48.58	41.52	34.16	29.54	29.64	25.70	42.89	36.66

Table 175. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.12	0.12	0.12	0.12	-	-	-	-	0.07	0.07
180	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.25	0.24
175	1.15	1.10	1.13	1.09	0.24	0.24	0.14	0.13	0.60	0.58
170	1.94	1.86	1.93	1.85	0.55	0.53	0.39	0.38	1.19	1.14
160	4.71	4.34	4.65	4.31	1.92	1.83	1.45	1.39	2.99	2.85
150	9.86	8.86	9.82	8.82	4.34	4.08	3.52	3.28	7.04	6.14
140	17.78	15.86	17.72	15.80	9.21	8.15	7.51	6.52	13.91	12.38
130	28.96	25.87	28.86	25.78	17.86	15.53	14.88	12.86	24.24	21.59
120	44.94	38.55	44.71	38.37	30.85	26.93	26.64	23.25	39.04	33.69

Table 176. Monopile foundation (12 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.37	0.36	0.36	0.35	0.09	0.09	0.04	0.04	0.14	0.13
175	0.74	0.72	0.74	0.71	0.14	0.13	0.11	0.11	0.38	0.37
170	1.45	1.39	1.43	1.38	0.38	0.37	0.23	0.23	0.75	0.72
160	3.64	3.44	3.60	3.41	1.43	1.37	1.01	0.96	2.42	2.30
150	8.30	7.32	8.25	7.26	3.48	3.26	2.76	2.61	5.69	4.95
140	15.23	13.64	15.16	13.58	7.58	6.57	6.19	5.39	11.43	10.07
130	25.41	22.81	25.31	22.73	14.98	13.07	12.26	10.58	20.11	17.91
120	39.47	34.25	39.27	34.11	26.48	23.32	22.36	19.28	33.78	29.63

Table 177. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.07	0.07	0.07	0.07	-	-	-	-	-	-
190	0.35	0.34	0.35	0.34	0.07	0.07	0.02	0.02	0.12	0.12
180	1.46	1.40	1.44	1.38	0.31	0.31	0.14	0.14	0.75	0.72
175	2.46	2.35	2.44	2.32	0.67	0.65	0.41	0.40	1.40	1.34
170	3.76	3.54	3.72	3.51	1.31	1.26	0.85	0.82	2.34	2.22
160	8.08	7.10	8.00	7.04	3.30	3.08	2.62	2.48	5.37	4.70
150	13.91	12.39	13.84	12.33	6.99	6.06	5.86	5.04	9.82	8.78
140	22.09	19.36	21.97	19.25	13.06	11.37	10.55	9.18	17.73	15.42
130	34.31	30.12	34.12	29.99	23.58	20.34	19.55	16.83	29.70	26.22
120	57.31	47.95	56.81	47.54	41.67	34.58	35.42	30.26	51.54	42.71

Table 178. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.07	0.07	0.07	0.07	-	-	-	-	-	-
180	0.35	0.34	0.35	0.34	0.07	0.07	0.02	0.02	0.12	0.12
175	0.77	0.74	0.76	0.73	0.12	0.12	0.09	0.09	0.34	0.33
170	1.46	1.40	1.44	1.38	0.31	0.31	0.14	0.14	0.75	0.72
160	3.76	3.54	3.72	3.51	1.31	1.26	0.85	0.82	2.34	2.22
150	8.08	7.10	8.00	7.04	3.30	3.08	2.62	2.48	5.37	4.70
140	13.91	12.39	13.84	12.33	6.99	6.06	5.86	5.04	9.82	8.78
130	22.09	19.36	21.97	19.25	13.06	11.37	10.55	9.18	17.73	15.42
120	34.31	30.12	34.12	29.99	23.58	20.34	19.55	16.83	29.70	26.22

Table 179. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.05	0.05	0.05	0.05	-	-	-	-	-	-
180	0.22	0.22	0.22	0.22	0.03	0.03	-	-	0.10	0.10
175	0.57	0.55	0.56	0.53	0.10	0.10	0.07	0.07	0.22	0.21
170	1.17	1.12	1.16	1.10	0.20	0.19	0.12	0.12	0.54	0.52
160	3.12	2.94	3.08	2.91	1.00	0.95	0.68	0.65	1.91	1.83
150	7.10	6.21	7.04	6.16	2.80	2.66	2.18	2.07	4.38	4.10
140	12.60	11.27	12.53	11.20	6.21	5.38	4.71	4.40	8.85	7.82
130	19.70	17.48	19.63	17.42	11.45	9.90	9.25	8.20	16.00	13.94
120	31.45	27.84	31.32	27.73	20.51	17.66	17.58	15.02	27.02	23.96

Table 180. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.12	0.12	0.12	0.12	-	-	-	-	0.07	0.07
175	0.35	0.34	0.35	0.34	0.07	0.07	0.02	0.02	0.12	0.12
170	0.77	0.74	0.76	0.73	0.12	0.12	0.09	0.09	0.34	0.33
160	2.46	2.35	2.44	2.32	0.67	0.65	0.41	0.40	1.40	1.34
150	5.87	5.09	5.81	5.04	2.18	2.07	1.64	1.57	3.53	3.31
140	10.58	9.37	10.49	9.31	4.76	4.42	3.86	3.61	7.41	6.42
130	17.45	15.40	17.39	15.33	9.29	8.24	7.89	6.82	13.63	11.99
120	27.79	24.74	27.70	24.65	17.43	14.99	14.77	12.70	23.33	20.34

Table 181. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
190	0.41	0.40	0.40	0.39	0.10	0.09	0.06	0.06	0.15	0.14
180	1.61	1.55	1.59	1.53	0.41	0.40	0.26	0.25	0.91	0.86
175	2.58	2.45	2.56	2.43	0.81	0.77	0.51	0.49	1.62	1.55
170	3.90	3.70	3.87	3.66	1.55	1.48	1.13	1.08	2.56	2.44
160	8.80	7.79	8.74	7.74	3.68	3.45	2.88	2.73	6.03	5.21
150	15.83	14.22	15.76	14.17	8.06	7.01	6.51	5.68	12.16	10.80
140	26.45	23.73	26.36	23.65	15.70	13.77	12.90	11.30	21.36	18.94
130	41.18	35.59	40.98	35.44	27.77	24.49	23.75	20.68	35.50	30.95
120	62.95	53.20	62.45	52.82	47.07	39.27	41.18	34.58	56.20	47.34

Table 182. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.41	0.40	0.40	0.39	0.10	0.09	0.06	0.06	0.15	0.14
175	0.91	0.86	0.89	0.85	0.15	0.14	0.12	0.12	0.42	0.40
170	1.61	1.55	1.59	1.53	0.41	0.40	0.26	0.25	0.91	0.86
160	3.90	3.70	3.87	3.66	1.55	1.48	1.13	1.08	2.56	2.44
150	8.80	7.79	8.74	7.74	3.68	3.45	2.88	2.73	6.03	5.21
140	15.83	14.22	15.76	14.17	8.06	7.01	6.51	5.68	12.16	10.80
130	26.45	23.73	26.36	23.65	15.70	13.77	12.90	11.30	21.36	18.94
120	41.18	35.59	40.98	35.44	27.77	24.49	23.75	20.68	35.50	30.95

Table 183. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.07	0.07	0.07	0.07	-	-	-	-	-	-
180	0.31	0.30	0.30	0.29	0.08	0.08	-	-	0.13	0.13
175	0.66	0.64	0.65	0.63	0.13	0.13	0.10	0.10	0.30	0.29
170	1.30	1.25	1.28	1.23	0.26	0.26	0.15	0.14	0.67	0.64
160	3.27	3.09	3.22	3.05	1.25	1.20	0.83	0.79	2.14	2.03
150	7.72	6.74	7.67	6.68	3.08	2.90	2.52	2.38	4.94	4.48
140	14.27	12.83	14.21	12.77	6.96	6.07	5.66	4.94	10.44	9.24
130	24.08	21.58	23.99	21.49	13.87	12.25	11.15	9.67	19.10	17.05
120	37.64	32.85	37.47	32.73	24.97	22.11	20.69	18.01	32.15	28.38

Table 184. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.03	0.03	0.03	0.03	-	-	-	-	-	-
180	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
175	0.41	0.40	0.40	0.39	0.10	0.09	0.06	0.06	0.15	0.14
170	0.91	0.86	0.89	0.85	0.15	0.14	0.12	0.12	0.42	0.40
160	2.58	2.45	2.56	2.43	0.81	0.77	0.51	0.49	1.62	1.55
150	6.25	5.43	6.19	5.38	2.49	2.36	1.89	1.81	3.82	3.60
140	12.11	10.78	12.05	10.71	5.66	4.94	4.30	4.02	8.63	7.60
130	19.99	18.04	19.92	17.98	11.27	9.88	9.04	7.98	16.37	14.56
120	32.89	29.12	32.76	29.01	20.70	18.16	17.60	15.26	27.89	24.91

Table 185. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
190	0.54	0.52	0.53	0.51	0.12	0.12	0.09	0.09	0.24	0.23
180	1.88	1.81	1.87	1.79	0.48	0.46	0.38	0.36	1.12	1.07
175	2.92	2.78	2.90	2.76	1.09	1.03	0.72	0.70	1.90	1.82
170	4.53	4.23	4.48	4.19	1.86	1.77	1.39	1.33	2.91	2.77
160	9.73	8.70	9.67	8.65	4.22	3.98	3.42	3.18	6.86	5.96
150	17.32	15.49	17.24	15.43	9.02	7.91	7.33	6.36	13.49	12.02
140	28.34	25.24	28.24	25.16	17.28	15.08	14.37	12.49	23.53	20.88
130	43.60	37.56	43.36	37.39	29.90	26.25	25.79	22.64	37.75	32.84
120	67.95	56.73	67.07	56.21	50.59	42.10	44.66	37.19	59.88	50.50

Table 186. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
180	0.54	0.52	0.53	0.51	0.12	0.12	0.09	0.09	0.24	0.23
175	1.09	1.04	1.07	1.03	0.24	0.23	0.13	0.13	0.55	0.53
170	1.88	1.81	1.87	1.79	0.48	0.46	0.38	0.36	1.12	1.07
160	4.53	4.23	4.48	4.19	1.86	1.77	1.39	1.33	2.91	2.77
150	9.73	8.70	9.67	8.65	4.22	3.98	3.42	3.18	6.86	5.96
140	17.32	15.49	17.24	15.43	9.02	7.91	7.33	6.36	13.49	12.02
130	28.34	25.24	28.24	25.16	17.28	15.08	14.37	12.49	23.53	20.88
120	43.60	37.56	43.36	37.39	29.90	26.25	25.79	22.64	37.75	32.84

Table 187. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.40	0.38	0.39	0.38	0.09	0.09	0.05	0.05	0.14	0.14
175	0.84	0.80	0.83	0.78	0.14	0.14	0.12	0.12	0.41	0.39
170	1.55	1.49	1.53	1.47	0.40	0.39	0.25	0.24	0.84	0.81
160	3.84	3.63	3.80	3.60	1.52	1.45	1.10	1.05	2.54	2.41
150	8.70	7.68	8.66	7.63	3.66	3.43	2.88	2.72	5.97	5.15
140	15.64	14.03	15.57	13.97	7.93	6.85	6.44	5.61	11.96	10.51
130	26.11	23.26	25.99	23.18	15.35	13.44	12.65	11.02	20.63	18.35
120	39.92	34.75	39.73	34.61	26.99	23.87	22.97	20.00	34.25	30.13

Table 188. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.23	0.23	0.23	0.22	0.05	0.05	-	-	0.12	0.12
175	0.54	0.52	0.53	0.51	0.12	0.12	0.09	0.09	0.24	0.23
170	1.09	1.04	1.07	1.03	0.24	0.23	0.13	0.13	0.55	0.53
160	2.92	2.78	2.90	2.76	1.09	1.03	0.72	0.70	1.90	1.82
150	7.09	6.18	7.03	6.13	2.84	2.70	2.28	2.16	4.46	4.13
140	13.44	12.01	13.38	11.95	6.45	5.61	5.00	4.57	9.60	8.53
130	22.46	19.88	22.35	19.77	12.74	11.21	9.94	8.82	17.86	15.84
120	34.90	30.84	34.75	30.72	22.90	20.11	19.07	16.66	29.81	26.52

Table 189. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
190	0.69	0.67	0.68	0.66	0.13	0.13	0.10	0.10	0.35	0.34
180	2.26	2.16	2.24	2.13	0.68	0.66	0.43	0.41	1.39	1.33
175	3.46	3.28	3.43	3.24	1.32	1.27	0.93	0.89	2.28	2.16
170	5.60	4.90	5.52	4.85	2.20	2.08	1.67	1.60	3.42	3.23
160	11.07	9.77	11.00	9.70	4.92	4.49	3.90	3.66	7.86	6.85
150	18.95	16.99	18.88	16.93	10.00	8.90	8.23	7.21	15.16	13.45
140	30.77	27.34	30.66	27.24	19.06	16.73	16.17	13.94	25.87	23.14
130	47.33	40.52	47.08	40.34	33.02	28.56	28.55	24.77	41.57	35.60
120	74.58	61.69	73.54	60.98	54.01	45.38	48.45	40.48	64.95	54.34

Table 190. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
180	0.69	0.67	0.68	0.66	0.13	0.13	0.10	0.10	0.35	0.34
175	1.36	1.31	1.35	1.30	0.34	0.34	0.20	0.19	0.70	0.68
170	2.26	2.16	2.24	2.13	0.68	0.66	0.43	0.41	1.39	1.33
160	5.60	4.90	5.52	4.85	2.20	2.08	1.67	1.60	3.42	3.23
150	11.07	9.77	11.00	9.70	4.92	4.49	3.90	3.66	7.86	6.85
140	18.95	16.99	18.88	16.93	10.00	8.90	8.23	7.21	15.16	13.45
130	30.77	27.34	30.66	27.24	19.06	16.73	16.17	13.94	25.87	23.14
120	47.33	40.52	47.08	40.34	33.02	28.56	28.55	24.77	41.57	35.60

Table 191. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
180	0.53	0.51	0.52	0.50	0.11	0.11	0.09	0.09	0.23	0.23
175	1.06	1.02	1.05	1.01	0.23	0.22	0.13	0.13	0.54	0.52
170	1.86	1.78	1.84	1.77	0.46	0.44	0.36	0.35	1.09	1.05
160	4.47	4.18	4.42	4.15	1.82	1.73	1.35	1.28	2.88	2.73
150	9.65	8.65	9.59	8.61	4.14	3.91	3.32	3.11	6.80	5.93
140	17.33	15.46	17.26	15.40	8.90	7.86	7.24	6.29	13.44	12.00
130	28.16	25.20	28.03	25.12	17.25	15.00	14.31	12.41	23.41	20.78
120	43.66	37.52	43.45	37.37	29.81	26.00	25.58	22.36	37.87	32.70

Table 192. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.08	0.08	0.08	0.08	-	-	-	-	-	-
180	0.34	0.33	0.33	0.32	0.09	0.09	0.02	0.02	0.13	0.13
175	0.69	0.67	0.68	0.66	0.13	0.13	0.10	0.10	0.35	0.34
170	1.36	1.31	1.35	1.30	0.34	0.34	0.20	0.19	0.70	0.68
160	3.46	3.28	3.43	3.24	1.32	1.27	0.93	0.89	2.28	2.16
150	8.09	7.10	8.03	7.05	3.28	3.08	2.64	2.50	5.32	4.73
140	14.81	13.30	14.74	13.25	7.30	6.32	6.00	5.17	10.93	9.65
130	24.66	22.17	24.58	22.08	14.44	12.63	11.74	10.11	19.56	17.44
120	38.42	33.38	38.24	33.25	25.50	22.47	21.31	18.39	32.84	28.77

Table 193. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.15	0.14	0.14	0.14	0.02	0.02	-	-	0.09	0.09
190	0.90	0.86	0.89	0.85	0.14	0.14	0.12	0.12	0.41	0.39
180	2.58	2.46	2.56	2.44	0.85	0.80	0.53	0.50	1.63	1.57
175	3.92	3.72	3.90	3.68	1.57	1.50	1.13	1.08	2.60	2.47
170	6.28	5.46	6.24	5.41	2.53	2.40	1.92	1.83	3.88	3.67
160	12.18	10.79	12.11	10.72	5.76	5.02	4.34	4.06	8.67	7.61
150	20.08	18.05	19.98	17.99	11.37	9.84	9.05	7.95	16.48	14.56
140	32.98	29.10	32.85	29.00	20.72	18.05	17.68	15.20	27.93	24.81
130	50.21	43.06	49.93	42.85	36.26	30.82	31.26	26.81	44.66	38.02
120	82.80	67.88	81.49	66.86	58.64	48.90	52.54	43.67	72.69	59.26

Table 194. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.03	0.03	0.03	0.03	-	-	-	-	-	-
190	0.15	0.14	0.14	0.14	0.02	0.02	-	-	0.09	0.09
180	0.90	0.86	0.89	0.85	0.14	0.14	0.12	0.12	0.41	0.39
175	1.60	1.54	1.58	1.52	0.41	0.39	0.26	0.24	0.92	0.88
170	2.58	2.46	2.56	2.44	0.85	0.80	0.53	0.50	1.63	1.57
160	6.28	5.46	6.24	5.41	2.53	2.40	1.92	1.83	3.88	3.67
150	12.18	10.79	12.11	10.72	5.76	5.02	4.34	4.06	8.67	7.61
140	20.08	18.05	19.98	17.99	11.37	9.84	9.05	7.95	16.48	14.56
130	32.98	29.10	32.85	29.00	20.72	18.05	17.68	15.20	27.93	24.81
120	50.21	43.06	49.93	42.85	36.26	30.82	31.26	26.81	44.66	38.02

Table 195. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.12	0.12	0.12	0.12	-	-	-	-	0.08	0.08
180	0.65	0.63	0.65	0.62	0.13	0.13	0.10	0.10	0.33	0.32
175	1.28	1.23	1.26	1.22	0.26	0.26	0.15	0.14	0.67	0.64
170	2.12	2.02	2.10	2.00	0.65	0.62	0.41	0.40	1.31	1.26
160	5.18	4.68	5.09	4.64	2.08	1.97	1.59	1.52	3.26	3.08
150	10.55	9.30	10.48	9.25	4.70	4.35	3.76	3.52	7.58	6.56
140	18.50	16.55	18.44	16.49	9.69	8.60	8.00	6.94	14.68	13.02
130	30.18	26.85	30.06	26.76	18.68	16.30	15.72	13.52	25.34	22.64
120	46.50	39.88	46.27	39.71	32.50	28.04	28.04	24.26	40.85	35.00

Table 196. Monopile foundation (12 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.40	0.39	0.40	0.38	0.10	0.09	0.06	0.06	0.19	0.18
175	0.90	0.86	0.89	0.85	0.14	0.14	0.12	0.12	0.41	0.39
170	1.60	1.54	1.58	1.52	0.41	0.39	0.26	0.24	0.92	0.88
160	3.92	3.72	3.90	3.68	1.57	1.50	1.13	1.08	2.60	2.47
150	8.81	7.78	8.75	7.73	3.72	3.50	2.92	2.76	6.14	5.31
140	15.95	14.27	15.89	14.21	8.10	7.03	6.61	5.75	12.21	10.79
130	26.53	23.74	26.43	23.65	15.83	13.74	13.00	11.26	21.40	18.89
120	41.11	35.52	40.92	35.38	27.82	24.32	23.73	20.45	35.55	30.82

Table 197. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.08	0.08	0.08	0.07	-	-	-	-	-	-
190	0.41	0.39	0.41	0.39	0.06	0.06	-	-	0.13	0.13
180	1.63	1.51	1.61	1.48	0.27	0.26	0.15	0.15	0.77	0.72
175	2.74	2.54	2.71	2.51	0.65	0.59	0.44	0.42	1.50	1.39
170	4.28	3.92	4.22	3.88	1.35	1.26	0.90	0.85	2.58	2.38
160	8.45	7.61	8.37	7.53	3.66	3.30	2.78	2.56	5.52	5.02
150	15.87	14.16	15.75	14.05	6.81	6.19	5.74	5.24	10.15	9.06
140	29.53	23.74	29.39	23.62	14.62	11.90	10.79	9.22	22.91	17.40
130	49.61	39.00	49.30	38.76	31.28	23.94	25.78	19.27	41.78	32.35
120	87.20	70.21	85.33	68.98	58.55	46.05	50.18	39.15	73.86	58.84

Table 198. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.08	0.08	0.08	0.07	-	-	-	-	-	-
180	0.41	0.39	0.41	0.39	0.06	0.06	-	-	0.13	0.13
175	0.83	0.78	0.82	0.77	0.13	0.13	0.10	0.09	0.38	0.37
170	1.63	1.51	1.61	1.48	0.27	0.26	0.15	0.15	0.77	0.72
160	4.28	3.92	4.22	3.88	1.35	1.26	0.90	0.85	2.58	2.38
150	8.45	7.61	8.37	7.53	3.66	3.30	2.78	2.56	5.52	5.02
140	15.87	14.16	15.75	14.05	6.81	6.19	5.74	5.24	10.15	9.06
130	29.53	23.74	29.39	23.62	14.62	11.90	10.79	9.22	22.91	17.40
120	49.61	39.00	49.30	38.76	31.28	23.94	25.78	19.27	41.78	32.35

Table 199. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.05	0.05	0.05	0.05	-	-	-	-	-	-
180	0.26	0.24	0.26	0.24	0.02	0.02	-	-	0.11	0.11
175	0.55	0.52	0.54	0.51	0.10	0.10	0.05	0.05	0.25	0.24
170	1.27	1.18	1.24	1.15	0.20	0.20	0.13	0.13	0.53	0.51
160	3.60	3.30	3.56	3.26	1.00	0.94	0.64	0.58	2.07	1.91
150	7.38	6.65	7.30	6.58	3.04	2.77	2.35	2.14	4.85	4.44
140	14.17	12.74	14.05	12.65	6.13	5.58	5.12	4.66	8.88	8.06
130	26.50	21.43	26.38	21.30	12.30	10.27	8.99	8.19	19.47	15.51
120	44.80	35.14	44.55	34.95	27.44	20.82	22.01	16.27	37.36	28.79

Table 200. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.14	0.13	0.13	0.13	-	-	-	-	0.07	0.07
175	0.41	0.39	0.41	0.39	0.06	0.06	-	-	0.13	0.13
170	0.83	0.78	0.82	0.77	0.13	0.13	0.10	0.09	0.38	0.37
160	2.74	2.54	2.71	2.51	0.65	0.59	0.44	0.42	1.50	1.39
150	6.05	5.50	5.98	5.44	2.37	2.17	1.72	1.59	3.96	3.61
140	11.95	10.66	11.82	10.54	5.16	4.70	4.22	3.83	7.40	6.66
130	22.01	18.01	21.86	17.92	9.24	8.30	7.46	6.81	15.75	12.97
120	38.50	30.17	38.27	30.01	22.03	16.38	17.14	13.33	31.34	24.13

Table 201. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.06	0.06	0.06	0.06	-	-	-	-	-	-
190	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
180	1.26	1.17	1.23	1.15	0.23	0.22	0.15	0.14	0.57	0.54
175	2.17	2.00	2.14	1.97	0.53	0.49	0.32	0.30	1.17	1.11
170	3.44	3.12	3.38	3.08	1.04	0.98	0.72	0.63	2.09	1.92
160	7.40	6.58	7.33	6.52	3.08	2.79	2.42	2.21	4.83	4.40
150	15.13	13.26	15.02	13.17	6.31	5.68	5.17	4.68	9.68	8.62
140	26.94	23.83	26.81	23.72	12.80	11.32	9.76	8.76	19.76	17.22
130	47.11	38.98	46.80	38.75	28.99	22.64	23.14	17.77	39.63	31.53
120	87.34	70.64	85.33	69.52	56.34	43.78	47.80	36.93	73.65	57.88

Table 202. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
175	0.60	0.57	0.58	0.56	0.12	0.12	0.09	0.09	0.26	0.26
170	1.26	1.17	1.23	1.15	0.23	0.22	0.15	0.14	0.57	0.54
160	3.44	3.12	3.38	3.08	1.04	0.98	0.72	0.63	2.09	1.92
150	7.40	6.58	7.33	6.52	3.08	2.79	2.42	2.21	4.83	4.40
140	15.13	13.26	15.02	13.17	6.31	5.68	5.17	4.68	9.68	8.62
130	26.94	23.83	26.81	23.72	12.80	11.32	9.76	8.76	19.76	17.22
120	47.11	38.98	46.80	38.75	28.99	22.64	23.14	17.77	39.63	31.53

Table 203. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	0.02	0.02	-	-	-	-	-	-
180	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
175	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.15
170	0.93	0.88	0.92	0.87	0.16	0.15	0.13	0.12	0.44	0.42
160	2.86	2.64	2.84	2.61	0.85	0.80	0.54	0.49	1.71	1.59
150	6.41	5.75	6.37	5.69	2.65	2.43	1.95	1.82	4.20	3.83
140	13.33	11.70	13.23	11.61	5.57	5.02	4.54	4.12	8.51	7.55
130	24.03	21.32	23.90	21.20	10.81	9.58	8.68	7.73	17.30	15.26
120	42.43	35.28	42.17	35.10	24.98	19.45	19.23	15.52	35.23	28.28

Table 204. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
175	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
170	0.60	0.57	0.58	0.56	0.12	0.12	0.09	0.09	0.26	0.26
160	2.17	2.00	2.14	1.97	0.53	0.49	0.32	0.30	1.17	1.11
150	5.16	4.65	5.10	4.61	1.95	1.82	1.43	1.33	3.29	2.98
140	10.67	9.28	10.55	9.20	4.54	4.14	3.70	3.29	6.84	6.12
130	19.74	17.61	19.64	17.52	8.83	7.87	7.04	6.32	14.01	12.51
120	36.23	30.46	36.02	30.32	19.23	15.86	15.03	12.65	28.99	23.95

Table 205. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.11	0.11	0.11	0.11	-	-	-	-	0.02	0.02
190	0.46	0.44	0.46	0.44	0.10	0.10	0.03	0.03	0.19	0.16
180	1.86	1.74	1.84	1.72	0.44	0.42	0.27	0.26	0.96	0.92
175	2.96	2.74	2.94	2.72	0.90	0.85	0.57	0.52	1.81	1.70
170	4.55	4.15	4.51	4.11	1.71	1.58	1.16	1.10	2.90	2.68
160	9.52	8.42	9.44	8.35	4.12	3.74	3.26	2.89	6.11	5.49
150	18.39	16.30	18.29	16.21	7.88	7.01	6.34	5.73	12.63	11.23
140	33.12	28.09	32.92	27.96	17.40	14.40	13.35	11.47	26.09	21.87
130	56.31	46.72	55.81	46.39	37.25	28.63	30.94	23.62	48.23	38.21
120	>90	83.47	89.99	83.37	74.27	57.48	61.72	48.02	89.99	75.31

Table 206. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.02	0.02
180	0.46	0.44	0.46	0.44	0.10	0.10	0.03	0.03	0.19	0.16
175	0.98	0.93	0.98	0.92	0.16	0.15	0.13	0.13	0.46	0.43
170	1.86	1.74	1.84	1.72	0.44	0.42	0.27	0.26	0.96	0.92
160	4.55	4.15	4.51	4.11	1.71	1.58	1.16	1.10	2.90	2.68
150	9.52	8.42	9.44	8.35	4.12	3.74	3.26	2.89	6.11	5.49
140	18.39	16.30	18.29	16.21	7.88	7.01	6.34	5.73	12.63	11.23
130	33.12	28.09	32.92	27.96	17.40	14.40	13.35	11.47	26.09	21.87
120	56.31	46.72	55.81	46.39	37.25	28.63	30.94	23.62	48.23	38.21

Table 207. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.36	0.34	0.35	0.34	0.06	0.06	0.02	0.02	0.14	0.14
175	0.76	0.71	0.74	0.69	0.14	0.13	0.10	0.10	0.35	0.33
170	1.54	1.41	1.50	1.39	0.29	0.27	0.16	0.16	0.75	0.69
160	3.90	3.57	3.88	3.53	1.35	1.25	0.90	0.85	2.50	2.30
150	8.25	7.30	8.19	7.23	3.54	3.17	2.75	2.52	5.33	4.82
140	16.50	14.49	16.41	14.40	6.82	6.13	5.65	5.10	10.82	9.46
130	29.40	25.48	29.23	25.37	14.71	12.53	10.93	9.71	22.61	18.93
120	50.71	41.97	50.35	41.72	32.47	25.11	26.43	20.28	42.96	34.13

Table 208. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	0.02	0.02	-	-	-	-	-	-
180	0.22	0.20	0.21	0.20	0.02	0.02	-	-	0.11	0.11
175	0.46	0.44	0.46	0.44	0.10	0.10	0.03	0.03	0.19	0.16
170	0.98	0.93	0.98	0.92	0.16	0.15	0.13	0.13	0.46	0.43
160	2.96	2.74	2.94	2.72	0.90	0.85	0.57	0.52	1.81	1.70
150	6.58	5.89	6.54	5.84	2.75	2.53	2.08	1.90	4.33	3.96
140	13.75	12.05	13.66	11.96	5.69	5.13	4.66	4.24	8.70	7.72
130	24.68	21.93	24.55	21.80	11.22	9.98	8.93	7.94	18.05	15.77
120	43.36	35.94	43.08	35.75	25.97	20.39	20.25	16.14	36.11	28.94

Table 209. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
190	0.60	0.57	0.58	0.56	0.13	0.13	0.10	0.09	0.28	0.27
180	2.21	2.03	2.18	2.00	0.55	0.51	0.40	0.38	1.24	1.16
175	3.48	3.16	3.44	3.13	1.13	1.05	0.81	0.72	2.20	2.00
170	5.17	4.67	5.13	4.63	2.06	1.89	1.51	1.40	3.43	3.10
160	10.57	9.21	10.46	9.14	4.68	4.28	3.84	3.44	7.10	6.31
150	19.88	17.68	19.80	17.60	9.16	8.15	7.32	6.52	14.62	12.70
140	38.58	31.23	38.35	31.08	21.17	16.44	16.43	13.11	31.28	24.82
130	67.19	53.80	66.50	53.29	44.25	34.08	36.88	28.22	57.30	45.04
120	>90	83.89	>90	83.85	87.37	68.86	73.12	57.83	89.99	79.54

Table 210. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
180	0.60	0.57	0.58	0.56	0.13	0.13	0.10	0.09	0.28	0.27
175	1.26	1.18	1.24	1.16	0.26	0.25	0.15	0.15	0.58	0.56
170	2.21	2.03	2.18	2.00	0.55	0.51	0.40	0.38	1.24	1.16
160	5.17	4.67	5.13	4.63	2.06	1.89	1.51	1.40	3.43	3.10
150	10.57	9.21	10.46	9.14	4.68	4.28	3.84	3.44	7.10	6.31
140	19.88	17.68	19.80	17.60	9.16	8.15	7.32	6.52	14.62	12.70
130	38.58	31.23	38.35	31.08	21.17	16.44	16.43	13.11	31.28	24.82
120	67.19	53.80	66.50	53.29	44.25	34.08	36.88	28.22	57.30	45.04

Table 211. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.46	0.44	0.45	0.43	0.10	0.10	0.03	0.03	0.17	0.16
175	0.94	0.89	0.94	0.88	0.16	0.15	0.13	0.13	0.46	0.44
170	1.80	1.68	1.78	1.65	0.46	0.43	0.28	0.26	0.95	0.89
160	4.44	4.05	4.39	4.01	1.69	1.56	1.12	1.05	2.86	2.64
150	9.21	8.16	9.14	8.10	4.12	3.75	3.22	2.88	6.19	5.54
140	17.79	15.86	17.69	15.77	8.03	7.12	6.43	5.80	12.38	11.05
130	34.28	28.18	34.07	28.05	18.03	14.36	13.61	11.42	27.39	21.94
120	59.91	47.96	59.37	47.58	38.78	29.74	31.82	24.33	50.93	39.91

Table 212. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.28	0.27	0.28	0.26	0.03	0.03	-	-	0.13	0.13
175	0.60	0.57	0.58	0.56	0.13	0.13	0.10	0.09	0.28	0.27
170	1.26	1.18	1.24	1.16	0.26	0.25	0.15	0.15	0.58	0.56
160	3.48	3.16	3.44	3.13	1.13	1.05	0.81	0.72	2.20	2.00
150	7.47	6.62	7.41	6.56	3.24	2.90	2.53	2.31	5.00	4.52
140	14.91	13.18	14.81	13.09	6.54	5.86	5.35	4.81	9.92	8.80
130	28.62	24.21	28.48	24.09	13.80	11.68	10.06	9.01	21.81	17.68
120	50.77	40.66	50.42	40.40	31.42	24.17	25.36	19.10	42.82	33.29

Table 213. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.15	0.15	0.15	0.15	-	-	-	-	0.10	0.09
190	0.84	0.79	0.83	0.78	0.15	0.15	0.12	0.12	0.40	0.38
180	2.70	2.49	2.66	2.46	0.80	0.73	0.52	0.48	1.61	1.50
175	4.13	3.78	4.10	3.75	1.52	1.42	1.02	0.96	2.67	2.46
170	5.99	5.39	5.94	5.34	2.57	2.35	1.90	1.77	4.06	3.70
160	12.29	10.80	12.19	10.70	5.43	4.89	4.46	4.06	8.06	7.17
150	23.67	20.12	23.52	19.99	10.41	9.21	8.42	7.57	17.35	14.50
140	43.47	34.54	43.16	34.34	25.80	19.53	19.79	15.34	36.01	27.96
130	79.48	63.10	78.14	62.07	52.64	40.50	44.41	34.00	68.17	53.16
120	>90	84.05	>90	84.03	89.99	79.28	89.99	75.02	89.99	82.16

Table 214. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.15	0.15	0.15	0.15	-	-	-	-	0.10	0.09
180	0.84	0.79	0.83	0.78	0.15	0.15	0.12	0.12	0.40	0.38
175	1.64	1.52	1.62	1.50	0.40	0.38	0.22	0.17	0.84	0.79
170	2.70	2.49	2.66	2.46	0.80	0.73	0.52	0.48	1.61	1.50
160	5.99	5.39	5.94	5.34	2.57	2.35	1.90	1.77	4.06	3.70
150	12.29	10.80	12.19	10.70	5.43	4.89	4.46	4.06	8.06	7.17
140	23.67	20.12	23.52	19.99	10.41	9.21	8.42	7.57	17.35	14.50
130	43.47	34.54	43.16	34.34	25.80	19.53	19.79	15.34	36.01	27.96
120	79.48	63.10	78.14	62.07	52.64	40.50	44.41	34.00	68.17	53.16

Table 215. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
180	0.61	0.57	0.60	0.56	0.13	0.13	0.10	0.09	0.28	0.27
175	1.28	1.20	1.26	1.18	0.26	0.25	0.15	0.15	0.60	0.56
170	2.23	2.05	2.21	2.02	0.56	0.52	0.42	0.40	1.26	1.18
160	5.14	4.67	5.10	4.62	2.12	1.92	1.54	1.44	3.44	3.11
150	10.53	9.21	10.42	9.14	4.74	4.33	3.92	3.53	6.97	6.25
140	19.97	17.62	19.88	17.53	9.06	8.14	7.34	6.60	14.75	12.66
130	38.81	31.14	38.55	30.98	21.69	16.58	16.86	13.32	31.65	24.83
120	70.37	55.28	69.37	54.51	45.74	35.07	38.50	29.37	59.54	46.24

Table 216. Monopile foundation (13 m typical monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.40	0.38	0.40	0.37	0.09	0.09	0.02	0.02	0.15	0.15
175	0.84	0.79	0.83	0.78	0.15	0.15	0.12	0.12	0.40	0.38
170	1.64	1.52	1.62	1.50	0.40	0.38	0.22	0.17	0.84	0.79
160	4.13	3.78	4.10	3.75	1.52	1.42	1.02	0.96	2.67	2.46
150	8.59	7.63	8.51	7.56	3.90	3.52	3.00	2.74	5.68	5.14
140	16.77	14.88	16.67	14.79	7.40	6.64	6.11	5.52	11.45	10.13
130	32.54	26.72	32.36	26.60	16.82	13.48	12.84	10.78	25.77	20.36
120	58.20	45.68	57.60	45.26	37.25	28.49	30.75	23.34	49.05	37.98

Table 217. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.08	0.07	0.07	0.07	-	-	-	-	-	-
190	0.40	0.38	0.39	0.38	0.05	0.05	-	-	0.13	0.13
180	1.57	1.44	1.54	1.41	0.26	0.25	0.15	0.15	0.74	0.69
175	2.66	2.47	2.64	2.44	0.63	0.56	0.43	0.41	1.45	1.35
170	4.16	3.81	4.12	3.77	1.31	1.22	0.87	0.82	2.52	2.32
160	8.28	7.43	8.20	7.36	3.56	3.21	2.74	2.51	5.41	4.92
150	15.54	13.95	15.44	13.85	6.72	6.10	5.66	5.14	9.90	8.94
140	29.15	23.59	28.99	23.46	14.34	11.74	10.49	9.08	22.53	17.25
130	49.13	38.73	48.79	38.50	30.87	23.66	25.43	18.97	41.38	32.06
120	86.32	69.41	84.63	68.23	57.79	45.40	49.53	38.64	73.26	58.23

Table 218. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.08	0.07	0.07	0.07	-	-	-	-	-	-
180	0.40	0.38	0.39	0.38	0.05	0.05	-	-	0.13	0.13
175	0.80	0.75	0.78	0.74	0.13	0.13	0.10	0.09	0.37	0.36
170	1.57	1.44	1.54	1.41	0.26	0.25	0.15	0.15	0.74	0.69
160	4.16	3.81	4.12	3.77	1.31	1.22	0.87	0.82	2.52	2.32
150	8.28	7.43	8.20	7.36	3.56	3.21	2.74	2.51	5.41	4.92
140	15.54	13.95	15.44	13.85	6.72	6.10	5.66	5.14	9.90	8.94
130	29.15	23.59	28.99	23.46	14.34	11.74	10.49	9.08	22.53	17.25
120	49.13	38.73	48.79	38.50	30.87	23.66	25.43	18.97	41.38	32.06

Table 219. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.05	0.05	0.05	0.05	-	-	-	-	-	-
180	0.26	0.24	0.25	0.24	0.02	0.02	-	-	0.11	0.11
175	0.52	0.50	0.51	0.49	0.10	0.10	0.05	0.05	0.24	0.23
170	1.19	1.11	1.16	1.08	0.20	0.18	0.13	0.13	0.51	0.48
160	3.50	3.19	3.46	3.15	0.96	0.92	0.60	0.56	1.98	1.86
150	7.21	6.49	7.12	6.42	2.96	2.71	2.30	2.08	4.75	4.35
140	13.96	12.53	13.85	12.44	6.04	5.48	5.02	4.57	8.75	7.93
130	26.14	21.26	25.99	21.12	12.05	10.08	8.89	8.07	19.22	15.37
120	44.38	34.94	44.12	34.75	27.01	20.54	21.55	16.05	36.94	28.55

Table 220. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.13	0.13	0.13	0.13	-	-	-	-	0.07	0.07
175	0.40	0.38	0.39	0.38	0.05	0.05	-	-	0.13	0.13
170	0.80	0.75	0.78	0.74	0.13	0.13	0.10	0.09	0.37	0.36
160	2.66	2.47	2.64	2.44	0.63	0.56	0.43	0.41	1.45	1.35
150	5.91	5.37	5.85	5.31	2.31	2.10	1.65	1.54	3.86	3.52
140	11.71	10.40	11.59	10.27	5.06	4.61	4.14	3.75	7.27	6.55
130	21.57	17.83	21.41	17.73	9.04	8.18	7.35	6.70	15.44	12.81
120	38.07	30.02	37.87	29.84	21.61	16.17	16.80	13.16	30.97	23.90

Table 221. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
190	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
180	1.78	1.66	1.76	1.64	0.43	0.41	0.26	0.25	0.92	0.86
175	2.86	2.64	2.84	2.61	0.86	0.81	0.55	0.50	1.73	1.60
170	4.39	4.00	4.35	3.96	1.63	1.51	1.08	1.02	2.78	2.57
160	9.12	8.11	9.05	8.04	4.02	3.62	3.12	2.80	5.96	5.36
150	17.86	15.78	17.76	15.69	7.75	6.89	6.26	5.65	12.23	10.85
140	32.41	27.68	32.23	27.55	16.58	13.95	12.70	11.12	25.43	21.27
130	56.03	46.05	55.54	45.73	36.20	27.94	29.76	22.81	47.29	37.51
120	89.99	82.71	89.99	82.34	71.98	56.06	60.16	46.65	89.99	73.72

Table 222. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
175	0.93	0.88	0.92	0.87	0.16	0.15	0.13	0.12	0.44	0.42
170	1.78	1.66	1.76	1.64	0.43	0.41	0.26	0.25	0.92	0.86
160	4.39	4.00	4.35	3.96	1.63	1.51	1.08	1.02	2.78	2.57
150	9.12	8.11	9.05	8.04	4.02	3.62	3.12	2.80	5.96	5.36
140	17.86	15.78	17.76	15.69	7.75	6.89	6.26	5.65	12.23	10.85
130	32.41	27.68	32.23	27.55	16.58	13.95	12.70	11.12	25.43	21.27
120	56.03	46.05	55.54	45.73	36.20	27.94	29.76	22.81	47.29	37.51

Table 223. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.08	0.08	0.08	0.08	-	-	-	-	-	-
180	0.31	0.29	0.30	0.28	0.06	0.06	-	-	0.14	0.14
175	0.72	0.67	0.71	0.66	0.14	0.13	0.10	0.10	0.30	0.28
170	1.44	1.34	1.42	1.32	0.28	0.27	0.16	0.15	0.69	0.63
160	3.76	3.42	3.72	3.38	1.27	1.19	0.86	0.82	2.36	2.17
150	7.95	7.05	7.86	6.98	3.42	3.05	2.68	2.44	5.17	4.69
140	15.95	14.01	15.85	13.92	6.73	6.05	5.54	5.01	10.42	9.18
130	28.67	25.05	28.51	24.93	13.99	12.18	10.58	9.42	21.74	18.33
120	49.98	41.36	49.61	41.12	31.50	24.43	25.40	19.43	42.12	33.56

Table 224. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	0.02	0.02	-	-	-	-	-	-
180	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
175	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
170	0.93	0.88	0.92	0.87	0.16	0.15	0.13	0.12	0.44	0.42
160	2.86	2.64	2.84	2.61	0.86	0.81	0.55	0.50	1.73	1.60
150	6.38	5.71	6.32	5.66	2.67	2.45	1.98	1.84	4.20	3.83
140	13.23	11.62	13.12	11.53	5.59	5.04	4.56	4.14	8.51	7.56
130	23.99	21.28	23.86	21.16	10.88	9.65	8.76	7.79	17.34	15.29
120	42.60	35.47	42.33	35.29	25.15	19.62	19.35	15.64	35.43	28.47

Table 225. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
190	0.58	0.55	0.57	0.54	0.12	0.12	0.09	0.09	0.26	0.26
180	2.15	1.98	2.13	1.95	0.53	0.49	0.32	0.30	1.19	1.11
175	3.40	3.09	3.36	3.06	1.05	0.98	0.76	0.68	2.11	1.93
170	5.10	4.61	5.05	4.57	1.95	1.82	1.44	1.33	3.30	2.99
160	10.48	9.15	10.37	9.08	4.54	4.14	3.70	3.30	6.82	6.10
150	19.65	17.56	19.56	17.47	8.81	7.85	7.04	6.32	13.93	12.47
140	36.67	30.53	36.46	30.38	19.39	15.91	15.16	12.66	29.39	24.05
130	62.45	51.07	61.82	50.66	41.35	31.86	34.72	26.50	53.26	42.09
120	>90	83.79	>90	83.73	81.86	64.26	68.90	53.74	89.99	78.54

Table 226. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
180	0.58	0.55	0.57	0.54	0.12	0.12	0.09	0.09	0.26	0.26
175	1.24	1.15	1.21	1.13	0.23	0.22	0.15	0.14	0.56	0.53
170	2.15	1.98	2.13	1.95	0.53	0.49	0.32	0.30	1.19	1.11
160	5.10	4.61	5.05	4.57	1.95	1.82	1.44	1.33	3.30	2.99
150	10.48	9.15	10.37	9.08	4.54	4.14	3.70	3.30	6.82	6.10
140	19.65	17.56	19.56	17.47	8.81	7.85	7.04	6.32	13.93	12.47
130	36.67	30.53	36.46	30.38	19.39	15.91	15.16	12.66	29.39	24.05
120	62.45	51.07	61.82	50.66	41.35	31.86	34.72	26.50	53.26	42.09

Table 227. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.44	0.42	0.43	0.42	0.10	0.10	0.03	0.03	0.16	0.15
175	0.92	0.87	0.91	0.86	0.16	0.15	0.13	0.12	0.44	0.42
170	1.76	1.64	1.74	1.62	0.42	0.40	0.26	0.24	0.91	0.85
160	4.37	3.98	4.33	3.95	1.62	1.50	1.05	0.99	2.78	2.57
150	9.09	8.06	9.01	7.99	3.98	3.61	3.10	2.79	5.97	5.37
140	17.82	15.77	17.72	15.67	7.67	6.83	6.21	5.62	12.17	10.79
130	32.73	27.66	32.56	27.53	16.65	13.89	12.64	11.02	25.60	21.25
120	55.86	45.82	55.41	45.52	36.36	27.96	29.90	22.82	47.56	37.54

Table 228. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
175	0.58	0.55	0.57	0.54	0.12	0.12	0.09	0.09	0.26	0.26
170	1.24	1.15	1.21	1.13	0.23	0.22	0.15	0.14	0.56	0.53
160	3.40	3.09	3.36	3.06	1.05	0.98	0.76	0.68	2.11	1.93
150	7.31	6.50	7.24	6.44	3.10	2.80	2.45	2.23	4.83	4.40
140	14.97	13.14	14.87	13.06	6.30	5.67	5.17	4.68	9.64	8.57
130	27.22	23.82	27.07	23.70	12.81	11.30	9.75	8.74	19.91	17.25
120	47.77	39.21	47.46	38.98	29.36	22.79	23.41	17.87	40.11	31.74

Table 229. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
190	0.81	0.77	0.80	0.75	0.15	0.14	0.11	0.11	0.38	0.36
180	2.60	2.40	2.58	2.37	0.74	0.64	0.49	0.46	1.55	1.44
175	4.01	3.66	3.96	3.63	1.45	1.35	0.96	0.90	2.59	2.38
170	5.85	5.24	5.80	5.20	2.45	2.24	1.80	1.67	3.94	3.58
160	12.02	10.49	11.93	10.39	5.26	4.74	4.28	3.90	7.99	7.05
150	22.94	19.69	22.80	19.55	10.10	8.99	8.22	7.32	16.82	14.23
140	42.47	34.07	42.20	33.88	24.81	18.78	19.01	14.79	34.90	27.37
130	74.76	59.74	73.74	59.01	49.78	38.62	42.00	32.26	63.81	50.29
120	>90	84.10	>90	84.07	89.99	77.41	85.33	67.61	89.99	82.76

Table 230. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
180	0.81	0.77	0.80	0.75	0.15	0.14	0.11	0.11	0.38	0.36
175	1.56	1.45	1.54	1.43	0.31	0.29	0.17	0.16	0.83	0.77
170	2.60	2.40	2.58	2.37	0.74	0.64	0.49	0.46	1.55	1.44
160	5.85	5.24	5.80	5.20	2.45	2.24	1.80	1.67	3.94	3.58
150	12.02	10.49	11.93	10.39	5.26	4.74	4.28	3.90	7.99	7.05
140	22.94	19.69	22.80	19.55	10.10	8.99	8.22	7.32	16.82	14.23
130	42.47	34.07	42.20	33.88	24.81	18.78	19.01	14.79	34.90	27.37
120	74.76	59.74	73.74	59.01	49.78	38.62	42.00	32.26	63.81	50.29

Table 231. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.12	0.13	0.12	-	-	-	-	0.03	0.03
180	0.57	0.54	0.56	0.53	0.12	0.12	0.09	0.09	0.26	0.26
175	1.19	1.11	1.17	1.09	0.24	0.23	0.15	0.14	0.57	0.53
170	2.12	1.94	2.09	1.92	0.54	0.49	0.38	0.30	1.17	1.09
160	5.03	4.54	4.99	4.51	1.98	1.84	1.45	1.35	3.31	2.99
150	10.26	9.01	10.15	8.95	4.58	4.18	3.72	3.34	6.89	6.14
140	19.50	17.36	19.42	17.27	8.96	7.96	7.12	6.39	14.21	12.39
130	37.83	30.67	37.62	30.52	20.59	16.10	16.07	12.84	30.69	24.35
120	66.28	52.93	65.56	52.44	43.76	33.65	36.40	27.81	56.65	44.47

Table 232. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.37	0.35	0.37	0.34	0.09	0.09	0.02	0.02	0.15	0.14
175	0.81	0.77	0.80	0.75	0.15	0.14	0.11	0.11	0.38	0.36
170	1.56	1.45	1.54	1.43	0.31	0.29	0.17	0.16	0.83	0.77
160	4.01	3.66	3.96	3.63	1.45	1.35	0.96	0.90	2.59	2.38
150	8.42	7.44	8.35	7.38	3.74	3.36	2.86	2.62	5.59	5.03
140	16.47	14.59	16.37	14.50	7.26	6.47	5.94	5.35	11.31	9.87
130	31.66	26.30	31.50	26.18	16.16	13.11	12.08	10.35	25.03	19.90
120	55.93	44.63	55.49	44.31	35.64	27.33	29.11	22.21	47.55	37.00

Table 233. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
190	0.92	0.86	0.90	0.85	0.16	0.15	0.13	0.13	0.46	0.43
180	2.88	2.65	2.84	2.63	0.88	0.83	0.56	0.51	1.77	1.64
175	4.38	4.01	4.34	3.97	1.69	1.57	1.14	1.08	2.84	2.62
170	6.37	5.72	6.31	5.66	2.74	2.51	2.09	1.90	4.28	3.91
160	12.95	11.43	12.86	11.34	5.71	5.15	4.70	4.28	8.54	7.60
150	25.07	21.29	24.93	21.16	11.51	9.87	8.87	7.98	18.43	15.31
140	45.61	36.09	45.28	35.87	27.55	21.00	21.64	16.30	38.00	29.41
130	83.81	66.75	82.22	65.51	55.98	43.20	47.29	36.28	72.15	56.54
120	>90	84.09	>90	84.08	89.99	79.98	89.99	77.67	89.99	83.40

Table 234. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.02	0.02	0.02	0.02	-	-	-	-	-	-
190	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
180	0.92	0.86	0.90	0.85	0.16	0.15	0.13	0.13	0.46	0.43
175	1.78	1.66	1.76	1.64	0.46	0.43	0.28	0.26	0.92	0.86
170	2.88	2.65	2.84	2.63	0.88	0.83	0.56	0.51	1.77	1.64
160	6.37	5.72	6.31	5.66	2.74	2.51	2.09	1.90	4.28	3.91
150	12.95	11.43	12.86	11.34	5.71	5.15	4.70	4.28	8.54	7.60
140	25.07	21.29	24.93	21.16	11.51	9.87	8.87	7.98	18.43	15.31
130	45.61	36.09	45.28	35.87	27.55	21.00	21.64	16.30	38.00	29.41
120	83.81	66.75	82.22	65.51	55.98	43.20	47.29	36.28	72.15	56.54

Table 235. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.14	0.13	0.14	0.13	-	-	-	-	0.08	0.08
180	0.72	0.67	0.69	0.65	0.14	0.13	0.10	0.10	0.31	0.29
175	1.42	1.32	1.40	1.31	0.29	0.28	0.16	0.16	0.71	0.64
170	2.42	2.24	2.40	2.21	0.63	0.57	0.47	0.44	1.41	1.32
160	5.47	4.94	5.41	4.90	2.30	2.09	1.71	1.58	3.70	3.36
150	11.25	9.77	11.15	9.68	5.00	4.55	4.14	3.75	7.41	6.60
140	21.52	18.47	21.37	18.35	9.52	8.57	7.79	6.99	15.78	13.37
130	40.72	32.51	40.46	32.34	23.45	17.69	18.16	14.13	33.43	26.11
120	74.16	58.46	72.97	57.60	48.54	37.31	40.96	31.30	62.99	49.03

Table 236. Monopile foundation (13 m typical monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and R95% in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
175	0.92	0.86	0.90	0.85	0.16	0.15	0.13	0.13	0.46	0.43
170	1.78	1.66	1.76	1.64	0.46	0.43	0.28	0.26	0.92	0.86
160	4.38	4.01	4.34	3.97	1.69	1.57	1.14	1.08	2.84	2.62
150	9.06	8.05	8.99	7.99	4.12	3.75	3.26	2.90	6.02	5.42
140	17.56	15.60	17.45	15.51	7.86	7.03	6.39	5.80	12.22	10.85
130	34.20	27.89	33.98	27.75	18.03	14.27	13.86	11.47	27.29	21.63
120	61.39	48.10	60.61	47.59	39.60	30.26	32.84	24.96	51.79	40.11

Appendix G. Ranges to Regulatory Thresholds for Vibratory Pile-Setting Followed by Impact Pile Driving

The following subsections contain tables of ranges to injury and behavior thresholds described in Sections 2.4 and 2.4.2. Results are presented for pile driving operations assuming a 0, 10, 12, and 15 dB broadband attenuation achieved using noise attenuation systems.

G.1. Decidecade and Broadband Levels at 750 m

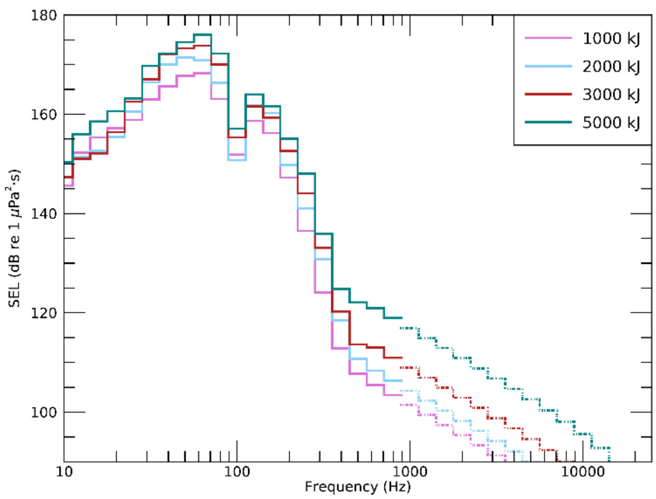

Figure G-1. Decidecade band levels at 750 m from location M1 for a 12 m monopile assuming an installation scenario with a MHU5000 kJ hammer with average sound speed profiles from May to December.

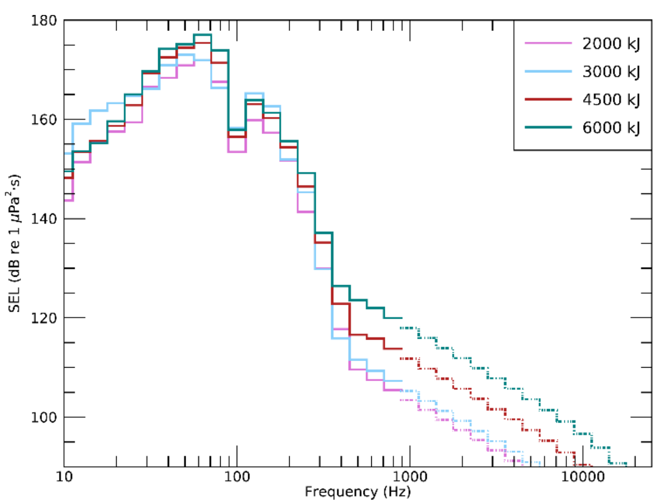

Figure G-2. Decidecade band levels at 750 m from location M1 for a 12 m monopile assuming an installation scenario with a MHU6000 kJ hammer with average sound speed profiles from May to December.

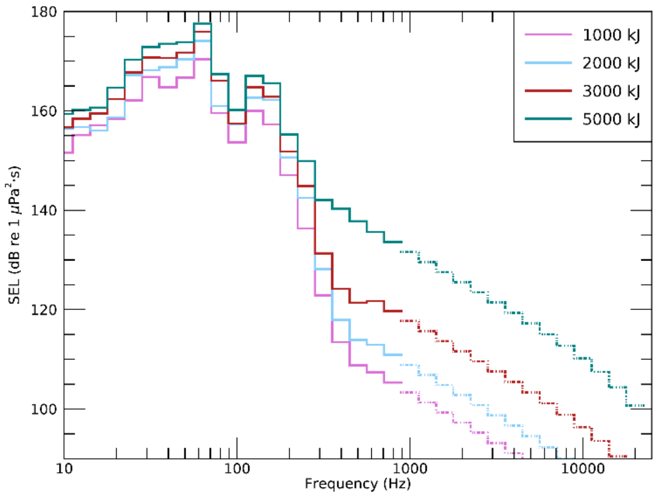

Figure G-3. Decidecade band levels at 750 m from location M2 for a 13 m monopile assuming an installation scenario with a MHU5000 kJ hammer with average sound speed profiles from May to December.

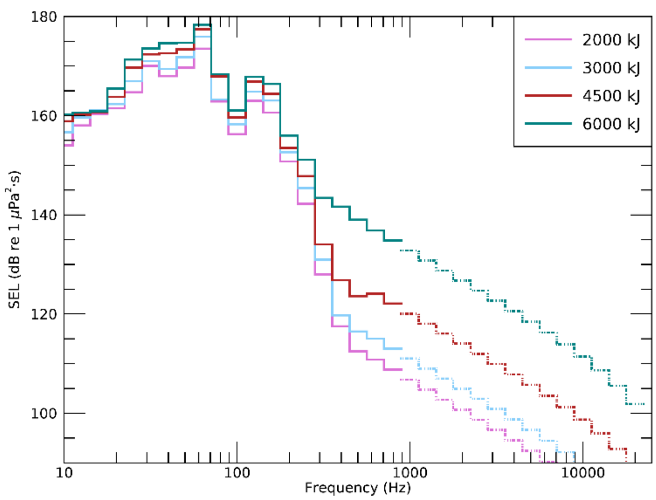

Figure G-4. Decidecade band levels at 750 m from location M2 for a 13 m monopile assuming an installation scenario with a MHU6000 kJ hammer with average sound speed profiles from May to December.

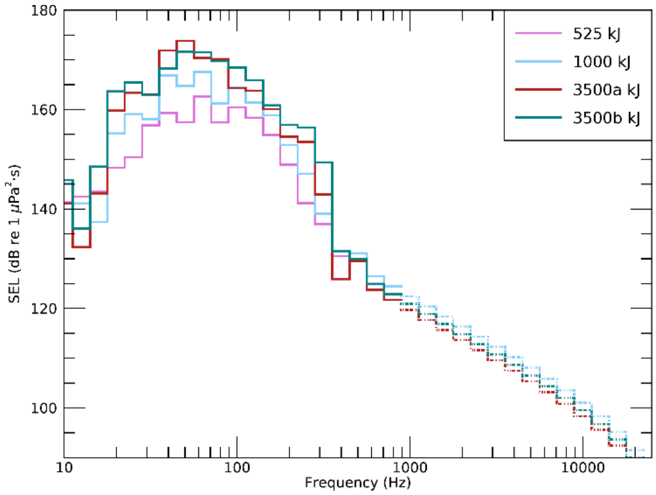

Figure G-5. Decidecade band levels at 750 m from location J1 for a 4 m jacket assuming an installation scenario with a MHU3500 kJ hammer with average sound speed profiles from May to December.

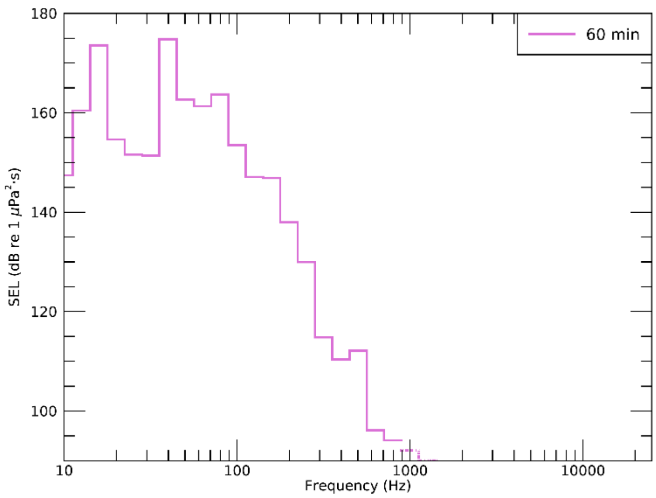

Figure G-6. Decidecade band levels at 750 m from location M1 for a 12 m monopile assuming a vibratory pile-setting installation scenario with a TR-CV640 hammer with average sound speed profiles from May to December.

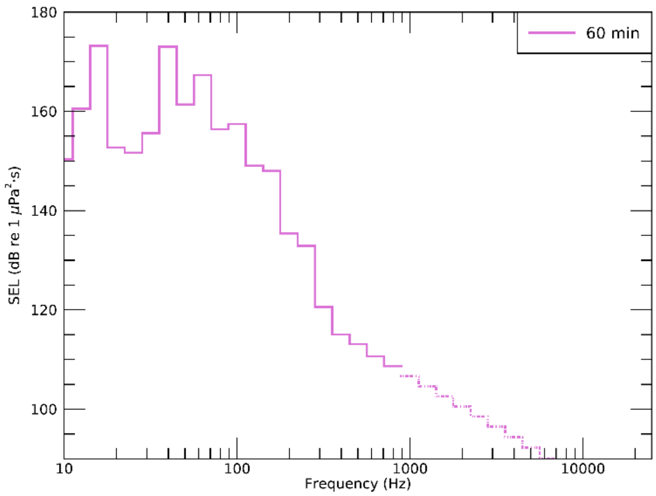

Figure G-7. Decidecade band levels at 750 m from location M2 for a 13 m monopile assuming an vibratory pile-setting installation scenario with a TR-CV640 hammer with average sound speed profiles from May to December.

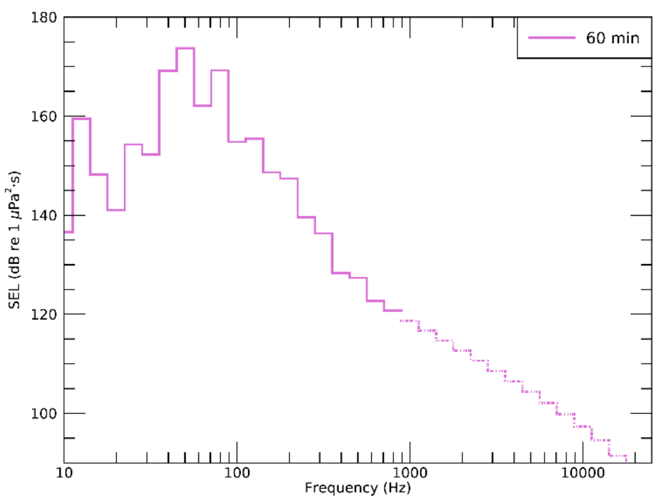

Figure G-8. Decidecade band levels at 750 m from location J1 for a 4 m monopile assuming an vibratory pile-setting installation scenario with a TR-CV640 hammer with average sound speed profiles from May to December.

Table G-1. Broadband level at 750 m (SEL dB re 1 µPa) for the 12 m monopile at location M1 for average conditions between May to December.

Scenario	Drivability	Hammer Duration/ Energy	Single Strike SEL
WTG (12 m monopile)	MHU 5000	**Vibratory pile setting**	
		60 min	177.8
		Impact pile driving	
		1000 kJ	173.7
		2000 kJ	177.0
		3000 kJ	179.2
		5000 kJ	180.8
	MHU 6000	**Vibratory pile setting**	
		60 min	177.8
		Impact pile driving	
		2000 kJ	176.9
		3000 kJ	178.4
		4500 kJ	180.4
		6000 kJ	181.9

Table G-2. Broadband level at 750 m (SEL dB re 1 µPa) for the 13 m monopile at location M2 for average conditions between May to December.

Scenario	Drivability	Hammer Duration/ Energy	Single Strike SEL
WTG (13 m monopile)	MHU 5000	**Vibratory pile setting**	
		60 min	177.3
		Impact pile driving	
		1000 kJ	174.6
		2000 kJ	177.9
		3000 kJ	179.7
		5000 kJ	181.8
	MHU 6000	**Vibratory pile setting**	
		60 min	177.3
		Impact pile driving	
		2000 kJ	176.9
		3000 kJ	178.4
		4500 kJ	180.4
		6000 kJ	181.9

Table G-3. Broadband level at 750 m (SEL dB re 1 uPa) for a 4 m jacket pin pile at location J1 for average conditions between May to December.

Scenario	Drivability	Hammer duration/ Energy	Single Strike SEL
Jacket (4 m pin pile)	MHU 3500	**Vibratory pile setting**	
		60 min	176.6
		Impact pile driving	
		525 kJ	168.4
		1000 kJ	173.6
		3500 (a) kJ	178.5
		3500 (b) kJ	178.2

G.2. Single-strike PK Acoustic Ranges

G.2.1. Impact Pile Driving

G.2.1.1. Monopile Foundations

Table G-4. Monopile foundation (12 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	0.04	0.05	0.06
MF	230	-	-	-	-
HF	202	0.33	0.44	0.50	0.62
PPW	218	-	0.05	0.06	0.09
TUW	232	-	-	-	-

Table G-5. Monopile foundation (12 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.06	0.10	0.12	0.20
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-6. Monopile foundation (12 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.05	0.07	0.10	0.13
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-7. Monopile foundation (12 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.02	0.05	0.06	0.09
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-8. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		.the			
		2000	3000	4500	6000
LF	219	0.04	0.05	0.06	0.08
MF	230	-	-	-	-
HF	202	0.44	0.52	0.61	0.67
PPW	218	0.05	0.06	0.06	0.09
TUW	232	-	-	-	-

Table G-9. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		2000	3000	4500	6000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.09	0.12	0.14	0.24
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-10. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		2000	3000	4500	6000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.07	0.09	0.12	0.13
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-11. Monopile foundation (12 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M1 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		2000	3000	4500	6000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.05	0.06	0.09	0.10
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-12. Monopile foundation (13 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	0.02	0.06	0.07
MF	230	-	-	-	-
HF	202	0.38	0.49	0.61	0.72
PPW	218	-	0.03	0.06	0.10
TUW	232	-	-	-	-

Table G-13. Monopile foundation (13 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.06	0.11	0.14	0.25
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-14. Monopile foundation (13 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.06	0.09	0.12	0.15
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-15. Monopile foundation (13 m monopile with an MHU 5500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		1000	2000	3000	5000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	-	0.06	0.07	0.11
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-16. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		2000	3000	4500	6000
LF	219	0.02	0.06	0.07	0.09
MF	230	-	-	-	-
HF	202	0.48	0.60	0.67	0.79
PPW	218	0.03	0.06	0.08	0.10
TUW	232	-	-	-	-

Table G-17. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		2000	3000	4500	6000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.11	0.13	0.17	0.28
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-18. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		2000	3000	4500	6000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.08	0.11	0.13	0.16
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-19. Monopile foundation (13 m typical monopile with an MHU 6000 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location M2 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		2000	3000	4500	6000
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.06	0.07	0.10	0.11
PPW	218	-	-	-	-
TUW	232	-	-	-	-

G.2.1.2. Jacket Foundations

Table G-20. Jacket foundation (4 m jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 0 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		525	1000	3500 (a)	3500 (b)
LF	219	-	-	0.09	0.09
MF	230	-	-	-	-
HF	202	0.26	0.41	0.76	0.72
PPW	218	-	-	0.10	0.09
TUW	232	-	-	-	-

Table G-21. Jacket foundation (4 m jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 10 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		525	1000	3500 (a)	3500 (b)
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.09	0.12	0.17	0.17
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-22. Jacket foundation (4 m jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 12 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		525	1000	3500 (a)	3500 (b)
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	0.03	0.09	0.15	0.14
PPW	218	-	-	-	-
TUW	232	-	-	-	-

Table G-23. Jacket foundation (4 m jacket with an MHU 3500 hammer) acoustic ranges to marine mammal and sea turtle injury thresholds ($R_{95\%}$ in km) during annual at location J1 with different energy levels at 15 dB.

Faunal group	Level (L_{pk})	Hammer energy (kJ)			
		525	1000	3500 (a)	3500 (b)
LF	219	-	-	-	-
MF	230	-	-	-	-
HF	202	-	0.02	0.12	0.11
PPW	218	-	-	-	-
TUW	232	-	-	-	-

G.3. Per-pile SEL Acoustic Ranges to Injury Threshold

Table G-24. to Table G-28. show distances to injury thresholds from the combined sound fields produced by vibratory and impact (impulsive signals) pile driving, for marine mammals and sea turtles. See for details on combining the sound field from vibratory and impact pile driving.

G.3.1.1. Monopile Foundations

Table G-24. Monopile foundation (12 m diameter typical, TRC V640 and MHU5500 hammer, 60min) acoustic ranges ($R_{95\%}$ in km) for vibratory pile-setting followed by impact, and vibratory pile-setting alone, with attenuation (Finneran et al. 2017, NMFS 2018) for location M1.

Hearing group	Threshold (dB)	Impact + Vibe				Threshold (dB)	Vibratory-Only			
		Attenuation Level (dB)					Attenuation Level (dB)			
		0	10	12	15		0	10	12	15
LF	183	7.60	3.67	3.06	2.42	199	0.92	0.20	0.16	0.09
MF	185	-	-	-	-	198	-	-	-	-
HF	155	0.14	-	-	-	173	-	-	-	-
PPW	185	1.58	0.42	0.31	0.15	201	0.03	-	-	-
TUW	204	2.32	0.73	0.56	0.35	220	0.09	-	-	-

Table G-25. Monopile foundation (12 m diameter typical, TRC V640 and MHU6000 hammer, 60min) acoustic ranges ($R_{95\%}$ in km) for vibratory pile-setting followed by impact, and vibratory pile-setting alone, with attenuation (Finneran et al. 2017, NMFS 2018) for location M1.

Hearing group	Threshold (dB)	Impact + Vibe				Threshold (dB)	Vibratory-Only			
		Attenuation Level (dB)					Attenuation Level (dB)			
		0	10	12	15		0	10	12	15
LF	183	8.31	4.08	3.50	2.70	199	0.92	0.20	0.16	0.09
MF	185	-	-	-	-	198	-	-	-	-
HF	155	0.25	0.04	-	-	173	-	-	-	-
PPW	185	1.81	0.49	0.40	0.23	201	0.03	-	-	-
TUW	204	2.61	0.91	0.67	0.43	220	0.09	-	-	-

Table G-26. Monopile foundation (13 m diameter typical, TRC V640 and MHU5500 hammer, 60min) acoustic ranges ($R_{95\%}$ in km) for vibratory pile-setting followed by impact, and vibratory pile-setting alone, with attenuation (Finneran et al. 2017, NMFS 2018) for location M2.

Hearing group	Threshold (dB)	Impact + Vibe				Threshold (dB)	Vibratory-Only			
		Attenuation Level (dB)					Attenuation Level (dB)			
		0	10	12	15		0	10	12	15
LF	183	8.17	4.12	3.51	2.64	199	0.84	0.15	0.13	0.09
MF	185	-	-	-	-	198	-	-	-	-
HF	155	0.52	0.09	0.07	0.05	173	-	-	-	-
PPW	185	1.70	0.45	0.29	0.16	201	0.03	-	-	-
TUW	204	2.58	0.81	0.59	0.39	220	0.10	-	-	-

Table G-27. Monopile foundation (13 m diameter typical, TRC V640 and MHU6000 hammer, 60min) acoustic ranges ($R_{95\%}$ in km) for vibratory pile-setting followed by impact, and vibratory pile-setting alone, with attenuation (Finneran et al. 2017, NMFS 2018) for location M2.

Hearing group	Threshold (dB)	Impact + Vibe				Threshold (dB)	Vibratory-Only			
		Attenuation Level (dB)					Attenuation Level (dB)			
		0	10	12	15		0	10	12	15
LF	183	8.90	4.58	3.95	2.99	199	0.84	0.15	0.13	0.09
MF	185	-	-	-	-	198	-	-	-	-
HF	155	0.70	0.11	0.09	0.06	173	-	-	-	-
PPW	185	1.97	0.53	0.43	0.24	201	0.03	-	-	-
TUW	204	2.91	0.94	0.76	0.46	220	0.10	-	-	-

G.3.1.2. Jacket Foundation

Table G-28. Jacket foundation (4 m diameter typical, TRC V640 and MHU3500 hammer, 60min) acoustic ranges ($R_{95\%}$ in km) for vibratory pile-setting followed by impact, and vibratory pile-setting alone, with attenuation (Finneran et al. 2017, NMFS 2018) for location J1.

Hearing group	Threshold (dB)	Impact + Vibe				Threshold (dB)	Vibratory-Only			
		Attenuation Level (dB)					Attenuation Level (dB)			
		0	10	12	15		0	10	12	15
LF	183	13.01	7.41	6.58	5.56	199	3.27	1.13	0.82	0.51
MF	185	0.05	-	-	-	198	-	-	-	-
HF	155	1.65	0.44	0.42	0.26	173	0.03	-	-	-
PPW	185	4.28	1.74	1.39	0.94	201	0.26	0.03	-	-
TUW	204	5.36	2.44	1.94	1.41	220	0.50	0.11	0.09	0.03

G.4. Fish and Sea Turtle Acoustic Distances to Threshold

G.4.1.1. Monopile Foundations

Table G-29. Monopile foundation (12 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	10.01				
	L_{pk} [a]	206	NA	0.13	0.26	0.38	0.46
	L_p [b]	150	7.94	12.13	14.38	15.86	17.39
Fish ≤ 2 g	L_E [a]	183	12.79				
	L_{pk} [a]	206	NA	0.13	0.26	0.38	0.46
	L_p [b]	150	7.94	12.13	14.38	15.86	17.39
Fish without swim bladder	L_E [c]	216	0.83				
	L_{pk} [c]	213	NA	0.06	0.09	0.11	0.14
Fish with swim bladder involved in hearing	L_E [c]	203	3.20				
	L_{pk} [c]	207	NA	0.12	0.23	0.35	0.43
Fish with swim bladder involved in hearing	L_E [c]	203	3.20				
	L_{pk} [c]	207	NA	0.12	0.23	0.35	0.43
Sea turtles	L_E [d]	204	2.89				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.89	1.84	2.50	2.83	3.44

Table G-30. Monopile foundation (12 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	5.14				
	L_{pk} [a]	206	NA	0.04	0.06	0.08	0.10
	L_p [b]	150	3.96	6.28	7.99	8.89	10.13
Fish ≤ 2 g	L_E [a]	183	6.82				
	L_{pk} [a]	206	NA	0.04	0.06	0.08	0.10
	L_p [b]	150	3.96	6.28	7.99	8.89	10.13
Fish without swim bladder	L_E [c]	216	0.16				
	L_{pk} [c]	213	NA	-	-	-	0.04
Fish with swim bladder involved in hearing	L_E [c]	203	1.23				
	L_{pk} [c]	207	NA	0.02	0.05	0.06	0.09
Fish with swim bladder involved in hearing	L_E [c]	203	1.23				
	L_{pk} [c]	207	NA	0.02	0.05	0.06	0.09
Sea turtles	L_E [d]	204	1.07				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.19	0.56	0.86	1.08	1.39

Table G-31. Monopile foundation (12 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	4.42				
	L_{pk} [a]	206	NA	-	0.05	0.06	0.09
	L_p [b]	150	3.40	5.43	6.95	7.89	8.86
Fish ≤ 2 g	L_E [a]	183	5.94				
	L_{pk} [a]	206	NA	-	0.05	0.06	0.09
	L_p [b]	150	3.40	5.43	6.95	7.89	8.86
Fish without swim bladder	L_E [c]	216	0.12				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.94				
	L_{pk} [c]	207	NA	-	0.04	0.05	0.06
Fish with swim bladder involved in hearing	L_E [c]	203	0.94				
	L_{pk} [c]	207	NA	-	0.04	0.05	0.06
Sea turtles	L_E [d]	204	0.83				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.14	0.39	0.66	0.87	1.10

Table G-32. Monopile foundation (12 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	3.51				
	L_{pk} [a]	206	NA	-	-	0.03	0.05
	L_p [b]	150	2.62	4.30	5.57	6.37	7.32
Fish ≤ 2 g	L_E [a]	183	4.77				
	L_{pk} [a]	206	NA	-	-	0.03	0.05
	L_p [b]	150	2.62	4.30	5.57	6.37	7.32
Fish without swim bladder	L_E [c]	216	0.09				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.62				
	L_{pk} [c]	207	NA	-	-	0.02	0.05
Fish with swim bladder involved in hearing	L_E [c]	203	0.62				
	L_{pk} [c]	207	NA	-	-	0.02	0.05
Sea turtles	L_E [d]	204	0.54				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.07	0.23	0.40	0.56	0.72

Table G-33. Monopile foundation (12 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	10.95				
	L_{pk} [a]	206	NA	0.24	0.37	0.44	0.47
	L_p [b]	150	7.94	14.22	15.49	16.99	18.05
Fish ≤ 2 g	L_E [a]	183	13.64				
	L_{pk} [a]	206	NA	0.24	0.37	0.44	0.47
	L_p [b]	150	7.94	14.22	15.49	16.99	18.05
Fish without swim bladder	L_E [c]	216	0.95				
	L_{pk} [c]	213	NA	0.09	0.11	0.13	0.18
Fish with swim bladder involved in hearing	L_E [c]	203	3.57				
	L_{pk} [c]	207	NA	0.20	0.34	0.39	0.45
Fish with swim bladder involved in hearing	L_E [c]	203	3.57				
	L_{pk} [c]	207	NA	0.20	0.34	0.39	0.45
Sea turtles	L_E [d]	204	3.27				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.89	2.45	2.78	3.28	3.72

Table G-34. Monopile foundation (12 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	5.61				
	L_{pk} [a]	206	NA	0.06	0.07	0.09	0.11
	L_p [b]	150	3.96	7.79	8.70	9.77	10.79
Fish ≤ 2 g	L_E [a]	183	7.44				
	L_{pk} [a]	206	NA	0.06	0.07	0.09	0.11
	L_p [b]	150	3.96	7.79	8.70	9.77	10.79
Fish without swim bladder	L_E [c]	216	0.21				
	L_{pk} [c]	213	NA	-	-	0.03	0.05
Fish with swim bladder involved in hearing	L_E [c]	203	1.40				
	L_{pk} [c]	207	NA	0.05	0.06	0.09	0.10
Fish with swim bladder involved in hearing	L_E [c]	203	1.40				
	L_{pk} [c]	207	NA	0.05	0.06	0.09	0.10
Sea turtles	L_E [d]	204	1.26				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.19	0.86	1.04	1.31	1.54

Table G-35. Monopile foundation (12 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	4.84				
	L_{pk} [a]	206	NA	0.05	0.06	0.06	0.09
	L_p [b]	150	3.40	6.74	7.68	8.65	9.30
Fish ≤ 2 g	L_E [a]	183	6.45				
	L_{pk} [a]	206	NA	0.05	0.06	0.06	0.09
	L_p [b]	150	3.40	6.74	7.68	8.65	9.30
Fish without swim bladder	L_E [c]	216	0.13				
	L_{pk} [c]	213	NA	-	-	-	0.02
Fish with swim bladder involved in hearing	L_E [c]	203	1.10				
	L_{pk} [c]	207	NA	0.04	0.05	0.06	0.08
Fish with swim bladder involved in hearing	L_E [c]	203	1.10				
	L_{pk} [c]	207	NA	0.04	0.05	0.06	0.08
Sea turtles	L_E [d]	204	0.95				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.14	0.64	0.80	1.02	1.23

Table G-36. Monopile foundation (12 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M1 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	3.87				
	L_{pk} [a]	206	NA	-	0.03	0.05	0.06
	L_p [b]	150	2.62	5.43	6.18	7.10	7.78
Fish ≤ 2 g	L_E [a]	183	5.22				
	L_{pk} [a]	206	NA	-	0.03	0.05	0.06
	L_p [b]	150	2.62	5.43	6.18	7.10	7.78
Fish without swim bladder	L_E [c]	216	0.10				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.73				
	L_{pk} [c]	207	NA	-	0.02	0.04	0.05
Fish with swim bladder involved in hearing	L_E [c]	203	0.73				
	L_{pk} [c]	207	NA	-	0.02	0.04	0.05
Sea turtles	L_E [d]	204	0.63				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.07	0.40	0.52	0.67	0.86

Table G-37. Monopile foundation (13 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	11.66				
	L_{pk} [a]	206	NA	0.15	0.31	0.43	0.50
	L_p [b]	150	9.08	13.26	16.30	17.68	20.12
Fish ≤ 2 g	L_E [a]	183	14.90				
	L_{pk} [a]	206	NA	0.15	0.31	0.43	0.50
	L_p [b]	150	9.08	13.26	16.30	17.68	20.12
Fish without swim bladder	L_E [c]	216	0.88				
	L_{pk} [c]	213	NA	0.06	0.10	0.13	0.16
Fish with swim bladder involved in hearing	L_E [c]	203	3.75				
	L_{pk} [c]	207	NA	0.13	0.27	0.40	0.46
Fish with swim bladder involved in hearing	L_E [c]	203	3.75				
	L_{pk} [c]	207	NA	0.13	0.27	0.40	0.46
Sea turtles	L_E [d]	204	3.41				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.86	2.00	2.74	3.16	3.78

Table G-38. Monopile foundation (13 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	5.81				
	L_{pk} [a]	206	NA	0.02	0.06	0.09	0.12
	L_p [b]	150	4.49	6.58	8.42	9.21	10.80
Fish ≤ 2 g	L_E [a]	183	7.67				
	L_{pk} [a]	206	NA	0.02	0.06	0.09	0.12
	L_p [b]	150	4.49	6.58	8.42	9.21	10.80
Fish without swim bladder	L_E [c]	216	0.16				
	L_{pk} [c]	213	NA	-	-	-	0.02
Fish with swim bladder involved in hearing	L_E [c]	203	1.34				
	L_{pk} [c]	207	NA	-	0.06	0.07	0.11
Fish with swim bladder involved in hearing	L_E [c]	203	1.34				
	L_{pk} [c]	207	NA	-	0.06	0.07	0.11
Sea turtles	L_E [d]	204	1.19				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.17	0.57	0.93	1.18	1.52

Table G-39. Monopile foundation (13 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	5.05				
	L_{pk} [a]	206	NA	-	0.03	0.06	0.10
	L_p [b]	150	3.86	5.75	7.30	8.16	9.21
Fish ≤ 2 g	L_E [a]	183	6.65				
	L_{pk} [a]	206	NA	-	0.03	0.06	0.10
	L_p [b]	150	3.86	5.75	7.30	8.16	9.21
Fish without swim bladder	L_E [c]	216	0.13				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	1.01				
	L_{pk} [c]	207	NA	-	0.02	0.06	0.07
Fish with swim bladder involved in hearing	L_E [c]	203	1.01				
	L_{pk} [c]	207	NA	-	0.02	0.06	0.07
Sea turtles	L_E [d]	204	0.88				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.12	0.43	0.71	0.89	1.20

Table G-40. Monopile foundation (13 m diameter, TRC V640 and MHU5500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	1000	2000	3000	5000
Fish ≥ 2g	L_E [a]	187	4.05				
	L_{pk} [a]	206	NA	-	-	0.02	0.06
	L_p [b]	150	2.86	4.65	5.89	6.62	7.63
Fish ≤ 2 g	L_E [a]	183	5.43				
	L_{pk} [a]	206	NA	-	-	0.02	0.06
	L_p [b]	150	2.86	4.65	5.89	6.62	7.63
Fish without swim bladder	L_E [c]	216	0.09				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.67				
	L_{pk} [c]	207	NA	-	-	-	0.04
Fish with swim bladder involved in hearing	L_E [c]	203	0.67				
	L_{pk} [c]	207	NA	-	-	-	0.04
Sea turtles	L_E [d]	204	0.58				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.06	0.26	0.44	0.57	0.79

Table G-41. Monopile foundation (13 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	12.54				
	L_{pk} [a]	206	NA	0.28	0.42	0.47	0.55
	L_p [b]	150	9.08	15.78	17.56	19.69	21.29
Fish ≤ 2 g	L_E [a]	183	15.99				
	L_{pk} [a]	206	NA	0.28	0.42	0.47	0.55
	L_p [b]	150	9.08	15.78	17.56	19.69	21.29
Fish without swim bladder	L_E [c]	216	1.05				
	L_{pk} [c]	213	NA	0.10	0.12	0.15	0.24
Fish with swim bladder involved in hearing	L_E [c]	203	4.12				
	L_{pk} [c]	207	NA	0.20	0.39	0.45	0.49
Fish with swim bladder involved in hearing	L_E [c]	203	4.12				
	L_{pk} [c]	207	NA	0.20	0.39	0.45	0.49
Sea turtles	L_E [d]	204	3.81				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.86	2.64	3.09	3.66	4.01

Table G-42. Monopile foundation (13 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	6.28				
	L_{pk} [a]	206	NA	0.06	0.08	0.11	0.13
	L_p [b]	150	4.49	8.11	9.15	10.49	11.43
Fish ≤ 2 g	L_E [a]	183	8.28				
	L_{pk} [a]	206	NA	0.06	0.08	0.11	0.13
	L_p [b]	150	4.49	8.11	9.15	10.49	11.43
Fish without swim bladder	L_E [c]	216	0.24				
	L_{pk} [c]	213	NA	-	-	0.02	0.03
Fish with swim bladder involved in hearing	L_E [c]	203	1.56				
	L_{pk} [c]	207	NA	0.06	0.07	0.10	0.11
Fish with swim bladder involved in hearing	L_E [c]	203	1.56				
	L_{pk} [c]	207	NA	0.06	0.07	0.10	0.11
Sea turtles	L_E [d]	204	1.39				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.17	0.88	1.15	1.45	1.66

Table G-43. Monopile foundation (13 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	5.50				
	L_{pk} [a]	206	NA	0.03	0.06	0.08	0.10
	L_p [b]	150	3.86	7.05	8.06	9.01	9.77
Fish ≤ 2 g	L_E [a]	183	7.23				
	L_{pk} [a]	206	NA	0.03	0.06	0.08	0.10
	L_p [b]	150	3.86	7.05	8.06	9.01	9.77
Fish without swim bladder	L_E [c]	216	0.15				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	1.23				
	L_{pk} [c]	207	NA	0.02	0.06	0.07	0.09
Fish with swim bladder involved in hearing	L_E [c]	203	1.23				
	L_{pk} [c]	207	NA	0.02	0.06	0.07	0.09
Sea turtles	L_E [d]	204	1.05				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.12	0.67	0.87	1.11	1.32

Table G-44. Monopile foundation (13 m diameter, TRC V640 and MHU6000) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location M2 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	2000	3000	4500	6000
Fish ≥ 2g	L_E [a]	187	4.44				
	L_{pk} [a]	206	NA	-	0.02	0.06	0.06
	L_p [b]	150	2.86	5.71	6.50	7.44	8.05
Fish ≤ 2 g	L_E [a]	183	5.88				
	L_{pk} [a]	206	NA	-	0.02	0.06	0.06
	L_p [b]	150	2.86	5.71	6.50	7.44	8.05
Fish without swim bladder	L_E [c]	216	0.11				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	0.81				
	L_{pk} [c]	207	NA	-	-	0.03	0.06
Fish with swim bladder involved in hearing	L_E [c]	203	0.81				
	L_{pk} [c]	207	NA	-	-	0.03	0.06
Sea turtles	L_E [d]	204	0.71				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.06	0.43	0.55	0.77	0.86

G.4.1.2. Jacket Foundation

Table G-45. Jacket foundation (4 m diameter, TRC V640 and MHU3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 0 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	16.22				
	L_{pk} [a]	206	NA	0.14	0.17	0.46	0.46
	L_p [b]	150	10.79	8.58	11.58	14.83	14.92
Fish ≤ 2 g	L_E [a]	183	19.42				
	L_{pk} [a]	206	NA	0.14	0.17	0.46	0.46
	L_p [b]	150	10.79	8.58	11.58	14.83	14.92
Fish without swim bladder	L_E [c]	216	2.41				
	L_{pk} [c]	213	NA	0.06	0.10	0.16	0.15
Fish with swim bladder involved in hearing	L_E [c]	203	6.48				
	L_{pk} [c]	207	NA	0.13	0.16	0.44	0.44
Fish with swim bladder involved in hearing	L_E [c]	203	6.48				
	L_{pk} [c]	207	NA	0.13	0.16	0.44	0.44
Sea turtles	L_E [d]	204	6.11				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	1.21	1.27	2.00	3.43	3.58

Table G-46. Jacket foundation (4 m diameter, TRC V640 and MHU3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 10 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	9.27				
	L_{pk} [a]	206	NA	-	0.06	0.13	0.12
	L_p [b]	150	5.36	4.67	6.17	8.24	8.66
Fish ≤ 2 g	L_E [a]	183	12.02				
	L_{pk} [a]	206	NA	-	0.06	0.13	0.12
	L_p [b]	150	5.36	4.67	6.17	8.24	8.66
Fish without swim bladder	L_E [c]	216	0.66				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	3.13				
	L_{pk} [c]	207	NA	-	0.02	0.12	0.11
Fish with swim bladder involved in hearing	L_E [c]	203	3.13				
	L_{pk} [c]	207	NA	-	0.02	0.12	0.11
Sea turtles	L_E [d]	204	2.84				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.27	0.27	0.56	1.39	1.35

Table G-47. Jacket foundation (4 m diameter, TRC V640 and MHU3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 12 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	8.33				
	L_{pk} [a]	206	NA	-	-	0.10	0.09
	L_p [b]	150	4.60	4.12	5.44	7.31	7.75
Fish ≤ 2 g	L_E [a]	183	10.66				
	L_{pk} [a]	206	NA	-	-	0.10	0.09
	L_p [b]	150	4.60	4.12	5.44	7.31	7.75
Fish without swim bladder	L_E [c]	216	0.51				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	2.61				
	L_{pk} [c]	207	NA	-	-	0.09	0.09
Fish with swim bladder involved in hearing	L_E [c]	203	2.61				
	L_{pk} [c]	207	NA	-	-	0.09	0.09
Sea turtles	L_E [d]	204	2.41				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.16	0.20	0.43	1.06	0.98

Table G-48. Jacket foundation (4 m diameter, TRC V640 and MHU3500) acoustic ranges ($R_{95\%}$ in km) to fish and sea turtle injury and behavioral thresholds at location J1 for different energy levels with 15 dB attenuation.

Faunal group	Metric	Threshold (dB)	Hammer energy (kJ)				
			Annual				
			Vibratory	525	1000	3500 (a)	3500 (b)
Fish ≥ 2g	L_E [a]	187	6.90				
	L_{pk} [a]	206	NA	-	-	0.06	0.03
	L_p [b]	150	3.69	3.28	4.51	6.23	6.56
Fish ≤ 2 g	L_E [a]	183	8.81				
	L_{pk} [a]	206	NA	-	-	0.06	0.03
	L_p [b]	150	3.69	3.28	4.51	6.23	6.56
Fish without swim bladder	L_E [c]	216	0.29				
	L_{pk} [c]	213	NA	-	-	-	-
Fish with swim bladder involved in hearing	L_E [c]	203	1.90				
	L_{pk} [c]	207	NA	-	-	0.02	0.02
Fish with swim bladder involved in hearing	L_E [c]	203	1.90				
	L_{pk} [c]	207	NA	-	-	0.02	0.02
Sea turtles	L_E [d]	204	1.73				
	L_{pk} [d]	232	NA	-	-	-	-
	L_p [e]	175	0.12	0.13	0.25	0.66	0.63

G.5. Single-strike SPL Acoustic Ranges

G.5.1. Impact Pile Driving

G.5.1.1. Monopile Foundations

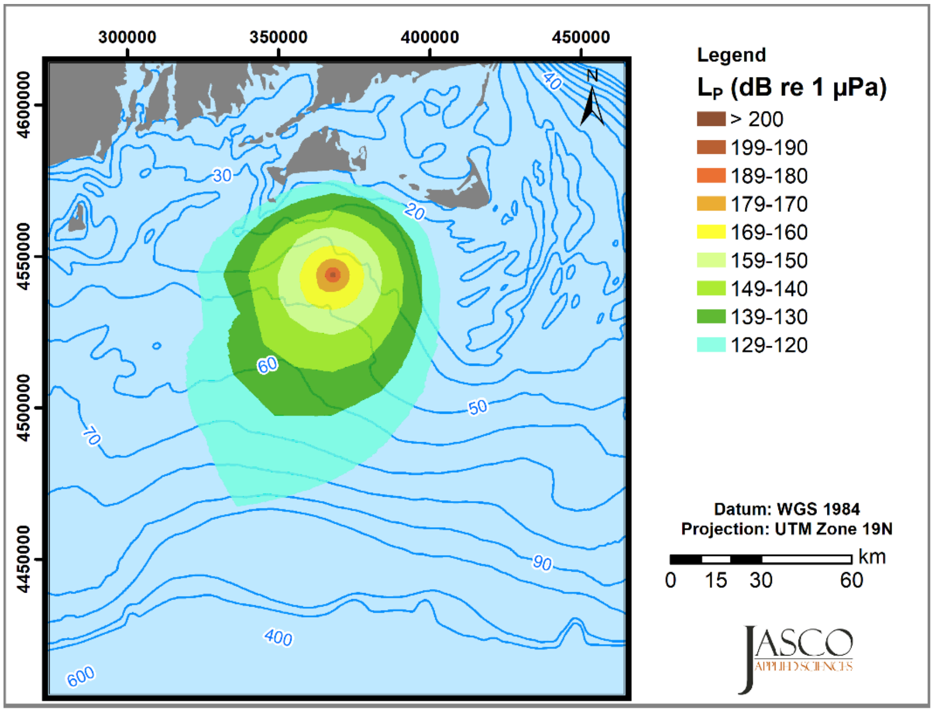

Figure G-9. 12 m monopile foundation unweighted single-strike sound pressure level (SPL) at 5000 kJ at M1.

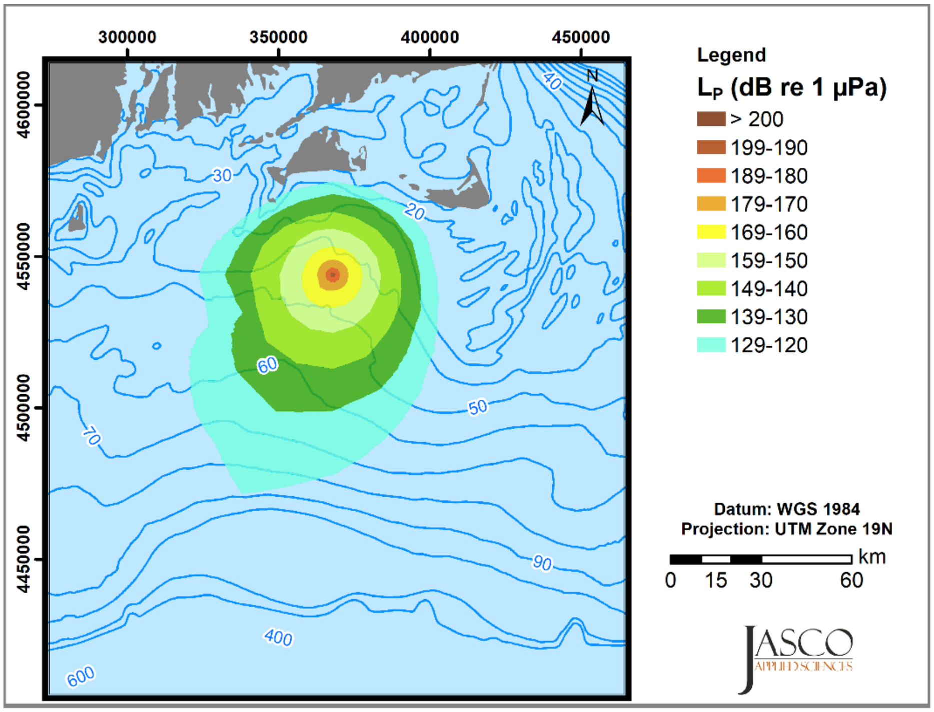

Figure G-10. 12 m monopile foundation unweighted single-strike sound pressure level (SPL) at 6000 kJ at M1.

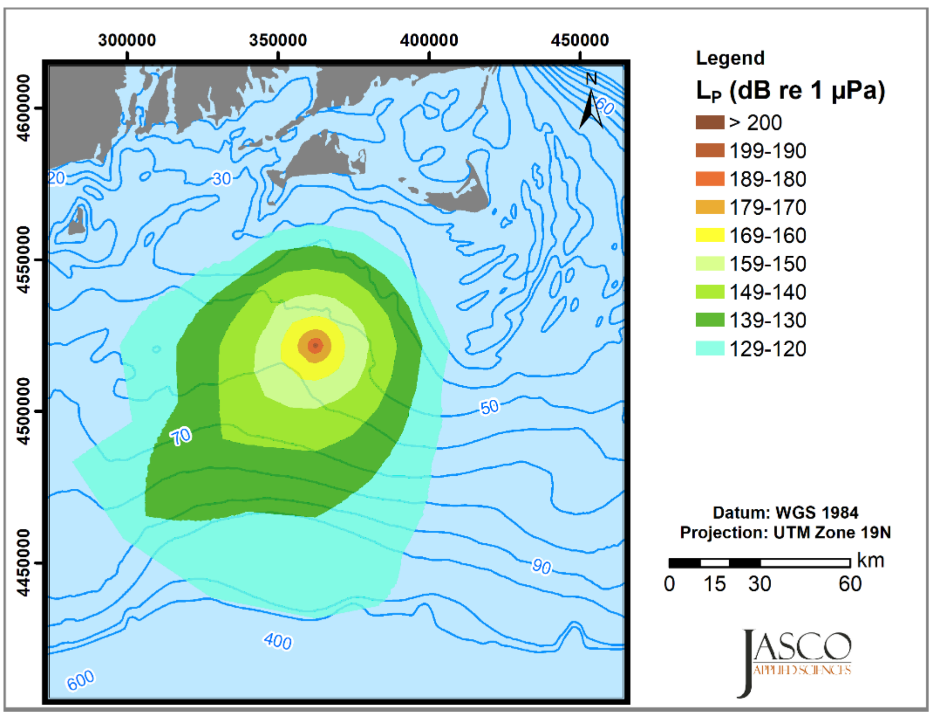

Figure G-11. 13 m monopile foundation unweighted single-strike sound pressure level (SPL) at 5000 kJ at M2.

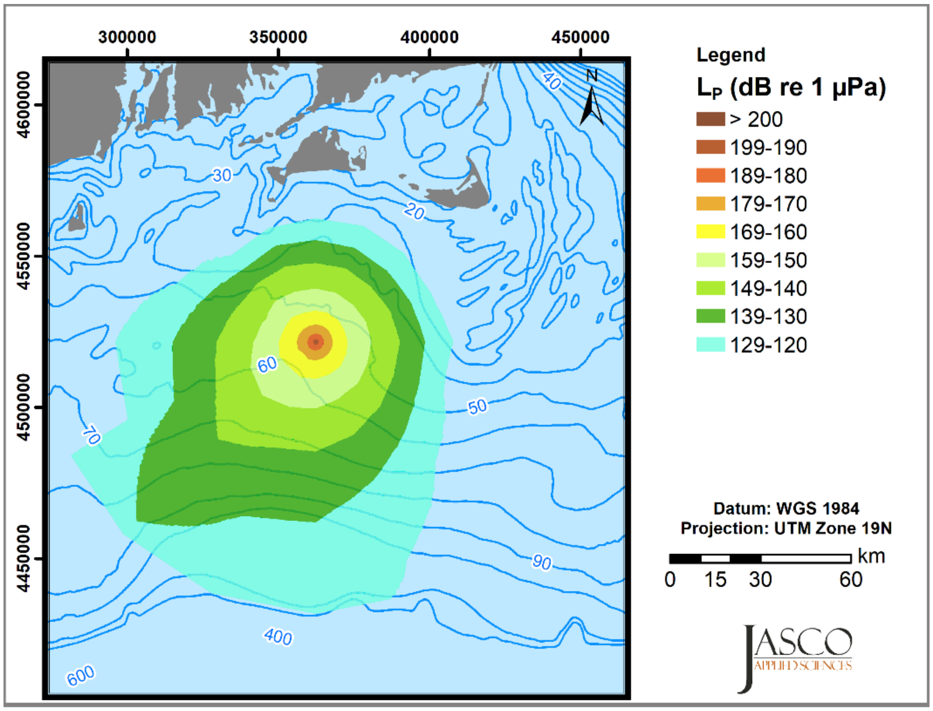

Figure G-12. 13 m monopile foundation unweighted single-strike sound pressure level (SPL) at 6000 kJ at M2.

Table G-49. Monopile foundation (12 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.06	0.06	0.06	0.06	-	-	-	-	-	-
190	0.24	0.23	0.23	0.23	0.05	0.05	-	-	0.12	0.12
180	1.13	1.08	1.10	1.06	0.23	0.23	0.13	0.13	0.57	0.56
175	1.92	1.84	1.90	1.82	0.48	0.47	0.37	0.36	1.13	1.09
170	2.96	2.82	2.94	2.80	1.09	1.03	0.72	0.69	1.92	1.83
160	7.18	6.28	7.13	6.23	2.84	2.69	2.26	2.14	4.48	4.16
150	13.48	12.13	13.42	12.07	6.46	5.63	4.96	4.56	9.63	8.63
140	22.56	20.18	22.46	20.09	12.88	11.33	10.01	8.88	18.12	16.04
130	35.61	31.21	35.46	31.09	23.28	20.37	19.24	16.79	30.33	26.82
120	54.56	46.24	54.21	45.98	39.37	33.40	34.07	29.24	48.46	40.94

Table G-50. Monopile foundation (12 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.24	0.23	0.23	0.23	0.05	0.05	-	-	0.12	0.12
175	0.58	0.56	0.57	0.54	0.12	0.12	0.09	0.09	0.24	0.23
170	1.13	1.08	1.10	1.06	0.23	0.23	0.13	0.13	0.57	0.56
160	2.96	2.82	2.94	2.80	1.09	1.03	0.72	0.69	1.92	1.83
150	7.18	6.28	7.13	6.23	2.84	2.69	2.26	2.14	4.48	4.16
140	13.48	12.13	13.42	12.07	6.46	5.63	4.96	4.56	9.63	8.63
130	22.56	20.18	22.46	20.09	12.88	11.33	10.01	8.88	18.12	16.04
120	35.61	31.21	35.46	31.09	23.28	20.37	19.24	16.79	30.33	26.82

Table G-51. Monopile foundation (12 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.03	0.03	0.03	0.03	-	-	-	-	-	-
180	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
175	0.41	0.39	0.40	0.39	0.09	0.09	0.05	0.05	0.15	0.14
170	0.89	0.85	0.87	0.83	0.14	0.14	0.12	0.12	0.41	0.39
160	2.58	2.45	2.54	2.43	0.78	0.75	0.48	0.47	1.60	1.53
150	6.25	5.43	6.19	5.39	2.46	2.33	1.87	1.78	3.80	3.59
140	12.06	10.75	11.99	10.68	5.61	4.90	4.24	3.98	8.53	7.53
130	19.92	17.94	19.86	17.88	11.11	9.70	8.88	7.85	16.26	14.41
120	32.58	28.80	32.44	28.69	20.34	17.85	17.36	15.00	27.58	24.57

Table G-52. Monopile foundation (12 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
175	0.24	0.23	0.23	0.23	0.05	0.05	-	-	0.12	0.12
170	0.58	0.56	0.57	0.54	0.12	0.12	0.09	0.09	0.24	0.23
160	1.92	1.84	1.90	1.82	0.48	0.47	0.37	0.36	1.13	1.09
150	4.63	4.30	4.57	4.26	1.85	1.77	1.39	1.32	2.92	2.78
140	9.79	8.79	9.73	8.75	4.21	3.97	3.38	3.16	6.90	6.02
130	17.54	15.65	17.48	15.59	9.02	7.99	7.33	6.36	13.62	12.17
120	28.57	25.54	28.45	25.46	17.49	15.24	14.48	12.59	23.82	21.20

Table G-53. Monopile foundation (12 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
190	0.42	0.40	0.41	0.40	0.10	0.09	0.06	0.06	0.17	0.17
180	1.63	1.57	1.61	1.55	0.42	0.41	0.26	0.25	0.94	0.89
175	2.63	2.50	2.60	2.49	0.81	0.78	0.54	0.51	1.67	1.59
170	4.01	3.79	3.97	3.75	1.60	1.52	1.17	1.11	2.62	2.50
160	8.95	7.99	8.90	7.94	3.74	3.52	2.94	2.78	6.07	5.27
150	16.19	14.38	16.12	14.32	8.12	7.09	6.53	5.70	12.34	10.89
140	26.27	23.57	26.17	23.49	16.03	13.86	13.24	11.40	21.49	18.83
130	41.54	35.66	41.33	35.51	27.92	24.36	23.93	20.58	35.81	30.91
120	64.56	54.16	63.86	53.74	48.08	39.74	41.96	34.71	57.59	48.21

Table G-54. Monopile foundation (12 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.42	0.40	0.41	0.40	0.10	0.09	0.06	0.06	0.17	0.17
175	0.92	0.86	0.90	0.83	0.15	0.14	0.12	0.12	0.43	0.42
170	1.63	1.57	1.61	1.55	0.42	0.41	0.26	0.25	0.94	0.89
160	4.01	3.79	3.97	3.75	1.60	1.52	1.17	1.11	2.62	2.50
150	8.95	7.99	8.90	7.94	3.74	3.52	2.94	2.78	6.07	5.27
140	16.19	14.38	16.12	14.32	8.12	7.09	6.53	5.70	12.34	10.89
130	26.27	23.57	26.17	23.49	16.03	13.86	13.24	11.40	21.49	18.83
120	41.54	35.66	41.33	35.51	27.92	24.36	23.93	20.58	35.81	30.91

Table G-55. Monopile foundation (12 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.07	0.07	0.07	0.07	-	-	-	-	-	-
180	0.31	0.31	0.31	0.30	0.08	0.08	0.02	0.02	0.13	0.13
175	0.68	0.66	0.68	0.65	0.13	0.13	0.10	0.10	0.32	0.31
170	1.31	1.25	1.29	1.24	0.27	0.26	0.15	0.14	0.70	0.68
160	3.35	3.18	3.32	3.14	1.28	1.23	0.84	0.80	2.20	2.09
150	7.89	6.95	7.84	6.89	3.16	2.97	2.57	2.44	5.07	4.55
140	14.56	13.01	14.49	12.95	7.03	6.12	5.70	4.97	10.52	9.32
130	24.01	21.47	23.92	21.38	14.20	12.33	11.52	9.79	19.23	17.02
120	37.87	32.81	37.70	32.69	25.09	21.97	20.96	18.02	32.33	28.24

Table G-56. Monopile foundation (12 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.03	0.03	0.03	0.03	-	-	-	-	-	-
180	0.17	0.17	0.16	0.16	0.02	0.02	-	-	0.09	0.09
175	0.42	0.40	0.41	0.40	0.10	0.09	0.06	0.06	0.17	0.17
170	0.92	0.86	0.90	0.83	0.15	0.14	0.12	0.12	0.43	0.42
160	2.63	2.50	2.60	2.49	0.81	0.78	0.54	0.51	1.67	1.59
150	6.35	5.57	6.31	5.52	2.55	2.42	1.94	1.84	3.91	3.69
140	12.30	11.02	12.25	10.95	5.70	4.97	4.36	4.07	8.68	7.70
130	20.23	18.05	20.12	17.98	11.61	9.99	9.20	8.06	16.63	14.60
120	32.98	28.96	32.85	28.85	20.94	18.13	17.91	15.36	27.92	24.71

Table G-57. Monopile foundation (12 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
190	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.24	0.24
180	1.93	1.85	1.91	1.83	0.49	0.46	0.38	0.37	1.15	1.10
175	2.98	2.83	2.96	2.81	1.10	1.05	0.72	0.69	1.94	1.85
170	4.71	4.34	4.64	4.31	1.87	1.79	1.42	1.35	2.94	2.80
160	9.87	8.89	9.83	8.84	4.27	4.02	3.44	3.21	7.04	6.15
150	17.77	15.86	17.71	15.79	9.16	8.13	7.50	6.52	13.88	12.38
140	28.97	25.81	28.87	25.72	17.74	15.46	14.75	12.80	24.12	21.46
130	44.80	38.43	44.59	38.26	30.67	26.67	26.31	23.01	39.00	33.54
120	67.34	56.78	66.54	56.29	50.24	42.40	44.92	37.70	59.21	50.49

Table G-58. Monopile foundation (12 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
180	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.24	0.24
175	1.13	1.08	1.11	1.07	0.24	0.23	0.14	0.13	0.59	0.57
170	1.93	1.85	1.91	1.83	0.49	0.46	0.38	0.37	1.15	1.10
160	4.71	4.34	4.64	4.31	1.87	1.79	1.42	1.35	2.94	2.80
150	9.87	8.89	9.83	8.84	4.27	4.02	3.44	3.21	7.04	6.15
140	17.77	15.86	17.71	15.79	9.16	8.13	7.50	6.52	13.88	12.38
130	28.97	25.81	28.87	25.72	17.74	15.46	14.75	12.80	24.12	21.46
120	44.80	38.43	44.59	38.26	30.67	26.67	26.31	23.01	39.00	33.54

Table G-59. Monopile foundation (12 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.40	0.39	0.40	0.38	0.09	0.09	0.05	0.05	0.15	0.14
175	0.91	0.87	0.90	0.85	0.14	0.14	0.12	0.12	0.41	0.39
170	1.60	1.53	1.58	1.52	0.40	0.39	0.26	0.24	0.92	0.88
160	3.94	3.73	3.90	3.69	1.54	1.47	1.12	1.07	2.58	2.45
150	8.88	7.89	8.83	7.84	3.68	3.47	2.88	2.74	6.12	5.30
140	16.06	14.37	15.99	14.31	8.10	7.07	6.58	5.73	12.23	10.90
130	26.41	23.76	26.31	23.66	15.82	13.80	12.99	11.31	21.43	18.92
120	41.28	35.58	41.09	35.45	27.65	24.26	23.53	20.45	35.57	30.81

Table G-60. Monopile foundation (12 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.24	0.23	0.24	0.23	0.06	0.06	-	-	0.12	0.12
175	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.24	0.24
170	1.13	1.08	1.11	1.07	0.24	0.23	0.14	0.13	0.59	0.57
160	2.98	2.83	2.96	2.81	1.10	1.05	0.72	0.69	1.94	1.85
150	7.30	6.37	7.24	6.32	2.86	2.72	2.30	2.18	4.57	4.22
140	13.66	12.30	13.59	12.24	6.62	5.74	5.15	4.63	9.76	8.76
130	22.84	20.46	22.75	20.37	13.14	11.54	10.30	9.02	18.36	16.26
120	36.26	31.59	36.11	31.48	23.54	20.62	19.41	17.00	30.77	27.07

Table G-61. Monopile foundation (12 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
190	0.74	0.72	0.74	0.71	0.14	0.13	0.11	0.11	0.38	0.37
180	2.40	2.28	2.36	2.25	0.74	0.71	0.45	0.44	1.49	1.42
175	3.64	3.44	3.60	3.41	1.43	1.37	1.01	0.96	2.42	2.30
170	5.86	5.07	5.80	5.03	2.34	2.22	1.78	1.70	3.62	3.41
160	11.46	10.13	11.37	10.06	5.32	4.70	4.09	3.83	8.15	7.12
150	19.37	17.39	19.31	17.34	10.53	9.23	8.54	7.50	15.67	13.87
140	31.56	28.02	31.45	27.91	19.62	17.27	16.78	14.46	26.72	23.86
130	48.83	41.72	48.58	41.52	34.16	29.54	29.64	25.70	42.89	36.66
120	78.26	64.65	77.13	63.82	56.55	47.37	50.62	42.11	68.50	56.86

Table G-62. Monopile foundation (12 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
180	0.74	0.72	0.74	0.71	0.14	0.13	0.11	0.11	0.38	0.37
175	1.45	1.39	1.43	1.38	0.38	0.37	0.23	0.23	0.75	0.72
170	2.40	2.28	2.36	2.25	0.74	0.71	0.45	0.44	1.49	1.42
160	5.86	5.07	5.80	5.03	2.34	2.22	1.78	1.70	3.62	3.41
150	11.46	10.13	11.37	10.06	5.32	4.70	4.09	3.83	8.15	7.12
140	19.37	17.39	19.31	17.34	10.53	9.23	8.54	7.50	15.67	13.87
130	31.56	28.02	31.45	27.91	19.62	17.27	16.78	14.46	26.72	23.86
120	48.83	41.72	48.58	41.52	34.16	29.54	29.64	25.70	42.89	36.66

Table G-63. Monopile foundation (12 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.12	0.12	0.12	0.12	-	-	-	-	0.07	0.07
180	0.58	0.56	0.58	0.56	0.12	0.12	0.09	0.09	0.25	0.24
175	1.15	1.10	1.13	1.09	0.24	0.24	0.14	0.13	0.60	0.58
170	1.94	1.86	1.93	1.85	0.55	0.53	0.39	0.38	1.19	1.14
160	4.71	4.34	4.65	4.31	1.92	1.83	1.45	1.39	2.99	2.85
150	9.86	8.86	9.82	8.82	4.34	4.08	3.52	3.28	7.04	6.14
140	17.78	15.86	17.72	15.80	9.21	8.15	7.51	6.52	13.91	12.38
130	28.96	25.87	28.86	25.78	17.86	15.53	14.88	12.86	24.24	21.59
120	44.94	38.55	44.71	38.37	30.85	26.93	26.64	23.25	39.04	33.69

Table G-64. Monopile foundation (12 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.37	0.36	0.36	0.35	0.09	0.09	0.04	0.04	0.14	0.13
175	0.74	0.72	0.74	0.71	0.14	0.13	0.11	0.11	0.38	0.37
170	1.45	1.39	1.43	1.38	0.38	0.37	0.23	0.23	0.75	0.72
160	3.64	3.44	3.60	3.41	1.43	1.37	1.01	0.96	2.42	2.30
150	8.30	7.32	8.25	7.26	3.48	3.26	2.76	2.61	5.69	4.95
140	15.23	13.64	15.16	13.58	7.58	6.57	6.19	5.39	11.43	10.07
130	25.41	22.81	25.31	22.73	14.98	13.07	12.26	10.58	20.11	17.91
120	39.47	34.25	39.27	34.11	26.48	23.32	22.36	19.28	33.78	29.63

Table G-65. Monopile foundation (12 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
190	0.41	0.40	0.40	0.39	0.10	0.09	0.06	0.06	0.15	0.14
180	1.61	1.55	1.59	1.53	0.41	0.40	0.26	0.25	0.91	0.86
175	2.58	2.45	2.56	2.43	0.81	0.77	0.51	0.49	1.62	1.55
170	3.90	3.70	3.87	3.66	1.55	1.48	1.13	1.08	2.56	2.44
160	8.80	7.79	8.74	7.74	3.68	3.45	2.88	2.73	6.03	5.21
150	15.83	14.22	15.76	14.17	8.06	7.01	6.51	5.68	12.16	10.80
140	26.45	23.73	26.36	23.65	15.70	13.77	12.90	11.30	21.36	18.94
130	41.18	35.59	40.98	35.44	27.77	24.49	23.75	20.68	35.50	30.95
120	62.95	53.20	62.45	52.82	47.07	39.27	41.18	34.58	56.20	47.34

Table G-66. Monopile foundation (12 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.41	0.40	0.40	0.39	0.10	0.09	0.06	0.06	0.15	0.14
175	0.91	0.86	0.89	0.85	0.15	0.14	0.12	0.12	0.42	0.40
170	1.61	1.55	1.59	1.53	0.41	0.40	0.26	0.25	0.91	0.86
160	3.90	3.70	3.87	3.66	1.55	1.48	1.13	1.08	2.56	2.44
150	8.80	7.79	8.74	7.74	3.68	3.45	2.88	2.73	6.03	5.21
140	15.83	14.22	15.76	14.17	8.06	7.01	6.51	5.68	12.16	10.80
130	26.45	23.73	26.36	23.65	15.70	13.77	12.90	11.30	21.36	18.94
120	41.18	35.59	40.98	35.44	27.77	24.49	23.75	20.68	35.50	30.95

Table G-67. Monopile foundation (12 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.07	0.07	0.07	0.07	-	-	-	-	-	-
180	0.31	0.30	0.30	0.29	0.08	0.08	-	-	0.13	0.13
175	0.66	0.64	0.65	0.63	0.13	0.13	0.10	0.10	0.30	0.29
170	1.30	1.25	1.28	1.23	0.26	0.26	0.15	0.14	0.67	0.64
160	3.27	3.09	3.22	3.05	1.25	1.20	0.83	0.79	2.14	2.03
150	7.72	6.74	7.67	6.68	3.08	2.90	2.52	2.38	4.94	4.48
140	14.27	12.83	14.21	12.77	6.96	6.07	5.66	4.94	10.44	9.24
130	24.08	21.58	23.99	21.49	13.87	12.25	11.15	9.67	19.10	17.05
120	37.64	32.85	37.47	32.73	24.97	22.11	20.69	18.01	32.15	28.38

Table G-68. Monopile foundation (12 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.03	0.03	0.03	0.03	-	-	-	-	-	-
180	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
175	0.41	0.40	0.40	0.39	0.10	0.09	0.06	0.06	0.15	0.14
170	0.91	0.86	0.89	0.85	0.15	0.14	0.12	0.12	0.42	0.40
160	2.58	2.45	2.56	2.43	0.81	0.77	0.51	0.49	1.62	1.55
150	6.25	5.43	6.19	5.38	2.49	2.36	1.89	1.81	3.82	3.60
140	12.11	10.78	12.05	10.71	5.66	4.94	4.30	4.02	8.63	7.60
130	19.99	18.04	19.92	17.98	11.27	9.88	9.04	7.98	16.37	14.56
120	32.89	29.12	32.76	29.01	20.70	18.16	17.60	15.26	27.89	24.91

Table G-69. Monopile foundation (12 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
190	0.54	0.52	0.53	0.51	0.12	0.12	0.09	0.09	0.24	0.23
180	1.88	1.81	1.87	1.79	0.48	0.46	0.38	0.36	1.12	1.07
175	2.92	2.78	2.90	2.76	1.09	1.03	0.72	0.70	1.90	1.82
170	4.53	4.23	4.48	4.19	1.86	1.77	1.39	1.33	2.91	2.77
160	9.73	8.70	9.67	8.65	4.22	3.98	3.42	3.18	6.86	5.96
150	17.32	15.49	17.24	15.43	9.02	7.91	7.33	6.36	13.49	12.02
140	28.34	25.24	28.24	25.16	17.28	15.08	14.37	12.49	23.53	20.88
130	43.60	37.56	43.36	37.39	29.90	26.25	25.79	22.64	37.75	32.84
120	67.95	56.73	67.07	56.21	50.59	42.10	44.66	37.19	59.88	50.50

Table G-70. Monopile foundation (12 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
180	0.54	0.52	0.53	0.51	0.12	0.12	0.09	0.09	0.24	0.23
175	1.09	1.04	1.07	1.03	0.24	0.23	0.13	0.13	0.55	0.53
170	1.88	1.81	1.87	1.79	0.48	0.46	0.38	0.36	1.12	1.07
160	4.53	4.23	4.48	4.19	1.86	1.77	1.39	1.33	2.91	2.77
150	9.73	8.70	9.67	8.65	4.22	3.98	3.42	3.18	6.86	5.96
140	17.32	15.49	17.24	15.43	9.02	7.91	7.33	6.36	13.49	12.02
130	28.34	25.24	28.24	25.16	17.28	15.08	14.37	12.49	23.53	20.88
120	43.60	37.56	43.36	37.39	29.90	26.25	25.79	22.64	37.75	32.84

Table G-71. Monopile foundation (12 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.40	0.38	0.39	0.38	0.09	0.09	0.05	0.05	0.14	0.14
175	0.84	0.80	0.83	0.78	0.14	0.14	0.12	0.12	0.41	0.39
170	1.55	1.49	1.53	1.47	0.40	0.39	0.25	0.24	0.84	0.81
160	3.84	3.63	3.80	3.60	1.52	1.45	1.10	1.05	2.54	2.41
150	8.70	7.68	8.66	7.63	3.66	3.43	2.88	2.72	5.97	5.15
140	15.64	14.03	15.57	13.97	7.93	6.85	6.44	5.61	11.96	10.51
130	26.11	23.26	25.99	23.18	15.35	13.44	12.65	11.02	20.63	18.35
120	39.92	34.75	39.73	34.61	26.99	23.87	22.97	20.00	34.25	30.13

Table G-72. Monopile foundation (12 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.23	0.23	0.23	0.22	0.05	0.05	-	-	0.12	0.12
175	0.54	0.52	0.53	0.51	0.12	0.12	0.09	0.09	0.24	0.23
170	1.09	1.04	1.07	1.03	0.24	0.23	0.13	0.13	0.55	0.53
160	2.92	2.78	2.90	2.76	1.09	1.03	0.72	0.70	1.90	1.82
150	7.09	6.18	7.03	6.13	2.84	2.70	2.28	2.16	4.46	4.13
140	13.44	12.01	13.38	11.95	6.45	5.61	5.00	4.57	9.60	8.53
130	22.46	19.88	22.35	19.77	12.74	11.21	9.94	8.82	17.86	15.84
120	34.90	30.84	34.75	30.72	22.90	20.11	19.07	16.66	29.81	26.52

Table G-73. Monopile foundation (12 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
190	0.69	0.67	0.68	0.66	0.13	0.13	0.10	0.10	0.35	0.34
180	2.26	2.16	2.24	2.13	0.68	0.66	0.43	0.41	1.39	1.33
175	3.46	3.28	3.43	3.24	1.32	1.27	0.93	0.89	2.28	2.16
170	5.60	4.90	5.52	4.85	2.20	2.08	1.67	1.60	3.42	3.23
160	11.07	9.77	11.00	9.70	4.92	4.49	3.90	3.66	7.86	6.85
150	18.95	16.99	18.88	16.93	10.00	8.90	8.23	7.21	15.16	13.45
140	30.77	27.34	30.66	27.24	19.06	16.73	16.17	13.94	25.87	23.14
130	47.33	40.52	47.08	40.34	33.02	28.56	28.55	24.77	41.57	35.60
120	74.58	61.69	73.54	60.98	54.01	45.38	48.45	40.48	64.95	54.34

Table G-74. Monopile foundation (12 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.09	0.09
180	0.69	0.67	0.68	0.66	0.13	0.13	0.10	0.10	0.35	0.34
175	1.36	1.31	1.35	1.30	0.34	0.34	0.20	0.19	0.70	0.68
170	2.26	2.16	2.24	2.13	0.68	0.66	0.43	0.41	1.39	1.33
160	5.60	4.90	5.52	4.85	2.20	2.08	1.67	1.60	3.42	3.23
150	11.07	9.77	11.00	9.70	4.92	4.49	3.90	3.66	7.86	6.85
140	18.95	16.99	18.88	16.93	10.00	8.90	8.23	7.21	15.16	13.45
130	30.77	27.34	30.66	27.24	19.06	16.73	16.17	13.94	25.87	23.14
120	47.33	40.52	47.08	40.34	33.02	28.56	28.55	24.77	41.57	35.60

Table G-75. Monopile foundation (12 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.06	0.06
180	0.53	0.51	0.52	0.50	0.11	0.11	0.09	0.09	0.23	0.23
175	1.06	1.02	1.05	1.01	0.23	0.22	0.13	0.13	0.54	0.52
170	1.86	1.78	1.84	1.77	0.46	0.44	0.36	0.35	1.09	1.05
160	4.47	4.18	4.42	4.15	1.82	1.73	1.35	1.28	2.88	2.73
150	9.65	8.65	9.59	8.61	4.14	3.91	3.32	3.11	6.80	5.93
140	17.33	15.46	17.26	15.40	8.90	7.86	7.24	6.29	13.44	12.00
130	28.16	25.20	28.03	25.12	17.25	15.00	14.31	12.41	23.41	20.78
120	43.66	37.52	43.45	37.37	29.81	26.00	25.58	22.36	37.87	32.70

Table G-76. Monopile foundation (12 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.08	0.08	0.08	0.08	-	-	-	-	-	-
180	0.34	0.33	0.33	0.32	0.09	0.09	0.02	0.02	0.13	0.13
175	0.69	0.67	0.68	0.66	0.13	0.13	0.10	0.10	0.35	0.34
170	1.36	1.31	1.35	1.30	0.34	0.34	0.20	0.19	0.70	0.68
160	3.46	3.28	3.43	3.24	1.32	1.27	0.93	0.89	2.28	2.16
150	8.09	7.10	8.03	7.05	3.28	3.08	2.64	2.50	5.32	4.73
140	14.81	13.30	14.74	13.25	7.30	6.32	6.00	5.17	10.93	9.65
130	24.66	22.17	24.58	22.08	14.44	12.63	11.74	10.11	19.56	17.44
120	38.42	33.38	38.24	33.25	25.50	22.47	21.31	18.39	32.84	28.77

Table G-77. Monopile foundation (12 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.15	0.14	0.14	0.14	0.02	0.02	-	-	0.09	0.09
190	0.90	0.86	0.89	0.85	0.14	0.14	0.12	0.12	0.41	0.39
180	2.58	2.46	2.56	2.44	0.85	0.80	0.53	0.50	1.63	1.57
175	3.92	3.72	3.90	3.68	1.57	1.50	1.13	1.08	2.60	2.47
170	6.28	5.46	6.24	5.41	2.53	2.40	1.92	1.83	3.88	3.67
160	12.18	10.79	12.11	10.72	5.76	5.02	4.34	4.06	8.67	7.61
150	20.08	18.05	19.98	17.99	11.37	9.84	9.05	7.95	16.48	14.56
140	32.98	29.10	32.85	29.00	20.72	18.05	17.68	15.20	27.93	24.81
130	50.21	43.06	49.93	42.85	36.26	30.82	31.26	26.81	44.66	38.02
120	82.80	67.88	81.49	66.86	58.64	48.90	52.54	43.67	72.69	59.26

Table G-78. Monopile foundation (12 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.03	0.03	0.03	0.03	-	-	-	-	-	-
190	0.15	0.14	0.14	0.14	0.02	0.02	-	-	0.09	0.09
180	0.90	0.86	0.89	0.85	0.14	0.14	0.12	0.12	0.41	0.39
175	1.60	1.54	1.58	1.52	0.41	0.39	0.26	0.24	0.92	0.88
170	2.58	2.46	2.56	2.44	0.85	0.80	0.53	0.50	1.63	1.57
160	6.28	5.46	6.24	5.41	2.53	2.40	1.92	1.83	3.88	3.67
150	12.18	10.79	12.11	10.72	5.76	5.02	4.34	4.06	8.67	7.61
140	20.08	18.05	19.98	17.99	11.37	9.84	9.05	7.95	16.48	14.56
130	32.98	29.10	32.85	29.00	20.72	18.05	17.68	15.20	27.93	24.81
120	50.21	43.06	49.93	42.85	36.26	30.82	31.26	26.81	44.66	38.02

Table G-79. Monopile foundation (12 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.12	0.12	0.12	0.12	-	-	-	-	0.08	0.08
180	0.65	0.63	0.65	0.62	0.13	0.13	0.10	0.10	0.33	0.32
175	1.28	1.23	1.26	1.22	0.26	0.26	0.15	0.14	0.67	0.64
170	2.12	2.02	2.10	2.00	0.65	0.62	0.41	0.40	1.31	1.26
160	5.18	4.68	5.09	4.64	2.08	1.97	1.59	1.52	3.26	3.08
150	10.55	9.30	10.48	9.25	4.70	4.35	3.76	3.52	7.58	6.56
140	18.50	16.55	18.44	16.49	9.69	8.60	8.00	6.94	14.68	13.02
130	30.18	26.85	30.06	26.76	18.68	16.30	15.72	13.52	25.34	22.64
120	46.50	39.88	46.27	39.71	32.50	28.04	28.04	24.26	40.85	35.00

Table G-80. Monopile foundation (12 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	0.02	0.02
180	0.40	0.39	0.40	0.38	0.10	0.09	0.06	0.06	0.19	0.18
175	0.90	0.86	0.89	0.85	0.14	0.14	0.12	0.12	0.41	0.39
170	1.60	1.54	1.58	1.52	0.41	0.39	0.26	0.24	0.92	0.88
160	3.92	3.72	3.90	3.68	1.57	1.50	1.13	1.08	2.60	2.47
150	8.81	7.78	8.75	7.73	3.72	3.50	2.92	2.76	6.14	5.31
140	15.95	14.27	15.89	14.21	8.10	7.03	6.61	5.75	12.21	10.79
130	26.53	23.74	26.43	23.65	15.83	13.74	13.00	11.26	21.40	18.89
120	41.11	35.52	40.92	35.38	27.82	24.32	23.73	20.45	35.55	30.82

Table G-81. Monopile foundation (13 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.06	0.06	0.06	0.06	-	-	-	-	-	-
190	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
180	1.26	1.17	1.23	1.15	0.23	0.22	0.15	0.14	0.57	0.54
175	2.17	2.00	2.14	1.97	0.53	0.49	0.32	0.30	1.17	1.11
170	3.44	3.12	3.38	3.08	1.04	0.98	0.72	0.63	2.09	1.92
160	7.40	6.58	7.33	6.52	3.08	2.79	2.42	2.21	4.83	4.40
150	15.13	13.26	15.02	13.17	6.31	5.68	5.17	4.68	9.68	8.62
140	26.94	23.83	26.81	23.72	12.80	11.32	9.76	8.76	19.76	17.22
130	47.11	38.98	46.80	38.75	28.99	22.64	23.14	17.77	39.63	31.53
120	87.34	70.64	85.33	69.52	56.34	43.78	47.80	36.93	73.65	57.88

Table G-82. Monopile foundation (13 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
175	0.60	0.57	0.58	0.56	0.12	0.12	0.09	0.09	0.26	0.26
170	1.26	1.17	1.23	1.15	0.23	0.22	0.15	0.14	0.57	0.54
160	3.44	3.12	3.38	3.08	1.04	0.98	0.72	0.63	2.09	1.92
150	7.40	6.58	7.33	6.52	3.08	2.79	2.42	2.21	4.83	4.40
140	15.13	13.26	15.02	13.17	6.31	5.68	5.17	4.68	9.68	8.62
130	26.94	23.83	26.81	23.72	12.80	11.32	9.76	8.76	19.76	17.22
120	47.11	38.98	46.80	38.75	28.99	22.64	23.14	17.77	39.63	31.53

Table G-83. Monopile foundation (13 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	0.02	0.02	-	-	-	-	-	-
180	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
175	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.15
170	0.93	0.88	0.92	0.87	0.16	0.15	0.13	0.12	0.44	0.42
160	2.86	2.64	2.84	2.61	0.85	0.80	0.54	0.49	1.71	1.59
150	6.41	5.75	6.37	5.69	2.65	2.43	1.95	1.82	4.20	3.83
140	13.33	11.70	13.23	11.61	5.57	5.02	4.54	4.12	8.51	7.55
130	24.03	21.32	23.90	21.20	10.81	9.58	8.68	7.73	17.30	15.26
120	42.43	35.28	42.17	35.10	24.98	19.45	19.23	15.52	35.23	28.28

Table G-84. Monopile foundation (13 m monopile with an MHU 5500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
175	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
170	0.60	0.57	0.58	0.56	0.12	0.12	0.09	0.09	0.26	0.26
160	2.17	2.00	2.14	1.97	0.53	0.49	0.32	0.30	1.17	1.11
150	5.16	4.65	5.10	4.61	1.95	1.82	1.43	1.33	3.29	2.98
140	10.67	9.28	10.55	9.20	4.54	4.14	3.70	3.29	6.84	6.12
130	19.74	17.61	19.64	17.52	8.83	7.87	7.04	6.32	14.01	12.51
120	36.23	30.46	36.02	30.32	19.23	15.86	15.03	12.65	28.99	23.95

Table G-85. Monopile foundation (13 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.11	0.11	0.11	0.11	-	-	-	-	0.02	0.02
190	0.46	0.44	0.46	0.44	0.10	0.10	0.03	0.03	0.19	0.16
180	1.86	1.74	1.84	1.72	0.44	0.42	0.27	0.26	0.96	0.92
175	2.96	2.74	2.94	2.72	0.90	0.85	0.57	0.52	1.81	1.70
170	4.55	4.15	4.51	4.11	1.71	1.58	1.16	1.10	2.90	2.68
160	9.52	8.42	9.44	8.35	4.12	3.74	3.26	2.89	6.11	5.49
150	18.39	16.30	18.29	16.21	7.88	7.01	6.34	5.73	12.63	11.23
140	33.12	28.09	32.92	27.96	17.40	14.40	13.35	11.47	26.09	21.87
130	56.31	46.72	55.81	46.39	37.25	28.63	30.94	23.62	48.23	38.21
120	>90	83.47	89.99	83.37	74.27	57.48	61.72	48.02	89.99	75.31

Table G-86. Monopile foundation (13 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.11	-	-	-	-	0.02	0.02
180	0.46	0.44	0.46	0.44	0.10	0.10	0.03	0.03	0.19	0.16
175	0.98	0.93	0.98	0.92	0.16	0.15	0.13	0.13	0.46	0.43
170	1.86	1.74	1.84	1.72	0.44	0.42	0.27	0.26	0.96	0.92
160	4.55	4.15	4.51	4.11	1.71	1.58	1.16	1.10	2.90	2.68
150	9.52	8.42	9.44	8.35	4.12	3.74	3.26	2.89	6.11	5.49
140	18.39	16.30	18.29	16.21	7.88	7.01	6.34	5.73	12.63	11.23
130	33.12	28.09	32.92	27.96	17.40	14.40	13.35	11.47	26.09	21.87
120	56.31	46.72	55.81	46.39	37.25	28.63	30.94	23.62	48.23	38.21

Table G-87. Monopile foundation (13 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.36	0.34	0.35	0.34	0.06	0.06	0.02	0.02	0.14	0.14
175	0.76	0.71	0.74	0.69	0.14	0.13	0.10	0.10	0.35	0.33
170	1.54	1.41	1.50	1.39	0.29	0.27	0.16	0.16	0.75	0.69
160	3.90	3.57	3.88	3.53	1.35	1.25	0.90	0.85	2.50	2.30
150	8.25	7.30	8.19	7.23	3.54	3.17	2.75	2.52	5.33	4.82
140	16.50	14.49	16.41	14.40	6.82	6.13	5.65	5.10	10.82	9.46
130	29.40	25.48	29.23	25.37	14.71	12.53	10.93	9.71	22.61	18.93
120	50.71	41.97	50.35	41.72	32.47	25.11	26.43	20.28	42.96	34.13

Table G-88. Monopile foundation (13 m monopile with an MHU 5500 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	0.02	0.02	-	-	-	-	-	-
180	0.22	0.20	0.21	0.20	0.02	0.02	-	-	0.11	0.11
175	0.46	0.44	0.46	0.44	0.10	0.10	0.03	0.03	0.19	0.16
170	0.98	0.93	0.98	0.92	0.16	0.15	0.13	0.13	0.46	0.43
160	2.96	2.74	2.94	2.72	0.90	0.85	0.57	0.52	1.81	1.70
150	6.58	5.89	6.54	5.84	2.75	2.53	2.08	1.90	4.33	3.96
140	13.75	12.05	13.66	11.96	5.69	5.13	4.66	4.24	8.70	7.72
130	24.68	21.93	24.55	21.80	11.22	9.98	8.93	7.94	18.05	15.77
120	43.36	35.94	43.08	35.75	25.97	20.39	20.25	16.14	36.11	28.94

Table G-89. Monopile foundation (13 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
190	0.60	0.57	0.58	0.56	0.13	0.13	0.10	0.09	0.28	0.27
180	2.21	2.03	2.18	2.00	0.55	0.51	0.40	0.38	1.24	1.16
175	3.48	3.16	3.44	3.13	1.13	1.05	0.81	0.72	2.20	2.00
170	5.17	4.67	5.13	4.63	2.06	1.89	1.51	1.40	3.43	3.10
160	10.57	9.21	10.46	9.14	4.68	4.28	3.84	3.44	7.10	6.31
150	19.88	17.68	19.80	17.60	9.16	8.15	7.32	6.52	14.62	12.70
140	38.58	31.23	38.35	31.08	21.17	16.44	16.43	13.11	31.28	24.82
130	67.19	53.80	66.50	53.29	44.25	34.08	36.88	28.22	57.30	45.04
120	>90	83.89	>90	83.85	87.37	68.86	73.12	57.83	89.99	79.54

Table G-90. Monopile foundation (13 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
180	0.60	0.57	0.58	0.56	0.13	0.13	0.10	0.09	0.28	0.27
175	1.26	1.18	1.24	1.16	0.26	0.25	0.15	0.15	0.58	0.56
170	2.21	2.03	2.18	2.00	0.55	0.51	0.40	0.38	1.24	1.16
160	5.17	4.67	5.13	4.63	2.06	1.89	1.51	1.40	3.43	3.10
150	10.57	9.21	10.46	9.14	4.68	4.28	3.84	3.44	7.10	6.31
140	19.88	17.68	19.80	17.60	9.16	8.15	7.32	6.52	14.62	12.70
130	38.58	31.23	38.35	31.08	21.17	16.44	16.43	13.11	31.28	24.82
120	67.19	53.80	66.50	53.29	44.25	34.08	36.88	28.22	57.30	45.04

Table G-91. Monopile foundation (13 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.46	0.44	0.45	0.43	0.10	0.10	0.03	0.03	0.17	0.16
175	0.94	0.89	0.94	0.88	0.16	0.15	0.13	0.13	0.46	0.44
170	1.80	1.68	1.78	1.65	0.46	0.43	0.28	0.26	0.95	0.89
160	4.44	4.05	4.39	4.01	1.69	1.56	1.12	1.05	2.86	2.64
150	9.21	8.16	9.14	8.10	4.12	3.75	3.22	2.88	6.19	5.54
140	17.79	15.86	17.69	15.77	8.03	7.12	6.43	5.80	12.38	11.05
130	34.28	28.18	34.07	28.05	18.03	14.36	13.61	11.42	27.39	21.94
120	59.91	47.96	59.37	47.58	38.78	29.74	31.82	24.33	50.93	39.91

Table G-92. Monopile foundation (13 m monopile with an MHU 5500 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.28	0.27	0.28	0.26	0.03	0.03	-	-	0.13	0.13
175	0.60	0.57	0.58	0.56	0.13	0.13	0.10	0.09	0.28	0.27
170	1.26	1.18	1.24	1.16	0.26	0.25	0.15	0.15	0.58	0.56
160	3.48	3.16	3.44	3.13	1.13	1.05	0.81	0.72	2.20	2.00
150	7.47	6.62	7.41	6.56	3.24	2.90	2.53	2.31	5.00	4.52
140	14.91	13.18	14.81	13.09	6.54	5.86	5.35	4.81	9.92	8.80
130	28.62	24.21	28.48	24.09	13.80	11.68	10.06	9.01	21.81	17.68
120	50.77	40.66	50.42	40.40	31.42	24.17	25.36	19.10	42.82	33.29

Table G-93. Monopile foundation (13 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.15	0.15	0.15	0.15	-	-	-	-	0.10	0.09
190	0.84	0.79	0.83	0.78	0.15	0.15	0.12	0.12	0.40	0.38
180	2.70	2.49	2.66	2.46	0.80	0.73	0.52	0.48	1.61	1.50
175	4.13	3.78	4.10	3.75	1.52	1.42	1.02	0.96	2.67	2.46
170	5.99	5.39	5.94	5.34	2.57	2.35	1.90	1.77	4.06	3.70
160	12.29	10.80	12.19	10.70	5.43	4.89	4.46	4.06	8.06	7.17
150	23.67	20.12	23.52	19.99	10.41	9.21	8.42	7.57	17.35	14.50
140	43.47	34.54	43.16	34.34	25.80	19.53	19.79	15.34	36.01	27.96
130	79.48	63.10	78.14	62.07	52.64	40.50	44.41	34.00	68.17	53.16
120	>90	84.05	>90	84.03	89.99	79.28	89.99	75.02	89.99	82.16

Table G-94. Monopile foundation (13 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.15	0.15	0.15	0.15	-	-	-	-	0.10	0.09
180	0.84	0.79	0.83	0.78	0.15	0.15	0.12	0.12	0.40	0.38
175	1.64	1.52	1.62	1.50	0.40	0.38	0.22	0.17	0.84	0.79
170	2.70	2.49	2.66	2.46	0.80	0.73	0.52	0.48	1.61	1.50
160	5.99	5.39	5.94	5.34	2.57	2.35	1.90	1.77	4.06	3.70
150	12.29	10.80	12.19	10.70	5.43	4.89	4.46	4.06	8.06	7.17
140	23.67	20.12	23.52	19.99	10.41	9.21	8.42	7.57	17.35	14.50
130	43.47	34.54	43.16	34.34	25.80	19.53	19.79	15.34	36.01	27.96
120	79.48	63.10	78.14	62.07	52.64	40.50	44.41	34.00	68.17	53.16

Table G-95. Monopile foundation (13 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
180	0.61	0.57	0.60	0.56	0.13	0.13	0.10	0.09	0.28	0.27
175	1.28	1.20	1.26	1.18	0.26	0.25	0.15	0.15	0.60	0.56
170	2.23	2.05	2.21	2.02	0.56	0.52	0.42	0.40	1.26	1.18
160	5.14	4.67	5.10	4.62	2.12	1.92	1.54	1.44	3.44	3.11
150	10.53	9.21	10.42	9.14	4.74	4.33	3.92	3.53	6.97	6.25
140	19.97	17.62	19.88	17.53	9.06	8.14	7.34	6.60	14.75	12.66
130	38.81	31.14	38.55	30.98	21.69	16.58	16.86	13.32	31.65	24.83
120	70.37	55.28	69.37	54.51	45.74	35.07	38.50	29.37	59.54	46.24

Table G-96. Monopile foundation (13 m monopile with an MHU 5500 hammer, 5000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.40	0.38	0.40	0.37	0.09	0.09	0.02	0.02	0.15	0.15
175	0.84	0.79	0.83	0.78	0.15	0.15	0.12	0.12	0.40	0.38
170	1.64	1.52	1.62	1.50	0.40	0.38	0.22	0.17	0.84	0.79
160	4.13	3.78	4.10	3.75	1.52	1.42	1.02	0.96	2.67	2.46
150	8.59	7.63	8.51	7.56	3.90	3.52	3.00	2.74	5.68	5.14
140	16.77	14.88	16.67	14.79	7.40	6.64	6.11	5.52	11.45	10.13
130	32.54	26.72	32.36	26.60	16.82	13.48	12.84	10.78	25.77	20.36
120	58.20	45.68	57.60	45.26	37.25	28.49	30.75	23.34	49.05	37.98

Table G-97. Monopile foundation (13 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
190	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
180	1.78	1.66	1.76	1.64	0.43	0.41	0.26	0.25	0.92	0.86
175	2.86	2.64	2.84	2.61	0.86	0.81	0.55	0.50	1.73	1.60
170	4.39	4.00	4.35	3.96	1.63	1.51	1.08	1.02	2.78	2.57
160	9.12	8.11	9.05	8.04	4.02	3.62	3.12	2.80	5.96	5.36
150	17.86	15.78	17.76	15.69	7.75	6.89	6.26	5.65	12.23	10.85
140	32.41	27.68	32.23	27.55	16.58	13.95	12.70	11.12	25.43	21.27
130	56.03	46.05	55.54	45.73	36.20	27.94	29.76	22.81	47.29	37.51
120	89.99	82.71	89.99	82.34	71.98	56.06	60.16	46.65	89.99	73.72

Table G-98. Monopile foundation (13 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
175	0.93	0.88	0.92	0.87	0.16	0.15	0.13	0.12	0.44	0.42
170	1.78	1.66	1.76	1.64	0.43	0.41	0.26	0.25	0.92	0.86
160	4.39	4.00	4.35	3.96	1.63	1.51	1.08	1.02	2.78	2.57
150	9.12	8.11	9.05	8.04	4.02	3.62	3.12	2.80	5.96	5.36
140	17.86	15.78	17.76	15.69	7.75	6.89	6.26	5.65	12.23	10.85
130	32.41	27.68	32.23	27.55	16.58	13.95	12.70	11.12	25.43	21.27
120	56.03	46.05	55.54	45.73	36.20	27.94	29.76	22.81	47.29	37.51

Table G-99. Monopile foundation (13 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.08	0.08	0.08	0.08	-	-	-	-	-	-
180	0.31	0.29	0.30	0.28	0.06	0.06	-	-	0.14	0.14
175	0.72	0.67	0.71	0.66	0.14	0.13	0.10	0.10	0.30	0.28
170	1.44	1.34	1.42	1.32	0.28	0.27	0.16	0.15	0.69	0.63
160	3.76	3.42	3.72	3.38	1.27	1.19	0.86	0.82	2.36	2.17
150	7.95	7.05	7.86	6.98	3.42	3.05	2.68	2.44	5.17	4.69
140	15.95	14.01	15.85	13.92	6.73	6.05	5.54	5.01	10.42	9.18
130	28.67	25.05	28.51	24.93	13.99	12.18	10.58	9.42	21.74	18.33
120	49.98	41.36	49.61	41.12	31.50	24.43	25.40	19.43	42.12	33.56

Table G-100. Monopile foundation (13 m monopile with an MHU 6000 hammer, 2000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	0.02	0.02	-	-	-	-	-	-
180	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
175	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
170	0.93	0.88	0.92	0.87	0.16	0.15	0.13	0.12	0.44	0.42
160	2.86	2.64	2.84	2.61	0.86	0.81	0.55	0.50	1.73	1.60
150	6.38	5.71	6.32	5.66	2.67	2.45	1.98	1.84	4.20	3.83
140	13.23	11.62	13.12	11.53	5.59	5.04	4.56	4.14	8.51	7.56
130	23.99	21.28	23.86	21.16	10.88	9.65	8.76	7.79	17.34	15.29
120	42.60	35.47	42.33	35.29	25.15	19.62	19.35	15.64	35.43	28.47

Table G-101. Monopile foundation (13 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
190	0.58	0.55	0.57	0.54	0.12	0.12	0.09	0.09	0.26	0.26
180	2.15	1.98	2.13	1.95	0.53	0.49	0.32	0.30	1.19	1.11
175	3.40	3.09	3.36	3.06	1.05	0.98	0.76	0.68	2.11	1.93
170	5.10	4.61	5.05	4.57	1.95	1.82	1.44	1.33	3.30	2.99
160	10.48	9.15	10.37	9.08	4.54	4.14	3.70	3.30	6.82	6.10
150	19.65	17.56	19.56	17.47	8.81	7.85	7.04	6.32	13.93	12.47
140	36.67	30.53	36.46	30.38	19.39	15.91	15.16	12.66	29.39	24.05
130	62.45	51.07	61.82	50.66	41.35	31.86	34.72	26.50	53.26	42.09
120	>90	83.79	>90	83.73	81.86	64.26	68.90	53.74	89.99	78.54

Table G-102. Monopile foundation (13 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.06	0.06
180	0.58	0.55	0.57	0.54	0.12	0.12	0.09	0.09	0.26	0.26
175	1.24	1.15	1.21	1.13	0.23	0.22	0.15	0.14	0.56	0.53
170	2.15	1.98	2.13	1.95	0.53	0.49	0.32	0.30	1.19	1.11
160	5.10	4.61	5.05	4.57	1.95	1.82	1.44	1.33	3.30	2.99
150	10.48	9.15	10.37	9.08	4.54	4.14	3.70	3.30	6.82	6.10
140	19.65	17.56	19.56	17.47	8.81	7.85	7.04	6.32	13.93	12.47
130	36.67	30.53	36.46	30.38	19.39	15.91	15.16	12.66	29.39	24.05
120	62.45	51.07	61.82	50.66	41.35	31.86	34.72	26.50	53.26	42.09

Table G-103. Monopile foundation (13 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.44	0.42	0.43	0.42	0.10	0.10	0.03	0.03	0.16	0.15
175	0.92	0.87	0.91	0.86	0.16	0.15	0.13	0.12	0.44	0.42
170	1.76	1.64	1.74	1.62	0.42	0.40	0.26	0.24	0.91	0.85
160	4.37	3.98	4.33	3.95	1.62	1.50	1.05	0.99	2.78	2.57
150	9.09	8.06	9.01	7.99	3.98	3.61	3.10	2.79	5.97	5.37
140	17.82	15.77	17.72	15.67	7.67	6.83	6.21	5.62	12.17	10.79
130	32.73	27.66	32.56	27.53	16.65	13.89	12.64	11.02	25.60	21.25
120	55.86	45.82	55.41	45.52	36.36	27.96	29.90	22.82	47.56	37.54

Table G-104. Monopile foundation (13 m monopile with an MHU 6000 hammer, 3000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.27	0.26	0.27	0.26	0.03	0.03	-	-	0.13	0.13
175	0.58	0.55	0.57	0.54	0.12	0.12	0.09	0.09	0.26	0.26
170	1.24	1.15	1.21	1.13	0.23	0.22	0.15	0.14	0.56	0.53
160	3.40	3.09	3.36	3.06	1.05	0.98	0.76	0.68	2.11	1.93
150	7.31	6.50	7.24	6.44	3.10	2.80	2.45	2.23	4.83	4.40
140	14.97	13.14	14.87	13.06	6.30	5.67	5.17	4.68	9.64	8.57
130	27.22	23.82	27.07	23.70	12.81	11.30	9.75	8.74	19.91	17.25
120	47.77	39.21	47.46	38.98	29.36	22.79	23.41	17.87	40.11	31.74

Table G-105. Monopile foundation (13 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
190	0.81	0.77	0.80	0.75	0.15	0.14	0.11	0.11	0.38	0.36
180	2.60	2.40	2.58	2.37	0.74	0.64	0.49	0.46	1.55	1.44
175	4.01	3.66	3.96	3.63	1.45	1.35	0.96	0.90	2.59	2.38
170	5.85	5.24	5.80	5.20	2.45	2.24	1.80	1.67	3.94	3.58
160	12.02	10.49	11.93	10.39	5.26	4.74	4.28	3.90	7.99	7.05
150	22.94	19.69	22.80	19.55	10.10	8.99	8.22	7.32	16.82	14.23
140	42.47	34.07	42.20	33.88	24.81	18.78	19.01	14.79	34.90	27.37
130	74.76	59.74	73.74	59.01	49.78	38.62	42.00	32.26	63.81	50.29
120	>90	84.10	>90	84.07	89.99	77.41	85.33	67.61	89.99	82.76

Table G-106. Monopile foundation (13 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.15	0.14	0.15	0.14	-	-	-	-	0.09	0.09
180	0.81	0.77	0.80	0.75	0.15	0.14	0.11	0.11	0.38	0.36
175	1.56	1.45	1.54	1.43	0.31	0.29	0.17	0.16	0.83	0.77
170	2.60	2.40	2.58	2.37	0.74	0.64	0.49	0.46	1.55	1.44
160	5.85	5.24	5.80	5.20	2.45	2.24	1.80	1.67	3.94	3.58
150	12.02	10.49	11.93	10.39	5.26	4.74	4.28	3.90	7.99	7.05
140	22.94	19.69	22.80	19.55	10.10	8.99	8.22	7.32	16.82	14.23
130	42.47	34.07	42.20	33.88	24.81	18.78	19.01	14.79	34.90	27.37
120	74.76	59.74	73.74	59.01	49.78	38.62	42.00	32.26	63.81	50.29

Table G-107. Monopile foundation (13 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.12	0.13	0.12	-	-	-	-	0.03	0.03
180	0.57	0.54	0.56	0.53	0.12	0.12	0.09	0.09	0.26	0.26
175	1.19	1.11	1.17	1.09	0.24	0.23	0.15	0.14	0.57	0.53
170	2.12	1.94	2.09	1.92	0.54	0.49	0.38	0.30	1.17	1.09
160	5.03	4.54	4.99	4.51	1.98	1.84	1.45	1.35	3.31	2.99
150	10.26	9.01	10.15	8.95	4.58	4.18	3.72	3.34	6.89	6.14
140	19.50	17.36	19.42	17.27	8.96	7.96	7.12	6.39	14.21	12.39
130	37.83	30.67	37.62	30.52	20.59	16.10	16.07	12.84	30.69	24.35
120	66.28	52.93	65.56	52.44	43.76	33.65	36.40	27.81	56.65	44.47

Table G-108. Monopile foundation (13 m monopile with an MHU 6000 hammer, 4500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.09	0.09	0.09	0.09	-	-	-	-	-	-
180	0.37	0.35	0.37	0.34	0.09	0.09	0.02	0.02	0.15	0.14
175	0.81	0.77	0.80	0.75	0.15	0.14	0.11	0.11	0.38	0.36
170	1.56	1.45	1.54	1.43	0.31	0.29	0.17	0.16	0.83	0.77
160	4.01	3.66	3.96	3.63	1.45	1.35	0.96	0.90	2.59	2.38
150	8.42	7.44	8.35	7.38	3.74	3.36	2.86	2.62	5.59	5.03
140	16.47	14.59	16.37	14.50	7.26	6.47	5.94	5.35	11.31	9.87
130	31.66	26.30	31.50	26.18	16.16	13.11	12.08	10.35	25.03	19.90
120	55.93	44.63	55.49	44.31	35.64	27.33	29.11	22.21	47.55	37.00

Table G-109. Monopile foundation (13 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
190	0.92	0.86	0.90	0.85	0.16	0.15	0.13	0.13	0.46	0.43
180	2.88	2.65	2.84	2.63	0.88	0.83	0.56	0.51	1.77	1.64
175	4.38	4.01	4.34	3.97	1.69	1.57	1.14	1.08	2.84	2.62
170	6.37	5.72	6.31	5.66	2.74	2.51	2.09	1.90	4.28	3.91
160	12.95	11.43	12.86	11.34	5.71	5.15	4.70	4.28	8.54	7.60
150	25.07	21.29	24.93	21.16	11.51	9.87	8.87	7.98	18.43	15.31
140	45.61	36.09	45.28	35.87	27.55	21.00	21.64	16.30	38.00	29.41
130	83.81	66.75	82.22	65.51	55.98	43.20	47.29	36.28	72.15	56.54
120	>90	84.09	>90	84.08	89.99	79.98	89.99	77.67	89.99	83.40

Table G-110. Monopile foundation (13 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.02	0.02	0.02	0.02	-	-	-	-	-	-
190	0.16	0.16	0.16	0.16	-	-	-	-	0.10	0.10
180	0.92	0.86	0.90	0.85	0.16	0.15	0.13	0.13	0.46	0.43
175	1.78	1.66	1.76	1.64	0.46	0.43	0.28	0.26	0.92	0.86
170	2.88	2.65	2.84	2.63	0.88	0.83	0.56	0.51	1.77	1.64
160	6.37	5.72	6.31	5.66	2.74	2.51	2.09	1.90	4.28	3.91
150	12.95	11.43	12.86	11.34	5.71	5.15	4.70	4.28	8.54	7.60
140	25.07	21.29	24.93	21.16	11.51	9.87	8.87	7.98	18.43	15.31
130	45.61	36.09	45.28	35.87	27.55	21.00	21.64	16.30	38.00	29.41
120	83.81	66.75	82.22	65.51	55.98	43.20	47.29	36.28	72.15	56.54

Table G-111. Monopile foundation (13 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.14	0.13	0.14	0.13	-	-	-	-	0.08	0.08
180	0.72	0.67	0.69	0.65	0.14	0.13	0.10	0.10	0.31	0.29
175	1.42	1.32	1.40	1.31	0.29	0.28	0.16	0.16	0.71	0.64
170	2.42	2.24	2.40	2.21	0.63	0.57	0.47	0.44	1.41	1.32
160	5.47	4.94	5.41	4.90	2.30	2.09	1.71	1.58	3.70	3.36
150	11.25	9.77	11.15	9.68	5.00	4.55	4.14	3.75	7.41	6.60
140	21.52	18.47	21.37	18.35	9.52	8.57	7.79	6.99	15.78	13.37
130	40.72	32.51	40.46	32.34	23.45	17.69	18.16	14.13	33.43	26.11
120	74.16	58.46	72.97	57.60	48.54	37.31	40.96	31.30	62.99	49.03

Table G-112. Monopile foundation (13 m monopile with an MHU 6000 hammer, 6000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location M2 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.10	0.10	0.10	-	-	-	-	0.02	0.02
180	0.45	0.43	0.44	0.42	0.10	0.10	0.03	0.03	0.16	0.16
175	0.92	0.86	0.90	0.85	0.16	0.15	0.13	0.13	0.46	0.43
170	1.78	1.66	1.76	1.64	0.46	0.43	0.28	0.26	0.92	0.86
160	4.38	4.01	4.34	3.97	1.69	1.57	1.14	1.08	2.84	2.62
150	9.06	8.05	8.99	7.99	4.12	3.75	3.26	2.90	6.02	5.42
140	17.56	15.60	17.45	15.51	7.86	7.03	6.39	5.80	12.22	10.85
130	34.20	27.89	33.98	27.75	18.03	14.27	13.86	11.47	27.29	21.63
120	61.39	48.10	60.61	47.59	39.60	30.26	32.84	24.96	51.79	40.11

G.5.1.2. Jacket Foundations

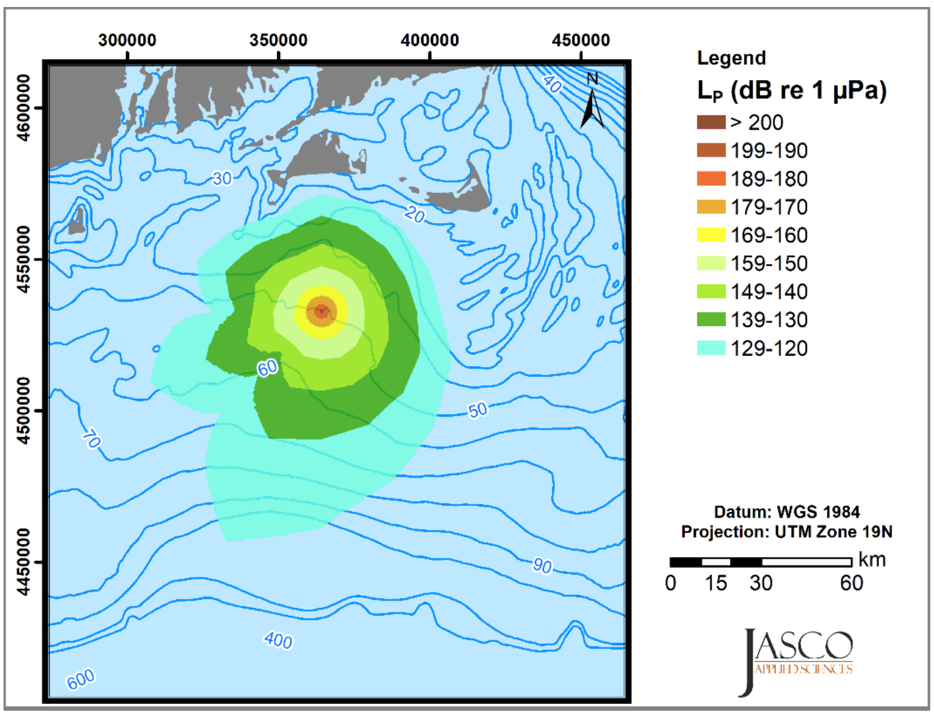

Figure G-13. 4 m jacket foundation unweighted single-strike sound pressure level (SPL) at 3500 kJ at J1.

Table G-113. Jacket foundation (4 m jacket with an MHU 3500 hammer, 525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
180	0.63	0.60	0.61	0.59	0.23	0.23	0.13	0.13	0.42	0.41
175	1.33	1.27	1.31	1.26	0.45	0.44	0.29	0.28	0.84	0.80
170	2.25	2.13	2.23	2.12	0.91	0.87	0.60	0.58	1.57	1.50
160	4.92	4.67	4.90	4.64	2.72	2.60	2.16	2.04	3.92	3.69
150	9.35	8.58	9.29	8.53	5.42	5.13	4.70	4.45	7.01	6.51
140	16.92	15.15	16.85	15.09	9.43	8.61	8.16	7.46	13.14	11.74
130	28.36	24.86	28.22	24.76	16.45	14.75	14.17	12.67	22.06	19.58
120	45.70	38.30	45.42	38.11	29.81	25.87	24.72	21.80	38.81	32.88

Table G-114. Jacket foundation (4 m jacket with an MHU 3500 hammer, 525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
175	0.28	0.27	0.28	0.27	0.11	0.10	0.08	0.08	0.15	0.14
170	0.63	0.60	0.61	0.59	0.23	0.23	0.13	0.13	0.42	0.41
160	2.25	2.13	2.23	2.12	0.91	0.87	0.60	0.58	1.57	1.50
150	4.92	4.67	4.90	4.64	2.72	2.60	2.16	2.04	3.92	3.69
140	9.35	8.58	9.29	8.53	5.42	5.13	4.70	4.45	7.01	6.51
130	16.92	15.15	16.85	15.09	9.43	8.61	8.16	7.46	13.14	11.74
120	28.36	24.86	28.22	24.76	16.45	14.75	14.17	12.67	22.06	19.58

Table G-115. Jacket foundation (4 m jacket with an MHU 3500 hammer, 525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.11	0.11	0.11	0.11	-	-	-	-	0.07	0.07
175	0.22	0.20	0.22	0.19	0.09	0.09	0.02	0.02	0.13	0.13
170	0.48	0.45	0.47	0.45	0.14	0.13	0.11	0.11	0.28	0.27
160	1.84	1.75	1.82	1.74	0.68	0.64	0.46	0.45	1.24	1.18
150	4.36	4.12	4.34	4.10	2.30	2.17	1.79	1.70	3.30	3.12
140	8.23	7.61	8.19	7.56	4.85	4.60	4.18	3.96	6.25	5.86
130	15.39	13.74	15.32	13.68	8.49	7.78	7.25	6.69	11.67	10.34
120	25.53	22.64	25.41	22.54	14.89	13.31	12.88	11.46	19.52	17.63

Table G-116. Jacket foundation (4 m jacket with an MHU 3500 hammer, 525 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.08	0.08	0.08	0.08	-	-	-	-	-	-
175	0.13	0.13	0.13	0.13	-	-	-	-	0.10	0.09
170	0.28	0.27	0.28	0.27	0.11	0.10	0.08	0.08	0.15	0.14
160	1.33	1.27	1.31	1.26	0.45	0.44	0.29	0.28	0.84	0.80
150	3.48	3.28	3.46	3.26	1.71	1.61	1.27	1.21	2.60	2.48
140	6.67	6.27	6.65	6.24	4.09	3.86	3.32	3.14	5.28	4.99
130	13.15	11.78	13.07	11.72	7.13	6.59	6.15	5.78	9.48	8.66
120	21.43	19.02	21.31	18.92	12.84	11.44	10.81	9.53	16.99	15.24

Table G-117. Jacket foundation (4 m jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.06	0.06	0.06	0.06	-	-	-	-	-	-
190	0.26	0.25	0.26	0.25	0.09	0.09	0.02	0.02	0.13	0.13
180	1.26	1.21	1.25	1.19	0.41	0.40	0.26	0.26	0.74	0.72
175	2.10	2.00	2.08	1.98	0.80	0.77	0.50	0.48	1.41	1.35
170	3.27	3.08	3.24	3.05	1.48	1.40	1.04	0.99	2.33	2.22
160	6.54	6.17	6.50	6.13	3.74	3.53	2.93	2.80	5.03	4.77
150	13.01	11.58	12.93	11.51	6.75	6.32	5.82	5.49	9.18	8.43
140	21.65	19.12	21.54	19.02	12.17	10.79	9.93	9.06	16.95	15.08
130	35.15	30.08	35.00	29.99	20.76	18.31	17.65	15.70	28.78	25.18
120	54.29	45.10	53.88	44.82	36.60	31.01	31.44	26.95	45.79	38.46

Table G-118. Jacket foundation (4 m jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.26	0.25	0.26	0.25	0.09	0.09	0.02	0.02	0.13	0.13
175	0.58	0.56	0.58	0.56	0.14	0.14	0.12	0.12	0.36	0.33
170	1.26	1.21	1.25	1.19	0.41	0.40	0.26	0.26	0.74	0.72
160	3.27	3.08	3.24	3.05	1.48	1.40	1.04	0.99	2.33	2.22
150	6.54	6.17	6.50	6.13	3.74	3.53	2.93	2.80	5.03	4.77
140	13.01	11.58	12.93	11.51	6.75	6.32	5.82	5.49	9.18	8.43
130	21.65	19.12	21.54	19.02	12.17	10.79	9.93	9.06	16.95	15.08
120	35.15	30.08	35.00	29.99	20.76	18.31	17.65	15.70	28.78	25.18

Table G-119. Jacket foundation (4 m jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.02	0.02	-	-	-	-	-	-	-	-
180	0.16	0.15	0.15	0.15	0.03	0.03	-	-	0.11	0.11
175	0.45	0.43	0.44	0.43	0.12	0.12	0.10	0.09	0.25	0.24
170	0.90	0.86	0.89	0.85	0.27	0.27	0.15	0.14	0.51	0.49
160	2.75	2.62	2.73	2.61	1.15	1.09	0.83	0.80	1.90	1.81
150	5.74	5.44	5.71	5.41	3.10	2.93	2.53	2.41	4.45	4.21
140	11.35	10.03	11.26	9.95	6.06	5.71	5.20	4.93	8.19	7.56
130	19.41	17.47	19.35	17.40	10.70	9.48	9.07	8.29	15.29	13.56
120	32.22	27.85	32.08	27.74	18.71	16.70	15.92	14.12	25.90	22.99

Table G-120. Jacket foundation (4 m jacket with an MHU 3500 hammer, 1000 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.12	0.12	0.12	0.12	-	-	-	-	0.09	0.09
175	0.26	0.25	0.26	0.25	0.09	0.09	0.02	0.02	0.13	0.13
170	0.58	0.56	0.58	0.56	0.14	0.14	0.12	0.12	0.36	0.33
160	2.10	2.00	2.08	1.98	0.80	0.77	0.50	0.48	1.41	1.35
150	4.74	4.51	4.72	4.49	2.45	2.33	1.88	1.78	3.61	3.40
140	9.14	8.40	9.07	8.36	5.12	4.86	4.37	4.14	6.74	6.32
130	16.97	15.15	16.91	15.09	9.02	8.27	7.71	7.10	12.85	11.40
120	28.03	24.67	27.91	24.58	16.08	14.27	13.59	12.05	21.95	19.32

Table G-121. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.14	0.13	0.13	0.13	-	-	-	-	0.09	0.09
190	0.69	0.66	0.68	0.65	0.15	0.15	0.13	0.13	0.42	0.40
180	2.39	2.29	2.38	2.26	0.88	0.84	0.54	0.52	1.54	1.47
175	3.61	3.43	3.58	3.40	1.64	1.53	1.18	1.12	2.55	2.44
170	4.99	4.74	4.96	4.71	2.63	2.51	2.07	1.95	3.82	3.63
160	8.95	8.24	8.88	8.17	5.22	4.94	4.50	4.27	6.77	6.30
150	16.39	14.83	16.30	14.75	8.81	8.03	7.69	7.05	12.27	11.01
140	28.06	24.54	27.92	24.46	15.54	14.11	13.27	11.93	21.74	19.28
130	45.14	37.80	44.88	37.60	28.75	25.05	23.90	21.08	37.93	32.18
120	80.58	66.62	79.43	65.69	51.97	42.74	43.47	36.20	68.02	55.72

Table G-122. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.14	0.13	0.13	0.13	-	-	-	-	0.09	0.09
180	0.69	0.66	0.68	0.65	0.15	0.15	0.13	0.13	0.42	0.40
175	1.45	1.39	1.43	1.37	0.45	0.44	0.28	0.27	0.84	0.80
170	2.39	2.29	2.38	2.26	0.88	0.84	0.54	0.52	1.54	1.47
160	4.99	4.74	4.96	4.71	2.63	2.51	2.07	1.95	3.82	3.63
150	8.95	8.24	8.88	8.17	5.22	4.94	4.50	4.27	6.77	6.30
140	16.39	14.83	16.30	14.75	8.81	8.03	7.69	7.05	12.27	11.01
130	28.06	24.54	27.92	24.46	15.54	14.11	13.27	11.93	21.74	19.28
120	45.14	37.80	44.88	37.60	28.75	25.05	23.90	21.08	37.93	32.18

Table G-123. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.11	0.11	0.11	0.10	-	-	-	-	0.03	0.03
180	0.53	0.51	0.52	0.50	0.13	0.13	0.10	0.10	0.28	0.27
175	1.11	1.06	1.10	1.05	0.29	0.28	0.16	0.16	0.58	0.57
170	1.93	1.85	1.91	1.83	0.62	0.59	0.46	0.45	1.21	1.16
160	4.44	4.22	4.40	4.19	2.23	2.10	1.73	1.63	3.20	3.05
150	7.93	7.31	7.88	7.26	4.68	4.43	4.00	3.80	6.08	5.72
140	14.77	13.32	14.68	13.25	8.01	7.31	6.92	6.42	10.65	9.51
130	25.43	22.41	25.31	22.31	14.01	12.63	11.90	10.57	19.23	17.40
120	40.90	34.50	40.72	34.36	25.57	22.53	20.46	18.42	34.29	29.30

Table G-124. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500a kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.31	0.30	0.30	0.29	0.10	0.10	0.03	0.03	0.15	0.15
175	0.69	0.66	0.68	0.65	0.15	0.15	0.13	0.13	0.42	0.40
170	1.45	1.39	1.43	1.37	0.45	0.44	0.28	0.27	0.84	0.80
160	3.61	3.43	3.58	3.40	1.64	1.53	1.18	1.12	2.55	2.44
150	6.66	6.23	6.61	6.19	3.90	3.71	3.12	2.96	5.14	4.88
140	12.54	11.30	12.45	11.22	6.82	6.34	5.91	5.57	8.88	8.10
130	21.19	18.83	21.05	18.72	11.89	10.58	9.70	8.84	16.37	14.78
120	35.63	30.35	35.47	30.24	20.63	18.51	17.31	15.76	29.26	25.47

Table G-125. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 0 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.12	0.12	0.12	-	-	-	-	0.09	0.09
190	0.65	0.63	0.65	0.62	0.15	0.14	0.12	0.12	0.35	0.32
180	2.39	2.29	2.36	2.26	0.87	0.84	0.55	0.53	1.52	1.44
175	3.79	3.58	3.75	3.55	1.64	1.56	1.12	1.07	2.57	2.45
170	5.29	5.02	5.26	4.98	2.65	2.52	2.07	1.94	3.98	3.75
160	9.46	8.66	9.40	8.60	5.46	5.17	4.67	4.42	7.17	6.62
150	16.73	14.92	16.65	14.84	9.25	8.43	8.12	7.40	12.71	11.32
140	27.13	24.10	26.98	24.00	15.90	14.19	13.73	12.25	21.19	18.67
130	45.42	38.05	45.09	37.83	28.40	25.06	24.03	21.06	38.14	32.44
120	82.26	66.82	80.73	65.69	55.14	44.98	46.74	38.46	69.75	56.53

Table G-126. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 10 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.13	0.12	0.12	0.12	-	-	-	-	0.09	0.09
180	0.65	0.63	0.65	0.62	0.15	0.14	0.12	0.12	0.35	0.32
175	1.41	1.35	1.40	1.33	0.41	0.39	0.26	0.26	0.83	0.78
170	2.39	2.29	2.36	2.26	0.87	0.84	0.55	0.53	1.52	1.44
160	5.29	5.02	5.26	4.98	2.65	2.52	2.07	1.94	3.98	3.75
150	9.46	8.66	9.40	8.60	5.46	5.17	4.67	4.42	7.17	6.62
140	16.73	14.92	16.65	14.84	9.25	8.43	8.12	7.40	12.71	11.32
130	27.13	24.10	26.98	24.00	15.90	14.19	13.73	12.25	21.19	18.67
120	45.42	38.05	45.09	37.83	28.40	25.06	24.03	21.06	38.14	32.44

Table G-127. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 12 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.10	0.09	0.10	0.09	-	-	-	-	0.03	0.03
180	0.53	0.51	0.52	0.50	0.13	0.13	0.10	0.09	0.26	0.24
175	1.04	0.98	1.03	0.97	0.28	0.27	0.15	0.15	0.58	0.56
170	1.94	1.86	1.92	1.84	0.60	0.58	0.44	0.42	1.14	1.09
160	4.67	4.43	4.64	4.40	2.18	2.05	1.70	1.61	3.32	3.14
150	8.42	7.75	8.38	7.70	4.87	4.61	4.12	3.90	6.45	6.02
140	15.24	13.55	15.15	13.47	8.42	7.68	7.32	6.70	11.33	9.94
130	24.59	21.94	24.48	21.83	14.37	12.83	12.47	11.04	19.01	17.08
120	40.87	34.61	40.64	34.44	25.24	22.28	20.83	18.40	34.05	29.28

Table G-128. Jacket foundation (4 m jacket with an MHU 3500 hammer, 3500 kJ max energy level) acoustic ranges (R_{max} and $R_{95\%}$ in km) for each of the flat and frequency weighted SPL categories (Finneran et al. 2017, NMFS 2018) during annual at location J1 at 15 dB.

Level	FLAT		LFC		MFC		HFC		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.06	0.06	0.06	0.06	-	-	-	-	-	-
180	0.26	0.25	0.26	0.25	0.09	0.09	0.03	0.03	0.14	0.13
175	0.65	0.63	0.65	0.62	0.15	0.14	0.12	0.12	0.35	0.32
170	1.41	1.35	1.40	1.33	0.41	0.39	0.26	0.26	0.83	0.78
160	3.79	3.58	3.75	3.55	1.64	1.56	1.12	1.07	2.57	2.45
150	7.06	6.56	6.99	6.52	4.05	3.82	3.17	3.01	5.43	5.13
140	13.10	11.69	13.01	11.62	7.19	6.62	6.23	5.83	9.33	8.53
130	20.89	18.51	20.78	18.43	12.41	11.00	10.33	9.24	16.45	14.69
120	35.29	30.24	35.09	30.11	20.67	18.31	17.75	15.85	28.26	25.00

G.5.2. Vibratory Pile Driving

G.5.2.1. Monopile Foundations

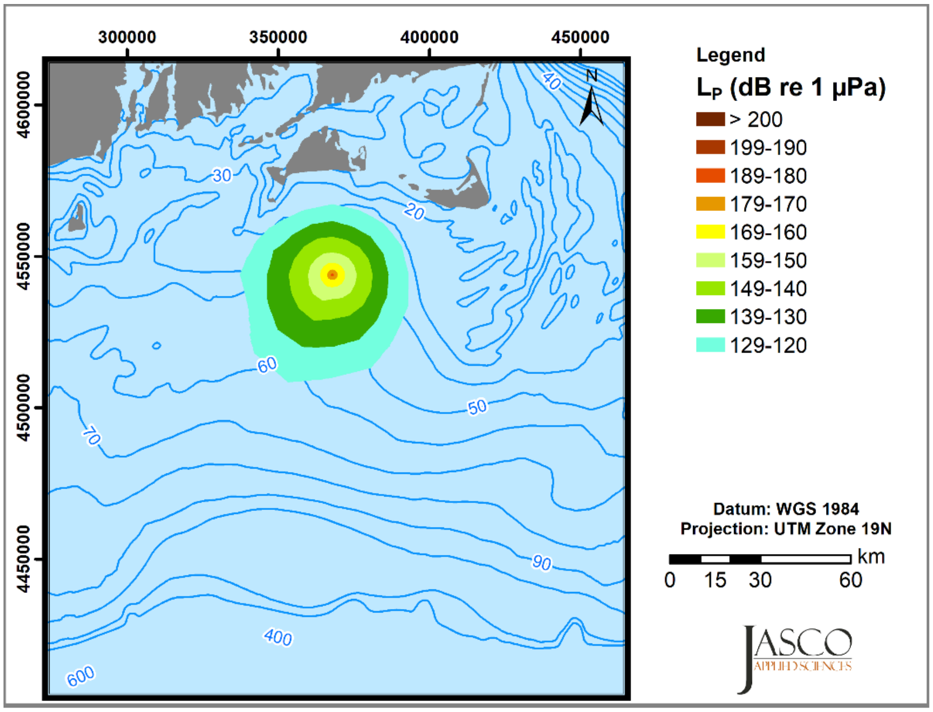

Figure G-14. 12 m monopile foundation unweighted single-strike sound pressure level (SPL) for 1 second of vibratory pile setting at M1.

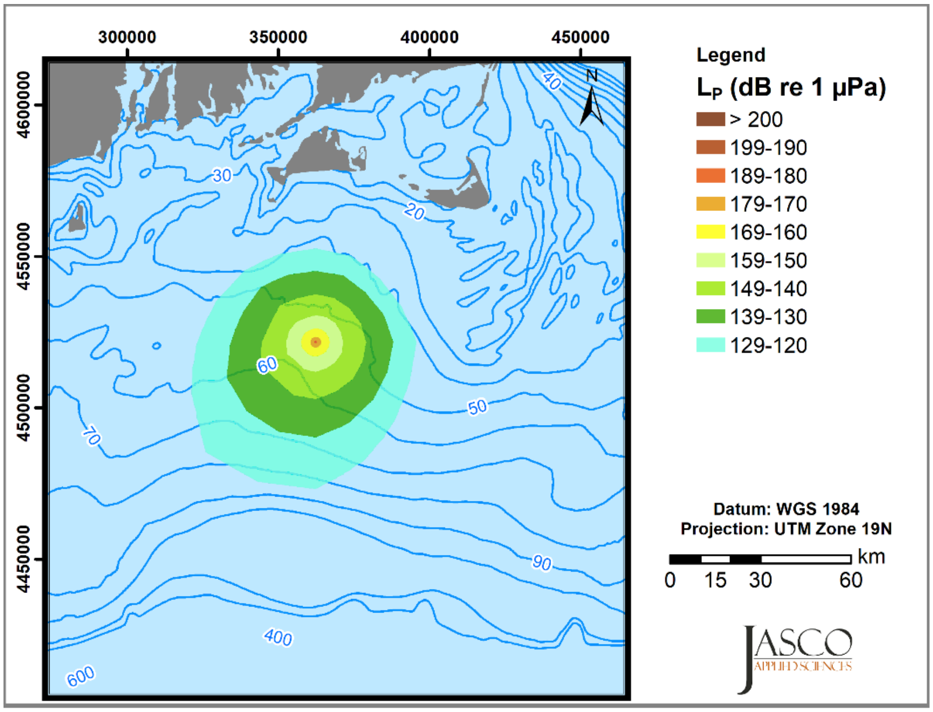

Figure G-15. 13 m monopile foundation unweighted single-strike sound pressure level (SPL) for 1 second of vibratory pile setting at M2.

G.5.2.2. Jacket Foundations

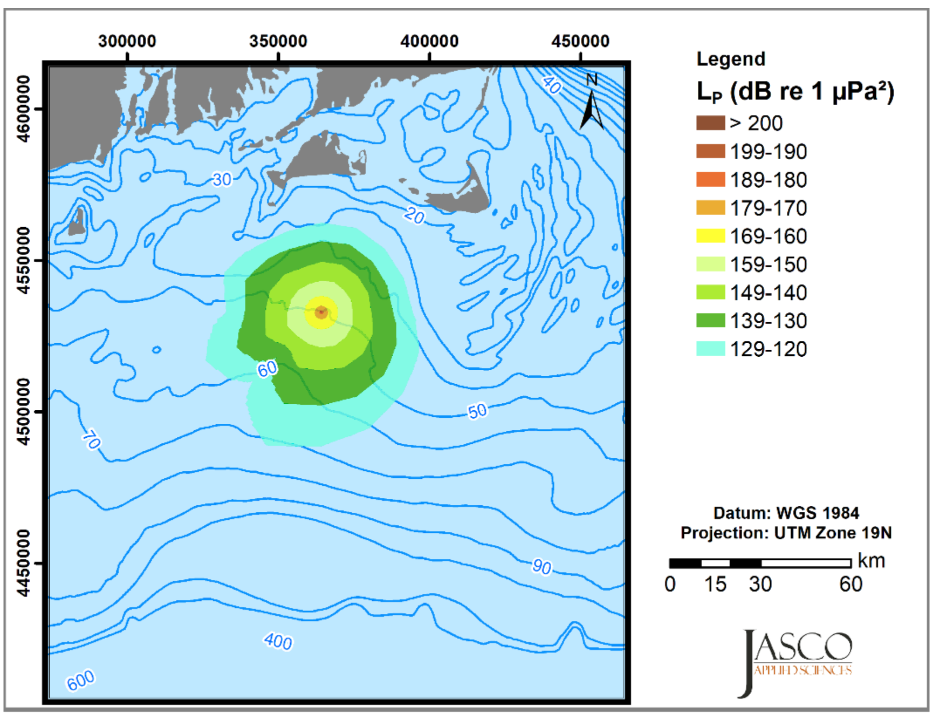

Figure G-16. 4 m jacket foundation unweighted single-strike sound pressure level (SPL) for 1 second of vibratory pile setting at J1.

Appendix H. Animal Movement and Exposure Modeling

H.1. Animal Movement Parameters

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 80 km (49.7 mi) from the Offshore Development Area (see figures in Appendix H.3). 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.3). 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

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 distances; both proximity and received levels are important factors in aversive responses (Dunlop et al. 2017). As a supplement to this modeling study for comparison purposes only, parameters determining aversion at specified sound levels were implemented for the North Atlantic right whale, in recognition of its Endangered status, and harbor porpoise, a species known to have a strong aversive response to loud sounds.

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. North Atlantic right whales: Aversion parameters for the animal movement simulation 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. Harbor porpoises: Aversion parameters for the animal movement simulation 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. Simulation Area: Animat Seeding

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.

H.2. Animal Movement Modeling Supplemental Results

H.2.1. Exposure Estimates – Based on Construction Schedules

This section contains marine mammal and sea turtle mean exposure estimates for each of the proposed construction schedules described in Section 1.2.7. Exposure estimates are shown assuming 0, 10, and 12 dB of broadband attenuation. Each construction schedule includes a combination of foundations installed with vibratory setting of piles followed by impact pile driving and foundations installed with impact pile driving alone.

H.2.1.1. Marine Mammals

Table H-3. 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	10	12	0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	44.03	13.33	10.30	0.36	0.02	0.02	472.78	260.87	229.85	91.72	37.41	31.06
	Minke whale (migrating)[b]	146.66	46.43	32.14	0.32	0.09	0.06	1037.42	637.91	618.22	1016.27	640.28	561.23
	Humpback whale	39.57	13.62	10.58	0.16	0.05	0.05	315.34	174.03	153.42	76.11	33.66	28.06
	North Atlantic right whale [c]	8.86	2.69	1.97	0.03	0	0	103.80	50.08	37.41	23.54	9.89	8.23
	Sei whale [c] (migrating)[b]	7.41	1.79	1.17	0.03	<0.01	<0.01	53.71	30.63	27.39	64.35	34.86	30.62
MF	Atlantic white sided dolphin	0	0	0	0.39	0	0	3875.42	2239.68	1994.30	520.80	222.62	189.13
	Atlantic spotted dolphin	0	0	0	<0.01	0	0	444.67	217.30	188.56	15.17	5.71	4.82
	Common dolphin	0	0	0	9.91	0	0	61093.16	36917.57	33402.10	6899.36	3204.79	2727.81
	Bottlenose dolphin, offshore	0	0	0	0	0	0	4513.50	2560.58	1892.11	390.87	165.39	136.62
	Risso's dolphin	0	0	0	<0.01	0	0	1022.69	568.94	220.72	36.54	16.66	14.04
	Long-finned pilot whale	0	0	0	<0.01	0	0	458.17	269.65	210.75	47.79	21.71	18.58
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	129.49	76.04	67.80	11.08	4.50	3.76
HF	Harbor porpoise (sensitive)[b]	0.83	0	0	35.23	7.11	2.06	2174.93	1202.72	1055.52	3038.18	1548.37	1314.11
PPW	Gray seal	4.83	0.37	0.08	0.04	0	0	3686.44	1465.82	1271.88	210.54	69.76	54.62
	Harbor seal	11.61	0.07	0	0.76	0.04	0	4294.89	794.75	682.26	256.49	100.43	82.75
	Harp seal	12.51	0.34	0.02	1.04	0.02	0.02	4473.69	1927.81	1696.25	270.29	101.52	82.72

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

Table H-4. 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 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
LF	Fin whale [c]	21.33	5.57	4.16	0.14	<0.01	<0.01	211.35	108.46	93.63	57.49	22.43	18.61
	Minke whale (migrating)[b]	67.21	16.88	10.49	0.06	<0.01	<0.01	486.41	284.57	246.68	565.54	367.74	320.93
	Humpback whale	18.64	5.58	4.08	0.06	0.02	0.02	145.87	75.24	64.86	44.60	19.02	15.81
	North Atlantic right whale [c]	3.95	0.98	0.65	0.01	0	0	46.11	19.36	16.53	13.40	5.39	4.48
	Sei whale [c] (migrating)[b]	2.85	0.54	0.30	<0.01	<0.01	<0.01	23.56	12.02	10.38	35.37	19.08	16.66
MF	Atlantic white sided dolphin	0	0	0	0.07	0	0	1787.03	951.70	824.83	257.48	100.09	83.31
	Atlantic spotted dolphin	0	0	0	0	0	0	185.04	81.79	68.41	7.20	2.30	1.83
	Common dolphin	0	0	0	2.84	0	0	25378.05	13739.47	12057.22	3119.00	1348.86	1112.79
	Bottlenose dolphin, offshore	0	0	0	0	0	0	1814.21	897.08	669.71	176.93	67.63	54.98
	Risso's dolphin	0	0	0	<0.01	0	0	393.54	168.60	79.33	16.65	6.97	5.77
	Long-finned pilot whale	0	0	0	<0.01	0	0	201.64	105.51	84.82	23.21	9.65	8.05
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	52.32	28.33	24.63	5.50	2.04	1.65
HF	Harbor porpoise (sensitive)[b]	0.08	0	0	13.95	1.58	0.69	965.28	485.64	417.48	1772.12	882.22	740.82
PPW	Gray seal	1.20	0.01	<0.01	<0.01	0	0	1758.66	593.10	501.22	134.20	43.61	33.71
	Harbor seal	2.03	<0.01	0	0.28	0.04	0	1842.37	333.67	280.31	145.44	54.23	44.08
	Harp seal	2.97	<0.01	0	0.44	<0.01	<0.01	2006.36	715.48	606.98	162.58	57.82	46.48

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

Table H-5. 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 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
LF	Fin whale [c]	22.70	7.75	6.15	0.22	0.02	0.02	261.42	152.41	136.22	34.22	14.98	12.46
	Minke whale (migrating)[b]	79.46	29.55	21.65	0.26	0.08	0.06	551.00	353.33	371.53	450.73	272.53	240.30
	Humpback whale	20.93	8.04	6.50	0.10	0.03	0.03	169.47	98.79	88.56	31.51	14.64	12.25
	North Atlantic right whale [c]	4.91	1.71	1.31	0.02	0	0	57.69	30.72	20.87	10.14	4.49	3.75
	Sei whale [c] (migrating)[b]	4.56	1.25	0.87	0.03	<0.01	<0.01	30.15	18.61	17.01	28.98	15.77	13.96
MF	Atlantic white sided dolphin	0	0	0	0.32	0	0	2088.39	1287.99	1169.46	263.33	122.53	105.81
	Atlantic spotted dolphin	0	0	0	<0.01	0	0	259.64	135.51	120.15	7.96	3.41	2.99
	Common dolphin	0	0	0	7.07	0	0	35715.11	23178.10	21344.89	3780.36	1855.93	1615.02
	Bottlenose dolphin, offshore	0	0	0	0	0	0	2699.29	1663.50	1222.40	213.95	97.76	81.64
	Risso's dolphin	0	0	0	<0.01	0	0	629.15	400.34	141.39	19.89	9.69	8.27
	Long-finned pilot whale	0	0	0	0	0	0	256.53	164.14	125.92	24.58	12.06	10.54
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	77.16	47.71	43.17	5.58	2.47	2.10
HF	Harbor porpoise (sensitive)[b]	0.74	0	0	21.28	5.52	1.37	1209.65	717.07	638.03	1266.06	666.15	573.30
PPW	Gray seal	3.63	0.36	0.08	0.04	0	0	1927.78	872.72	770.66	76.34	26.15	20.90
	Harbor seal	9.59	0.07	0	0.49	0	0	2452.52	461.08	401.95	111.05	46.20	38.66
	Harp seal	9.54	0.33	0.02	0.60	0.02	0.02	2467.33	1212.34	1089.27	107.71	43.70	36.24

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

Table H-6. 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 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
LF	Fin whale [c]	88.78	31.35	24.69	0.87	0.07	0.07	616.59	347.50	309.57	129.71	55.16	46.41
	Minke whale (migrating)[b]	361.86	138.78	102.32	1.41	0.39	0.33	1622.84	1007.39	1042.06	1833.05	1065.90	941.44
	Humpback whale	70.22	27.60	22.32	0.27	0.12	0.12	422.66	245.91	219.88	105.75	47.56	40.14
	North Atlantic right whale [c]	13.76	4.95	3.78	0.06	0	0	132.41	71.88	46.61	24.74	11.24	9.41
	Sei whale [c] (migrating)[b]	14.38	3.92	2.69	0.07	<0.01	<0.01	78.71	48.74	44.41	82.55	45.65	40.55
MF	Atlantic white sided dolphin	0	0	0	1.09	0	0	5478.74	3425.59	3098.86	852.20	401.24	347.79
	Atlantic spotted dolphin	0	0	0	<0.01	0	0	453.27	224.87	198.71	15.18	6.35	5.53
	Common dolphin	0	0	0	19.56	0	0	76657.61	48805.44	44637.76	10524.50	5125.28	4436.83
	Bottlenose dolphin, offshore	0	0	0	0	0	0	6071.07	3620.53	2701.94	697.57	317.82	265.97
	Risso's dolphin	0	0	0	<0.01	0	0	1197.86	696.11	273.48	54.36	26.25	22.47
	Long-finned pilot whale	0	0	0	0	0	0	592.24	368.00	289.11	78.58	38.68	33.91
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	157.33	95.27	85.61	16.12	7.03	5.96
HF	Harbor porpoise (sensitive)[b]	1.49	0	0	61.00	15.51	3.70	2805.23	1592.22	1412.82	3748.45	1779.99	1537.92
PPW	Gray seal	10.15	1.01	0.23	0.11	0	0	4414.50	2034.39	1798.65	156.93	53.12	42.68
	Harbor seal	26.22	0.20	0	1.27	0	0	5643.75	1070.90	936.80	251.90	108.70	91.35
	Harp seal	26.72	0.88	0.04	1.84	0.08	0.08	5634.83	2839.51	2552.20	239.54	98.93	82.44

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

Table H-7. 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 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
LF	Fin whale [c]	16.01	4.24	3.14	0.12	0.01	0.01	172.78	91.43	80.10	41.52	16.37	13.64
	Minke whale (migrating)[b]	57.17	15.02	9.44	0.03	0.01	<0.01	409.27	259.13	232.48	466.43	306.23	267.91
	Humpback whale	13.55	3.99	3.01	0.03	<0.01	<0.01	112.66	62.63	54.98	33.05	13.50	11.32
	North Atlantic right whale [c]	2.60	0.75	0.50	<0.01	0	0	34.67	13.21	11.02	8.56	3.45	2.89
	Sei whale [c] (migrating)[b]	1.98	0.41	0.24	<0.01	<0.01	<0.01	16.52	8.99	7.95	23.29	12.10	10.67
MF	Atlantic white sided dolphin	0	0	0	0.14	0	0	1310.28	754.22	665.59	178.71	70.41	58.44
	Atlantic spotted dolphin	0	0	0	<0.01	0	0	116.71	45.03	39.22	3.16	1.15	0.96
	Common dolphin	0	0	0	1.75	0	0	17662.30	9842.10	8842.97	1894.47	835.28	697.94
	Bottlenose dolphin, offshore	0	0	0	0	0	0	1368.33	656.25	544.67	117.64	45.81	37.19
	Risso's dolphin	0	0	0	<0.01	0	0	310.14	94.69	61.60	9.72	4.12	3.45
	Long-finned pilot whale	0	0	0	0	0	0	155.52	79.13	67.93	15.50	6.52	5.50
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	40.51	23.63	20.84	3.50	1.33	1.08
HF	Harbor porpoise (sensitive)[b]	0.09	0	0	9.78	1.06	0.59	750.42	391.52	340.89	1171.48	574.76	487.87
PPW	Gray seal	0.79	0.02	<0.01	<0.01	0	0	1350.80	297.91	257.96	83.94	28.40	22.53
	Harbor seal	1.97	<0.01	0	0.29	0	0	1531.78	268.75	228.98	92.90	34.57	28.53
	Harp seal	2.44	0.03	<0.01	0.29	<0.01	<0.01	1549.89	378.60	332.05	99.85	37.32	30.28

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

Table H-8. 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 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
LF	Fin whale [c]	51.85	19.32	15.36	0.53	0.04	0.04	326.71	188.88	169.31	62.68	27.57	23.29
	Minke whale (migrating)[b]	211.37	85.85	64.43	0.95	0.26	0.22	839.68	517.67	559.96	947.80	526.86	467.12
	Humpback whale	39.62	16.51	13.50	0.17	0.08	0.08	216.17	127.85	115.03	50.79	23.79	20.13
	North Atlantic right whale [c]	7.64	2.88	2.24	0.03	0	0	67.49	40.53	24.65	11.08	5.33	4.46
	Sei whale [c] (migrating)[b]	8.36	2.36	1.65	0.05	<0.01	<0.01	41.03	26.18	24.00	40.07	22.69	20.21
MF	Atlantic white sided dolphin	0	0	0	0.66	0	0	2869.87	1838.83	1674.83	470.37	231.05	202.09
	Atlantic spotted dolphin	0	0	0	<0.01	0	0	257.23	137.43	121.90	8.34	3.60	3.16
	Common dolphin	0	0	0	12.35	0	0	42868.60	28373.15	26087.33	6024.85	2995.08	2611.11
	Bottlenose dolphin, offshore	0	0	0	0	0	0	3427.15	2164.30	1577.88	410.82	192.70	162.06
	Risso's dolphin	0	0	0	0	0	0	675.54	458.24	158.83	31.24	15.49	13.31
	Long-finned pilot whale	0	0	0	0	0	0	317.23	210.13	160.61	44.56	22.71	20.06
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	88.08	54.21	49.03	8.96	4.04	3.47
HF	Harbor porpoise (sensitive)[b]	1.02	0	0	35.56	10.03	2.17	1458.63	863.37	771.07	1816.40	844.18	735.44
PPW	Gray seal	6.37	0.67	0.15	0.08	0	0	2084.65	1181.15	1047.92	49.85	16.89	13.77
	Harbor seal	16.51	0.13	0	0.67	0	0	2799.71	529.17	466.88	108.63	50.65	42.92
	Harp seal	16.55	0.57	0.02	1.06	0.06	0.06	2780.81	1674.77	1510.86	95.42	42.10	35.64

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

Table H-9. 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 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
LF	Fin whale [c]	20.92	7.79	6.19	0.21	0.02	0.02	117.11	67.19	60.16	25.51	11.22	9.48
	Minke whale (migrating)[b]	93.33	37.91	28.45	0.42	0.12	0.10	373.89	230.59	249.62	418.83	232.81	206.41
	Humpback whale	17.04	7.10	5.81	0.07	0.03	0.03	93.82	55.43	49.86	21.91	10.26	8.69
	North Atlantic right whale [c]	3.51	1.32	1.03	0.02	0	0	30.25	18.14	10.94	5.11	2.46	2.06
	Sei whale [c] (migrating)[b]	4.04	1.14	0.80	0.02	<0.01	<0.01	21.16	13.57	12.46	19.19	10.86	9.68
MF	Atlantic white sided dolphin	0	0	0	0.29	0	0	1298.59	832.54	758.44	203.12	99.77	87.26
	Atlantic spotted dolphin	0	0	0	<0.01	0	0	79.33	42.41	37.59	3.68	1.60	1.40
	Common dolphin	0	0	0	5.45	0	0	16126.71	10590.19	9707.46	2605.18	1294.92	1127.78
	Bottlenose dolphin, offshore	0	0	0	0	0	0	1275.59	799.98	579.39	169.11	79.31	66.71
	Risso's dolphin	0	0	0	0	0	0	212.18	143.19	53.05	13.40	6.64	5.71
	Long-finned pilot whale	0	0	0	0	0	0	119.49	78.75	60.58	18.52	9.44	8.34
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	28.74	17.44	15.74	3.66	1.65	1.41
HF	Harbor porpoise (sensitive)[b]	0.39	0	0	15.65	4.42	0.95	596.18	337.33	300.86	760.57	361.05	314.61
PPW	Gray seal	2.99	0.32	0.07	0.03	0	0	979.05	555.33	492.76	23.13	7.83	6.38
	Harbor seal	7.74	0.06	0	0.31	0	0	1312.26	272.98	240.95	50.37	23.49	19.90
	Harp seal	7.73	0.28	0.01	0.48	0.02	0.02	1304.14	786.14	709.29	44.27	19.51	16.51

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

H.2.1.2. Sea Turtles

Table H-10. 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	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	0.19	<0.01	<0.01	0	0	0	0.57	0.12	0.09
Leatherback turtle [a]	17.25	2.05	1.35	0	0	0	30.45	5.20	3.68
Loggerhead turtle	10.02	0.58	0.26	0	0	0	26.79	7.02	5.13
Green turtle	0.48	0.04	0.02	0	0	0	1.14	0.35	0.26

[a] Listed as Endangered under the ESA.

Table H-11. 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 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]	0.05	<0.01	<0.01	0	0	0	0.24	0.04	0.03
Leatherback turtle [a]	5.95	0.55	0.29	0	0	0	18.40	3.41	2.29
Loggerhead turtle	2.91	0.04	0.02	0	0	0	12.72	2.98	2.03
Green turtle	0.16	<0.01	<0.01	0	0	0	0.56	0.14	0.10

[a] Listed as Endangered under the ESA.

Table H-12. 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 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]	0.15	<0.01	<0.01	0	0	0	0.33	0.08	0.06
Leatherback turtle [a]	11.30	1.50	1.06	0	0	0	12.05	1.79	1.40
Loggerhead turtle	7.11	0.54	0.24	0	0	0	14.07	4.04	3.09
Green turtle	0.33	0.04	0.02	0	0	0	0.57	0.21	0.16

[a] Listed as Endangered under the ESA.

Table H-13.. 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 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]	0.45	0.02	<0.01	0	0	0	1.06	0.27	0.20
Leatherback turtle [a]	32.09	4.17	2.93	0	0	0	36.46	5.40	4.08
Loggerhead turtle	15.97	1.11	0.52	0	0	0	34.45	9.85	7.38
Green turtle	1.04	0.11	0.04	0	0	0	1.81	0.66	0.50

[a] Listed as Endangered under the ESA.

Table H-14. 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 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]	0.04	<0.01	<0.01	0	0	0	0.16	0.03	0.02
Leatherback turtle [a]	4.22	0.43	0.26	0	0	0	11.10	2.05	1.27
Loggerhead turtle	1.88	0.07	0.03	0	0	0	6.94	1.65	1.08
Green turtle	0.12	<0.01	<0.01	0	0	0	0.36	0.10	0.08

[a] Listed as Endangered under the ESA.

Table H-15. 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 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]	0.29	0.01	<0.01	0	0	0	0.64	0.17	0.13
Leatherback turtle [a]	19.69	2.65	1.89	0	0	0	17.88	2.36	1.98
Loggerhead turtle	9.84	0.73	0.34	0	0	0	19.06	5.67	4.36
Green turtle	0.65	0.08	0.03	0	0	0	1.02	0.40	0.30

[a] Listed as Endangered under the ESA.

Table H-16. 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 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]	0.12	<0.01	<0.01	0	0	0	0.26	0.07	0.05
Leatherback turtle [a]	8.17	1.09	0.78	0	0	0	7.48	0.99	0.83
Loggerhead turtle	4.25	0.31	0.15	0	0	0	8.45	2.53	1.95
Green turtle	0.27	0.03	0.01	0	0	0	0.42	0.16	0.12

[a] Listed as Endangered under the ESA.

H.2.2. Exposure Range Estimates – Impact Pile Driving Only

This section contains marine mammal and sea turtle exposure ranges for each of the modeled foundation types and seasons assuming 0, 10, and 12 dB broadband attenuation. Exposure ranges reported in this section (H.2.2) are foundations installed with impact pile driving alone.

H.2.2.1. Marine Mammals

Table H-17. 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
LF	Fin whale [c]	4.92	2.00	1.75	0.03	<0.01	<0.01	9.97	4.88	4.26	9.97	4.86	4.23
	Minke whale	2.92	0.82	0.69	0	0	0	9.33	4.61	3.80	26.28	16.51	14.58
	Humpback whale	4.32	1.71	1.21	0	0	0	9.87	4.86	4.10	9.85	4.78	4.10
	North Atlantic right whale [c]	3.50	1.19	0.96	<0.01	0	0	9.04	4.50	3.60	9.07	4.47	3.60
	Sei whale [c]	3.42	0.94	0.62	0	0	0	9.70	4.72	3.94	27.88	17.26	15.61
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	8.99	4.26	3.60	4.05	1.71	1.32
	Atlantic spotted dolphin	0	0	0	0	0	0	9.21	4.48	3.36	4.36	1.87	1.42
	Short-beaked common dolphin	0	0	0	0	0	0	9.15	4.47	3.80	4.03	1.79	1.50
	Bottlenose dolphin	0	0	0	0	0	0	8.18	3.98	3.32	3.65	1.39	1.10
	Risso's dolphin	0	0	0	0	0	0	8.59	4.30	3.55	4.15	1.63	1.26
	Long-finned pilot whale	0	0	0	0	0	0	8.95	4.20	3.45	3.93	1.59	1.36
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	9.42	4.68	4.00	4.26	1.79	1.49
HF	Harbor porpoise	0	0	0	0.40	<0.01	<0.01	8.02	4.23	3.44	32.80	20.61	18.79
PPW	Gray seal	0.51	0	0	0	0	0	10.37	5.10	4.51	7.25	3.46	2.91
	Harbor seal	0.27	0	0	0.02	0	0	8.69	3.80	3.26	5.76	2.78	2.40
	Harp seal	0.42	0	0	0.02	0	0	9.59	4.86	4.28	6.88	3.14	2.72

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

Table H-18. 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
LF	Fin whale [c]	5.35	2.13	1.85	0.03	0	0	9.83	4.92	4.12	9.86	4.82	4.13
	Minke whale	2.96	0.96	0.72	0	0	0	9.29	4.32	3.69	26.05	16.18	14.51
	Humpback whale	4.84	1.78	1.31	0.06	0	0	9.62	4.65	3.94	9.64	4.60	3.93
	North Atlantic right whale [c]	3.79	1.41	0.97	0.02	0	0	9.07	4.39	3.80	9.17	4.36	3.79
	Sei whale [c]	3.37	1.14	0.74	0.02	0	0	9.33	4.60	3.94	27.97	16.76	15.18
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	8.91	4.31	3.60	4.11	1.69	1.33
	Atlantic spotted dolphin	0	0	0	0	0	0	9.22	4.18	3.49	3.91	1.75	1.40
	Short-beaked common dolphin	0	0	0	<0.01	0	0	8.97	4.34	3.67	3.99	1.70	1.43
	Bottlenose dolphin	0	0	0	0	0	0	7.91	3.79	3.22	3.50	1.45	1.26
	Risso's dolphin	0	0	0	0	0	0	8.58	4.20	3.57	3.99	1.74	1.49
	Long-finned pilot whale	0	0	0	0	0	0	8.65	4.09	3.43	3.93	1.60	1.35
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	9.34	4.51	3.89	4.24	1.88	1.56
HF	Harbor porpoise	0	0	0	0.44	0.21	<0.01	7.89	3.94	3.38	32.51	20.67	18.90
PPW	Gray seal	0.65	0	0	0	0	0	10.22	5.13	4.41	7.29	3.39	2.99
	Harbor seal	0.33	0	0	0.03	0	0	8.69	4.06	3.32	5.77	2.73	2.21
	Harp seal	0.42	0	0	0.07	0	0	9.66	4.84	4.16	6.71	3.13	2.57

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

Table H-19. 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
LF	Fin whale [c]	5.03	2.05	1.87	0.05	<0.01	<0.01	10.47	5.28	4.54	10.49	5.27	4.54
LF	Minke whale	3.13	0.91	0.82	0	0	0	9.98	4.95	4.22	27.76	17.27	15.63
LF	Humpback whale	4.68	1.72	1.41	0.02	0	0	10.39	5.26	4.52	10.46	5.23	4.49
LF	North Atlantic right whale [c]	3.87	1.19	0.99	<0.01	0	0	9.82	4.91	4.16	9.87	5.00	4.11
LF	Sei whale [c]	3.62	1.36	0.81	0	0	0	10.43	5.19	4.25	29.15	18.72	16.58
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	9.78	4.87	4.16	4.59	1.90	1.55
MF	Atlantic spotted dolphin	0	0	0	<0.01	0	0	10.19	5.02	4.16	4.83	2.00	1.59
MF	Short-beaked common dolphin	0	0	0	<0.01	0	0	9.94	4.99	4.20	4.56	2.00	1.72
MF	Bottlenose dolphin	0	0	0	0	0	0	9.03	4.45	3.56	3.98	1.92	1.55
MF	Risso’s dolphin	0	0	0	0	0	0	9.53	4.72	4.00	4.53	2.02	1.55
MF	Long-finned pilot whale	0	0	0	0	0	0	9.68	4.75	4.01	4.45	1.84	1.56
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	9.95	5.22	4.29	4.68	2.09	1.69
HF	Harbor porpoise	0	0	0	0.57	0.20	<0.01	8.70	4.46	3.77	34.68	21.85	19.75
PPW	Gray seal	0.51	0	0	0	0	0	10.86	5.58	4.74	7.58	3.73	3.10
PPW	Harbor seal	0.40	0	0	0.02	0	0	9.24	4.45	3.77	6.44	2.97	2.60
PPW	Harp seal	0.32	0	0	<0.01	0	0	10.38	5.26	4.41	7.44	3.48	2.95

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

Table H-20. 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
LF	Fin whale [c]	5.43	2.16	1.87	0.06	0	0	10.43	5.29	4.39	10.48	5.31	4.35
	Minke whale	3.19	1.12	0.68	0	0	0	9.90	4.87	4.13	27.68	17.36	15.52
	Humpback whale	4.91	1.97	1.42	0.06	0	0	10.27	5.12	4.32	10.32	5.17	4.32
	North Atlantic right whale [c]	3.88	1.34	1.17	0.02	0	0	9.75	4.83	4.23	9.81	4.81	4.26
	Sei whale [c]	3.61	1.27	0.73	0.05	0	0	10.18	5.17	4.36	29.39	18.19	16.26
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	9.66	4.83	4.07	4.49	1.94	1.63
	Atlantic spotted dolphin	0	0	0	0	0	0	10.04	4.51	4.08	4.38	2.07	1.65
	Short-beaked common dolphin	0	0	0	<0.01	0	0	9.67	4.88	4.08	4.54	2.00	1.71
	Bottlenose dolphin	0	0	0	0	0	0	8.83	4.18	3.42	3.84	1.78	1.53
	Risso's dolphin	0	0	0	<0.01	0	0	9.28	4.74	4.04	4.44	1.98	1.68
	Long-finned pilot whale	0	0	0	0	0	0	9.56	4.72	3.88	4.38	1.84	1.55
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	9.96	5.16	4.23	4.76	2.08	1.75
HF	Harbor porpoise	0	0	0	0.49	0.12	<0.01	8.43	4.44	3.68	34.20	21.94	19.92
PPW	Gray seal	0.69	0	0	0	0	0	10.67	5.53	4.70	7.82	3.72	3.16
	Harbor seal	0.35	0	0	<0.01	0	0	9.11	4.41	3.69	6.34	2.96	2.57
	Harp seal	0.53	0	0	0.06	0	0	10.36	5.31	4.38	7.19	3.45	2.85

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

Table H-21. 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
LF	Fin whale [c]	5.38	2.04	1.81	0.02	0	0	10.61	5.08	4.31	10.59	5.09	4.29
LF	Minke whale	3.58	0.96	0.85	0	0	0	9.56	4.44	4.05	32.50	18.41	16.36
LF	Humpback whale	4.91	1.87	1.44	0.05	0	0	10.29	5.02	4.34	10.31	5.07	4.21
LF	North Atlantic right whale [c]	3.98	1.19	1.04	0.01	0	0	9.65	4.73	4.10	9.71	4.73	4.09
LF	Sei whale [c]	3.73	1.17	0.95	0	0	0	10.42	4.96	4.20	34.88	19.90	17.74
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	9.40	4.50	4.02	4.22	1.83	1.44
MF	Atlantic spotted dolphin	0	0	0	0	0	0	9.63	4.74	3.92	4.45	2.15	1.42
MF	Short-beaked common dolphin	0	0	0	<0.01	0	0	9.56	4.63	3.92	4.26	1.94	1.52
MF	Bottlenose dolphin	0	0	0	0	0	0	8.83	4.09	3.32	3.55	1.64	1.32
MF	Risso's dolphin	0	0	0	0	0	0	9.05	4.55	3.99	4.27	1.95	1.50
MF	Long-finned pilot whale	0	0	0	0	0	0	9.05	4.39	3.86	4.09	1.90	1.49
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	10.04	4.80	4.22	4.41	2.00	1.63
HF	Harbor porpoise	0	0	0	0.54	0.21	0	8.45	4.49	3.77	37.04	21.58	19.43
PPW	Gray seal	0.71	0	0	0	0	0	10.70	5.42	4.69	7.30	3.70	3.09
PPW	Harbor seal	0.31	0	0	0	0	0	8.99	4.33	3.55	5.98	3.01	2.37
PPW	Harp seal	0.30	0	0	0.06	0	0	10.32	5.02	4.38	6.81	3.29	2.92

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

Table H-22. 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
LF	Fin whale [c]	5.75	2.30	1.91	0.02	0	0	10.35	4.99	4.33	10.38	4.99	4.29
	Minke whale	3.45	1.02	0.67	0.02	0	0	9.58	4.67	4.08	32.60	18.45	16.05
	Humpback whale	5.03	1.99	1.48	0.05	<0.01	<0.01	10.21	4.93	4.39	10.25	4.94	4.26
	North Atlantic right whale [c]	3.95	1.37	1.11	0	0	0	9.55	4.51	3.83	9.67	4.49	3.83
	Sei whale [c]	3.71	1.30	1.23	0	0	0	10.25	4.90	4.32	33.44	19.77	17.12
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	9.29	4.47	3.89	4.22	1.67	1.39
	Atlantic spotted dolphin	0	0	0	0	0	0	9.60	4.58	3.89	4.27	1.99	1.54
	Short-beaked common dolphin	0	0	0	<0.01	0	0	9.48	4.55	3.99	4.25	1.83	1.48
	Bottlenose dolphin	0	0	0	0	0	0	8.47	4.12	3.41	3.54	1.64	1.24
	Risso's dolphin	0	0	0	0	0	0	9.03	4.50	3.98	4.22	1.89	1.42
	Long-finned pilot whale	0	0	0	<0.01	0	0	9.11	4.38	3.77	4.14	1.79	1.47
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	9.78	4.84	4.03	4.32	2.02	1.64
HF	Harbor porpoise	0.04	0	0	0.58	0.24	0.03	8.21	4.41	3.76	37.44	21.68	19.43
PPW	Gray seal	0.65	0	0	0	0	0	10.66	5.34	4.63	7.27	3.73	3.05
	Harbor seal	0.43	0	0	<0.01	<0.01	0	8.68	4.18	3.49	5.85	3.02	2.60
	Harp seal	0.55	0	0	0.05	0	0	10.29	4.96	4.35	6.89	3.27	2.89

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

Table H-23. 13 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
LF	Fin whale [c]	5.68	2.14	1.90	0.03	0	0	11.23	5.56	4.88	11.29	5.50	4.85
	Minke whale	3.75	1.22	0.88	0	0	0	10.57	5.05	4.41	34.43	19.93	17.60
	Humpback whale	4.96	1.96	1.52	0.06	0	0	10.99	5.27	4.70	11.01	5.24	4.68
	North Atlantic right whale [c]	4.17	1.56	1.10	0.02	0	0	10.52	5.28	4.34	10.55	5.19	4.34
	Sei whale [c]	4.07	1.32	0.89	0.04	0	0	11.12	5.44	4.48	36.73	20.99	19.05
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	10.35	5.01	4.27	4.51	2.05	1.65
	Atlantic spotted dolphin	0	0	0	0	0	0	10.62	4.88	4.40	4.70	2.26	1.99
	Short-beaked common dolphin	0	0	0	<0.01	0	0	10.47	5.28	4.36	4.74	2.02	1.63
	Bottlenose dolphin	0	0	0	0	0	0	9.73	4.70	3.93	4.08	1.78	1.51
	Risso's dolphin	0	0	0	<0.01	0	0	9.82	4.93	4.27	4.65	2.04	1.76
	Long-finned pilot whale	0	0	0	0	0	0	10.04	4.95	4.14	4.62	2.05	1.62
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	10.79	5.33	4.61	4.77	2.14	1.83
HF	Harbor porpoise	0	0	0	0.57	0.20	<0.01	8.99	4.74	4.08	38.84	22.87	20.72
PPW	Gray seal	0.72	0	0	0	0	0	11.35	5.85	4.88	7.75	3.81	3.42
	Harbor seal	0.37	0	0	0	0	0	9.55	4.43	4.02	6.30	3.30	2.84
	Harp seal	0.57	0	0	0.06	0	0	10.89	5.50	4.70	7.48	3.60	3.15

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

Table H-24. 13 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
LF	Fin whale [c]	5.96	2.58	2.04	0.06	0	0	11.04	5.40	4.70	11.08	5.40	4.70
LF	Minke whale	3.64	1.19	0.96	<0.01	0	0	10.32	5.05	4.39	34.76	19.75	17.38
LF	Humpback whale	5.32	1.99	1.54	0.05	<0.01	<0.01	10.71	5.40	4.57	10.78	5.38	4.55
LF	North Atlantic right whale [c]	4.22	1.62	1.30	0	0	0	10.23	5.18	4.32	10.30	5.13	4.31
LF	Sei whale [c]	4.13	1.31	1.30	0.04	0	0	10.92	5.34	4.64	35.10	20.69	18.48
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	10.19	4.98	4.30	4.50	2.08	1.74
MF	Atlantic spotted dolphin	0	0	0	0	0	0	10.59	4.84	4.47	4.66	2.18	1.84
MF	Short-beaked common dolphin	0	0	0	<0.01	0	0	10.40	5.10	4.36	4.67	2.07	1.73
MF	Bottlenose dolphin	0	0	0	0	0	0	9.36	4.65	4.04	4.21	1.82	1.51
MF	Risso's dolphin	0	0	0	<0.01	0	0	9.69	5.05	4.25	4.67	2.02	1.74
MF	Long-finned pilot whale	0	0	0	0	0	0	9.97	4.76	4.24	4.55	2.00	1.68
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	10.49	5.27	4.54	4.72	2.24	1.86
HF	Harbor porpoise	0	0	0	0.55	0.23	<0.01	8.96	4.75	4.18	39.46	23.22	20.80
PPW	Gray seal	0.81	0	0	0	0	0	11.34	5.77	4.90	7.76	3.97	3.43
PPW	Harbor seal	0.50	0	0	<0.01	0	0	9.37	4.56	3.97	6.48	3.31	2.84
PPW	Harp seal	0.54	0	0	0.06	0	0	10.87	5.45	4.66	7.55	3.63	3.23

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

Table H-25. 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
LF	Fin whale [c]	7.30	3.73	3.25	0.09	<0.01	<0.01	8.40	4.66	4.12	8.38	4.68	4.12
	Minke whale	4.34	1.76	1.46	0.01	<0.01	<0.01	7.91	4.24	3.63	23.65	14.41	13.10
	Humpback whale	6.52	2.94	2.49	0.04	<0.01	<0.01	8.23	4.65	4.10	8.24	4.66	4.10
	North Atlantic right whale [c]	5.20	2.35	1.89	0.09	0	0	7.91	4.54	3.80	7.95	4.55	3.81
	Sei whale [c]	4.75	2.10	1.54	0.07	<0.01	<0.01	8.06	4.52	4.06	24.68	14.78	13.21
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	7.91	4.40	3.79	4.59	2.28	1.92
	Atlantic spotted dolphin	0	0	0	0	0	0	7.89	4.47	4.05	4.86	2.37	1.86
	Short-beaked common dolphin	0	0	0	<0.01	0	0	7.80	4.48	3.84	4.71	2.30	1.96
	Bottlenose dolphin	0	0	0	0	0	0	7.24	4.02	3.46	4.22	1.98	1.63
	Risso's dolphin	0	0	0	0	0	0	7.78	4.31	3.75	4.55	2.24	1.89
	Long-finned pilot whale	0	0	0	0	0	0	7.61	4.11	3.60	4.50	2.17	1.89
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	0	0	0	0	0	0	8.05	4.52	3.97	4.77	2.28	1.94
HF	Harbor porpoise	0.02	0	0	0.61	0.23	0.07	7.44	4.20	3.63	31.72	18.88	16.91
PPW	Gray seal	2.47	0.79	0.36	0.06	0	0	8.63	4.97	4.42	6.54	3.63	3.25
	Harbor seal	1.02	0.02	0	0.02	0	0	7.31	4.09	3.60	6.01	3.29	2.77
	Harp seal	1.15	0.11	0	0.09	<0.01	<0.01	8.32	4.65	4.10	6.29	3.49	3.07

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

H.2.2.2. Sea Turtles

Table H-26. 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]	1.04	0	0	0	0	0	2.43	0.87	0.56
Leatherback turtle [a]	1.48	0.30	0	0	0	0	3.38	1.38	0.94
Loggerhead turtle	1.15	0	0	0	0	0	3.05	1.20	1.01
Green turtle	0.98	0	0	0	0	0	2.90	1.01	0.69

[a] Listed as Endangered under the ESA.

Table H-27. 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]	0.97	0	0	0	0	0	2.44	0.54	0.54
Leatherback turtle [a]	1.60	0.25	0.13	0	0	0	3.37	1.31	1.09
Loggerhead turtle	1.20	0	0	0	0	0	3.05	1.16	0.53
Green turtle	1.11	0	0	0	0	0	2.95	1.14	0.78

[a] Listed as Endangered under the ESA.

Table H-28. 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]	1.05	0	0	0	0	0	2.57	1.19	0.90
Leatherback turtle [a]	1.48	0.30	0	0	0	0	3.67	1.46	1.25
Loggerhead turtle	1.24	0	0	0	0	0	3.42	1.39	1.11
Green turtle	0.99	0	0	0	0	0	3.25	1.29	1.01

[a] Listed as Endangered under the ESA.

Table H-29. 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]	1.01	0	0	0	0	0	2.75	0.94	0.54
Leatherback turtle [a]	1.80	0.26	0.15	0	0	0	3.68	1.47	1.18
Loggerhead turtle	1.37	0	0	0	0	0	3.29	1.41	1.03
Green turtle	1.11	0	0	0	0	0	3.18	1.25	0.98

[a] Listed as Endangered under the ESA.

Table H-30. 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]	0.85	0	0	0	0	0	2.39	0.23	0.23
Leatherback turtle [a]	1.53	0.25	0.25	0	0	0	3.65	1.34	1.03
Loggerhead turtle	1.16	0	0	0	0	0	3.26	1.36	0.85
Green turtle	1.14	0	0	0	0	0	3.35	1.28	0.97

[a] Listed as Endangered under the ESA.

Table H-31. 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]	0.91	0	0	0	0	0	2.85	0.89	0.82
Leatherback turtle [a]	1.98	0.26	0.21	0	0	0	3.71	1.38	1.12
Loggerhead turtle	1.19	0	0	0	0	0	3.25	1.21	0.98
Green turtle	1.07	0.01	0.01	0	0	0	3.24	1.27	0.80

[a] Listed as Endangered under the ESA.

Table H-32. 13 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]	1.20	0	0	0	0	0	2.74	0.87	0.37
Leatherback turtle [a]	1.59	0.25	0.24	0	0	0	3.97	1.37	1.31
Loggerhead turtle	1.19	0	0	0	0	0	3.63	1.48	0.96
Green turtle	1.14	0.19	0	0	0	0	3.63	1.31	0.95

[a] Listed as Endangered under the ESA.

Table H-33. 13 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]	1.00	0	0	0	0	0	3.28	0.99	1.01
Leatherback turtle [a]	1.97	0.29	0.21	0	0	0	3.95	1.50	1.26
Loggerhead turtle	1.49	0	0	0	0	0	3.53	1.32	1.11
Green turtle	1.45	0.01	0.01	0	0	0	3.55	1.47	1.08

[a] Listed as Endangered under the ESA.

Table H-34. 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]	1.29	0.42	0.22	0	0	0	3.00	1.12	0.90
Leatherback turtle [a]	3.68	1.28	1.03	0	0	0	3.60	1.28	1.10
Loggerhead turtle	2.03	0.48	0.46	0	0	0	3.22	1.29	0.95
Green turtle	1.97	0.24	0.21	0	0	0	3.08	1.20	0.88

[a] Listed as Endangered under the ESA.

H.2.3. Exposure Ranges – Vibratory Pile Setting Followed by Impact Pile Driving

This section contains marine mammal and sea turtle exposure ranges for each of the modeled foundation types and seasons assuming 0, 10, and 12 dB broadband attenuation. Exposure ranges reported in this section (H.2.3) are foundations installed with vibratory pile setting followed by impact pile driving.

H.2.3.1. Marine Mammals

Table H-35. Injury: Monopile foundation (12 m diameter, 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	5.11	2.02	1.85	0.03	<0.01	<0.01	0.38	0.02	0
LF	Minke whale (migrating)	3.08	0.81	0.59	0	0	0	0	0	0
LF	Humpback whale	4.65	1.72	1.31	0	0	0	0.19	0	0
LF	North Atlantic right whale [a]	3.58	1.15	0.99	<0.01	0	0	0.02	0	0
LF	Sei whale [a] (migrating)	3.47	1.15	0.66	0	0	0	0	0	0
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0
MF	Common dolphin	0	0	0	0	0	0	0	0	0
MF	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
MF	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0.47	0.09	<0.01	0	0	0
PW	Gray seal	0.62	0	0	0	0	0	0	0	0
PW	Harbor seal	0.26	0	0	0.02	0	0	0	0	0
PW	Harp seal	0.41	0	0	0.02	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-36. Injury: Monopile foundation (12 m diameter, 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	5.64	2.16	1.85	0.03	0	0	0.42	0	0
	Minke whale (migrating)	3.09	1.02	0.78	0	0	0	0.02	0	0
	Humpback whale	5.12	1.84	1.32	0.06	0	0	0.24	0	0
	North Atlantic right whale [a]	3.91	1.35	0.99	0.02	0	0	0.02	0	0
	Sei whale [a] (migrating)	3.49	1.29	0.73	0.02	0	0	0.02	0	0
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	0	0	0
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0
	Common dolphin	0	0	0	<0.01	0	0	0	0	0
	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
	Risso’s dolphin	0	0	0	<0.01	0	0	0	0	0
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0.47	<0.01	<0.01	0	0	0
PW	Gray seal	0.69	0	0	0	0	0	0	0	0
	Harbor seal	0.33	0	0	<0.01	0	0	0	0	0
	Harp seal	0.41	0	0	0.06	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-37. Injury: Monopile foundation (12 m diameter, 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

	Species	Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	5.27	2.14	1.94	0.06	<0.01	<0.01	0.38	0.02	0
LF	Minke whale (migrating)	3.20	1.02	0.85	0	0	0	0	0	0
LF	Humpback whale	4.82	1.88	1.45	0.02	0	0	0.19	0	0
LF	North Atlantic right whale [a]	3.90	1.39	1.14	<0.01	<0.01	0	0.02	0	0
LF	Sei whale [a] (migrating)	3.74	1.64	0.81	0	0	0	0	0	0
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	<0.01	0	0	0	0	0
MF	Common dolphin	0	0	0	<0.01	0	0	0	0	0
MF	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
MF	Risso’s dolphin	0	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
MF	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0.57	0.21	<0.01	0	0	0
PW	Gray seal	0.77	0	0	0	0	0	0	0	0
PW	Harbor seal	0.42	0	0	<0.01	0	0	0	0	0
PW	Harp seal	0.55	0	0	<0.01	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-38. Injury: Monopile foundation (12 m diameter, 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	5.71	2.24	1.95	0.04	0	0	0.42	0	0
	Minke whale (migrating)	3.42	1.21	0.76	<0.01	0	0	0.02	0	0
	Humpback whale	5.18	1.98	1.48	0.06	0	0	0.24	0	0
	North Atlantic right whale [a]	4.17	1.44	1.28	0.02	0	0	0.02	0	0
	Sei whale [a] (migrating)	3.84	1.26	0.94	0.06	0	0	0.02	0	0
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	0	0	0
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0
	Common dolphin	0	0	0	<0.01	0	0	0	0	0
	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
	Risso’s dolphin	0	0	0	<0.01	0	0	0	0	0
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0.51	0.14	<0.01	0	0	0
PW	Gray seal	0.69	0	0	0	0	0	0	0	0
	Harbor seal	0.37	0	0	<0.01	0	0	0	0	0
	Harp seal	0.51	0	0	0.04	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-39. Injury: Monopile foundation (13 m diameter, 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	5.68	2.10	1.85	0.02	0	0	0.04	0	0
	Minke whale (migrating)	3.60	0.95	0.84	0	0	0	0	0	0
	Humpback whale	5.02	1.90	1.44	0.05	0	0	0.07	0	0
	North Atlantic right whale [a]	4.11	1.29	1.17	0.01	0	0	0.02	0	0
	Sei whale [a] (migrating)	3.76	1.23	0.93	0	0	0	0	0	0
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	0	0	0
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0
	Common dolphin	0	0	0	<0.01	0	0	0	0	0
	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
	Risso's dolphin	0	0	0	0	0	0	0	0	0
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0.54	0.21	0	0	0	0
PW	Gray seal	0.72	0	0	0	0	0	0	0	0
	Harbor seal	0.33	0	0	0.03	0	0	0	0	0
	Harp seal	0.38	0	0	0.06	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-40. Injury: Monopile foundation (13 m diameter, 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	6.01	2.61	1.97	<0.01	0	0	0.32	0	0
	Minke whale (migrating)	3.47	0.99	0.67	0.02	0	0	0	0	0
	Humpback whale	5.29	2.05	1.49	0.04	<0.01	<0.01	0.15	0	0
	North Atlantic right whale [a]	4.04	1.40	1.11	0	0	0	0	0	0
	Sei whale [a] (migrating)	3.89	1.30	1.15	0	0	0	0	0	0
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	0	0	0
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0
	Common dolphin	0	0	0	<0.01	0	0	0	0	0
	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
	Risso's dolphin	0	0	0	<0.01	0	0	0	0	0
	Long-finned pilot whale	0	0	0	<0.01	0	0	0	0	0
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0.03	0	0	0.55	0.13	0.03	0	0	0
PW	Gray seal	0.72	0	0	0	0	0	0	0	0
	Harbor seal	0.50	0	0	<0.01	<0.01	0	0	0	0
	Harp seal	0.54	0	0	0.05	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-41. Injury: Monopile foundation (13 m diameter, 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	5.81	2.16	1.97	0.03	0	0	0.04	0	0
	Minke whale (migrating)	3.76	1.20	0.88	0	0	0	0	0	0
	Humpback whale	5.17	1.94	1.55	0.06	0	0	0.07	0	0
	North Atlantic right whale [a]	4.43	1.54	1.22	0.02	0	0	0.02	0	0
	Sei whale [a] (migrating)	4.17	1.27	1.00	0.06	0	0	0	0	0
MF	Atlantic white-sided dolphin	0	0	0	0	0	0	0	0	0
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0
	Common dolphin	0	0	0	0	0	0	0	0	0
	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
	Risso's dolphin	0	0	0	<0.01	0	0	0	0	0
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0.60	0.24	<0.01	0	0	0
PW	Gray seal	0.72	0	0	0	0	0	0	0	0
	Harbor seal	0.51	0	0	0	0	0	0	0	0
	Harp seal	0.57	0	0	0.04	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-42. Injury: Monopile foundation (13 m diameter, 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

	Species	Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	6.29	2.69	2.08	0.06	0	0	0.32	0	0
	Minke whale (migrating)	3.76	1.18	0.95	<0.01	0	0	0	0	0
	Humpback whale	5.52	2.07	1.75	0.05	<0.01	<0.01	0.15	0	0
	North Atlantic right whale [a]	4.32	1.59	1.30	0	0	0	0	0	0
	Sei whale [a] (migrating)	4.28	1.33	1.30	0.04	0	0	0	0	0
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	0	0	0
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0
	Common dolphin	0	0	0	<0.01	0	0	0	0	0
	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
	Risso's dolphin	0	0	0	<0.01	0	0	0	0	0
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0.06	0	0	0.58	0.06	<0.01	0	0	0
PW	Gray seal	0.81	0	0	0	0	0	0	0	0
	Harbor seal	0.33	0	0	<0.01	0	0	0	0	0
	Harp seal	0.53	0	0	0.07	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-43. Injury: jacket foundation (4 m diameter, 3500 kJ hammer, four piles per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Vibratory + Impact						Vibratory		
		L_E			L_{pk}			L_E		
		Attenuation (dB)								
		0	10	12	0	10	12	0	10	12
LF	Fin whale [a]	7.99	4.02	3.58	0.07	<0.01	<0.01	1.10	0.04	0.04
LF	Minke whale (migrating)	4.61	1.94	1.50	0.01	<0.01	<0.01	0.33	0	0
LF	Humpback whale	7.03	3.32	2.79	0.04	<0.01	<0.01	1.05	0	0
LF	North Atlantic right whale [a]	5.61	2.44	2.15	0.09	0	0	0.58	0	0
LF	Sei whale [a] (migrating)	4.99	2.16	1.68	0.08	<0.01	<0.01	0.39	0	0
MF	Atlantic white-sided dolphin	0	0	0	<0.01	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	<0.01	0	0	0	0	0
MF	Common dolphin	0	0	0	<0.01	0	0	0	0	0
MF	Bottlenose dolphin, offshore	0	0	0	0	0	0	0	0	0
MF	Risso’s dolphin	0	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
MF	Sperm whale [a]	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0.23	0	0	0.62	0.23	0.07	0	0	0
PW	Gray seal	2.71	0.79	0.36	0.07	0	0	0	0	0
PW	Harbor seal	1.02	0.07	0	0.02	0	0	0	0	0
PW	Harp seal	1.35	0.12	0.13	0.09	0	0	0	0	0

[a] Listed as Endangered under the ESA.

Table H-44. Behavior: Monopile foundation (12 m diameter, 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	10.03	4.97	4.25	10.02	4.83	4.24	32.93	22.22	20.52
	Minke whale (migrating)	9.41	4.49	3.83	26.37	16.41	14.62	32.51	22.06	20.29
	Humpback whale	9.85	4.83	4.13	9.81	4.73	4.13	32.93	22.26	20.67
	North Atlantic right whale [c]	9.13	4.49	3.63	9.19	4.35	3.65	31.22	20.96	19.62
	Sei whale [c] (migrating)	9.89	4.60	3.82	27.89	17.21	15.54	32.94	22.30	20.62
MF	Atlantic white-sided dolphin	8.99	4.32	3.70	4.06	1.67	1.38	32.57	22.07	20.11
	Atlantic spotted dolphin	9.30	4.80	3.70	4.34	1.62	1.42	34.53	23.35	21.03
	Common dolphin	9.32	4.44	3.90	4.14	1.89	1.49	32.83	21.97	20.43
	Bottlenose dolphin, offshore	8.38	4.03	3.42	3.63	1.46	1.16	31.32	21.21	19.41
	Risso's dolphin	8.67	4.42	3.60	3.95	1.69	1.24	31.01	21.05	19.72
	Long-finned pilot whale	8.99	4.21	3.56	4.12	1.62	1.37	32.21	21.72	20.11
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	9.39	4.68	4.06	4.39	1.76	1.51	32.65	21.97	20.32
HF	Harbor porpoise (sensitive)	8.13	4.29	3.44	32.93	20.75	18.98	27.57	19.32	17.49
PW	Gray seal	10.39	5.16	4.51	7.25	3.45	2.95	33.13	22.32	20.66
	Harbor seal	8.81	3.81	3.33	5.90	2.80	2.36	28.12	19.80	18.29
	Harp seal	9.74	5.03	4.24	6.88	3.20	2.74	33.03	22.45	20.60

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

Table H-45. Behavior: Monopile foundation (12 m diameter, 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	9.95	4.89	4.17	9.95	4.76	4.18	32.98	22.14	20.54
	Minke whale (migrating)	9.28	4.43	3.85	26.31	16.29	14.58	32.45	21.93	20.14
	Humpback whale	9.62	4.73	4.04	9.69	4.67	4.02	32.95	22.28	20.59
	North Atlantic right whale [c]	9.17	4.38	3.95	9.29	4.34	3.95	31.33	21.10	19.53
	Sei whale [c] (migrating)	9.42	4.63	3.92	27.95	16.85	15.31	32.92	22.08	20.37
MF	Atlantic white-sided dolphin	9.01	4.40	3.60	4.00	1.76	1.33	32.16	21.72	20.14
	Atlantic spotted dolphin	9.24	4.22	3.51	3.87	1.82	1.38	34.05	23.10	21.20
	Common dolphin	9.04	4.34	3.83	4.12	1.69	1.47	32.30	21.89	20.08
	Bottlenose dolphin, offshore	8.01	3.71	3.21	3.41	1.42	1.21	31.17	20.81	19.34
	Risso’s dolphin	8.64	4.27	3.64	4.09	1.76	1.53	30.73	20.79	19.44
	Long-finned pilot whale	8.85	4.20	3.43	3.97	1.62	1.35	32.23	21.59	19.79
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	9.37	4.59	3.94	4.34	1.96	1.51	32.66	21.95	20.28
HF	Harbor porpoise (sensitive)	8.03	3.99	3.41	32.57	20.68	18.96	26.96	19.03	17.27
PW	Gray seal	10.25	5.13	4.42	7.28	3.40	2.98	33.25	22.29	20.55
	Harbor seal	8.69	4.03	3.51	5.79	2.69	2.25	27.73	19.89	18.12
	Harp seal	9.72	4.90	4.13	6.72	3.16	2.65	33.24	22.43	20.56

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

Table H-46. Behavior: Monopile foundation (12 m diameter, 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	10.52	5.30	4.59	10.59	5.29	4.56	32.93	22.22	20.52
	Minke whale (migrating)	9.94	5.01	4.32	27.95	17.40	15.74	32.51	22.06	20.29
	Humpback whale	10.39	5.35	4.62	10.41	5.25	4.58	32.93	22.26	20.67
	North Atlantic right whale [c]	9.79	4.91	4.22	9.84	4.95	4.20	31.22	20.96	19.62
	Sei whale [c] (migrating)	10.49	5.21	4.26	29.19	18.69	16.40	32.94	22.30	20.62
MF	Atlantic white-sided dolphin	9.81	5.08	4.16	4.61	1.97	1.68	32.57	22.07	20.11
	Atlantic spotted dolphin	10.20	5.17	4.13	4.90	1.98	1.94	34.53	23.35	21.03
	Common dolphin	10.00	5.02	4.21	4.56	2.05	1.80	32.83	21.97	20.43
	Bottlenose dolphin, offshore	9.27	4.29	3.59	4.01	1.94	1.72	31.32	21.21	19.41
	Risso's dolphin	9.43	4.78	4.02	4.50	2.04	1.60	31.01	21.05	19.72
	Long-finned pilot whale	9.66	4.86	4.03	4.55	1.90	1.64	32.21	21.72	20.11
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	10.19	5.17	4.41	4.70	2.05	1.81	32.65	21.97	20.32
HF	Harbor porpoise (sensitive)	8.79	4.56	3.89	34.81	21.94	19.88	27.57	19.32	17.49
PW	Gray seal	10.86	5.67	4.74	7.61	3.73	3.10	33.13	22.32	20.66
	Harbor seal	9.48	4.35	3.73	6.67	3.27	2.58	28.12	19.80	18.29
	Harp seal	10.41	5.25	4.42	7.43	3.44	2.96	33.03	22.45	20.60

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

Table H-47. Behavior: Monopile foundation (12 m diameter, 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	10.43	5.31	4.47	10.48	5.31	4.42	32.98	22.14	20.54
	Minke whale (migrating)	9.94	4.92	4.15	27.97	17.50	15.71	32.45	21.93	20.14
	Humpback whale	10.35	5.18	4.34	10.48	5.19	4.30	32.95	22.28	20.59
	North Atlantic right whale [c]	9.77	4.83	4.18	9.83	4.84	4.17	31.33	21.10	19.53
	Sei whale [c] (migrating)	10.28	5.24	4.30	29.48	18.14	16.30	32.92	22.08	20.37
MF	Atlantic white-sided dolphin	9.77	4.97	4.09	4.49	2.00	1.69	32.16	21.72	20.14
	Atlantic spotted dolphin	10.06	4.71	3.99	4.38	2.05	1.75	34.05	23.10	21.20
	Common dolphin	9.80	4.90	4.15	4.51	2.08	1.70	32.30	21.89	20.08
	Bottlenose dolphin, offshore	8.82	4.41	3.66	4.05	1.84	1.53	31.17	20.81	19.34
	Risso's dolphin	9.34	4.71	4.10	4.45	2.04	1.68	30.73	20.79	19.44
	Long-finned pilot whale	9.70	4.76	4.05	4.43	1.87	1.58	32.23	21.59	19.79
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	10.02	5.11	4.31	4.70	2.13	1.79	32.66	21.95	20.28
HF	Harbor porpoise (sensitive)	8.67	4.38	3.73	34.40	22.08	20.19	26.96	19.03	17.27
PW	Gray seal	10.67	5.53	4.70	7.82	3.72	3.16	33.25	22.29	20.55
	Harbor seal	9.33	4.42	3.82	6.33	3.03	2.57	27.73	19.89	18.12
	Harp seal	10.36	5.24	4.46	7.29	3.40	2.96	33.24	22.43	20.56

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

Table H-48. Behavior: Monopile foundation (13 m diameter, 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	10.70	5.12	4.30	10.62	5.12	4.29	45.57	29.40	26.55
	Minke whale (migrating)	9.80	4.62	4.12	32.60	18.55	16.48	44.13	28.66	25.87
	Humpback whale	10.42	5.09	4.35	10.44	5.10	4.20	45.51	29.27	26.65
	North Atlantic right whale [c]	9.81	4.58	4.06	9.85	4.75	4.02	42.10	28.07	25.50
	Sei whale [c] (migrating)	10.47	4.85	4.23	34.98	20.03	17.69	45.60	29.29	26.38
MF	Atlantic white-sided dolphin	9.66	4.50	4.06	4.30	1.76	1.42	43.60	28.30	25.61
	Atlantic spotted dolphin	9.96	4.66	4.12	4.35	2.12	1.42	45.98	29.75	27.04
	Common dolphin	9.64	4.61	3.94	4.23	1.92	1.54	45.27	29.10	26.30
	Bottlenose dolphin, offshore	8.90	4.15	3.46	3.64	1.50	1.31	43.94	27.88	25.22
	Risso’s dolphin	9.16	4.60	3.97	4.34	1.86	1.54	41.67	27.16	24.56
	Long-finned pilot whale	9.29	4.50	3.89	4.20	1.95	1.45	42.25	27.77	25.17
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	10.14	4.87	4.26	4.54	2.03	1.66	45.24	29.15	26.15
HF	Harbor porpoise (sensitive)	8.73	4.41	3.79	37.09	21.67	19.51	34.64	23.33	21.42
PW	Gray seal	10.73	5.42	4.74	7.30	3.70	3.13	45.74	29.51	26.60
	Harbor seal	8.95	4.33	3.68	5.96	3.08	2.40	36.75	24.96	22.88
	Harp seal	10.35	5.11	4.36	6.89	3.32	2.84	45.58	29.45	26.46

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

Table H-49. Behavior: Monopile foundation (13 m diameter, 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	10.43	4.97	4.41	10.44	4.98	4.34	45.76	29.41	26.49
	Minke whale (migrating)	9.70	4.75	4.07	32.57	18.57	16.22	43.53	28.38	25.59
	Humpback whale	10.22	4.95	4.34	10.26	4.98	4.30	45.27	29.03	26.39
	North Atlantic right whale [c]	9.67	4.52	3.86	9.76	4.51	3.86	42.40	27.45	25.01
	Sei whale [c] (migrating)	10.34	5.02	4.24	33.44	19.89	17.33	45.13	29.02	25.99
MF	Atlantic white-sided dolphin	9.36	4.57	3.89	4.28	1.80	1.49	44.12	28.64	25.76
	Atlantic spotted dolphin	9.85	4.68	3.88	4.29	1.99	1.47	46.54	30.12	27.22
	Common dolphin	9.60	4.64	4.04	4.33	1.94	1.59	44.42	28.53	25.76
	Bottlenose dolphin, offshore	8.69	4.12	3.43	3.66	1.57	1.25	43.34	27.42	24.63
	Risso's dolphin	9.17	4.59	3.96	4.26	1.84	1.53	42.88	27.41	24.79
	Long-finned pilot whale	9.17	4.48	3.81	4.21	1.80	1.54	42.16	27.45	24.96
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	9.92	4.86	4.16	4.31	2.05	1.61	45.17	28.87	26.02
HF	Harbor porpoise (sensitive)	8.32	4.37	3.76	37.44	21.85	19.53	34.17	23.20	21.20
PW	Gray seal	10.67	5.34	4.65	7.25	3.72	3.08	45.85	29.53	26.63
	Harbor seal	8.72	4.15	3.69	5.83	3.04	2.65	36.64	24.58	22.59
	Harp seal	10.28	4.98	4.38	6.88	3.38	2.88	45.51	29.44	26.28

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

Table H-50. Behavior: Monopile foundation (13 m diameter, 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	11.18	5.59	4.77	11.27	5.59	4.76	45.57	29.40	26.55
	Minke whale (migrating)	10.56	5.19	4.53	34.63	19.97	17.67	44.13	28.66	25.87
	Humpback whale	10.97	5.42	4.70	11.01	5.39	4.69	45.51	29.27	26.65
	North Atlantic right whale [c]	10.54	5.08	4.40	10.58	5.07	4.40	42.10	28.07	25.50
	Sei whale [c] (migrating)	11.10	5.38	4.50	36.77	21.28	19.02	45.60	29.29	26.38
MF	Atlantic white-sided dolphin	10.35	5.04	4.27	4.53	2.09	1.72	43.60	28.30	25.61
	Atlantic spotted dolphin	10.72	5.05	4.39	4.73	2.38	2.05	45.98	29.75	27.04
	Common dolphin	10.46	5.28	4.34	4.65	2.16	1.63	45.27	29.10	26.30
	Bottlenose dolphin, offshore	9.74	4.61	4.00	4.33	1.73	1.39	43.94	27.88	25.22
	Risso's dolphin	9.87	4.99	4.26	4.68	2.11	1.80	41.67	27.16	24.56
	Long-finned pilot whale	10.12	4.84	4.19	4.58	1.94	1.60	42.25	27.77	25.17
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	10.80	5.40	4.71	4.87	2.17	1.81	45.24	29.15	26.15
HF	Harbor porpoise (sensitive)	9.09	4.82	4.03	39.00	22.86	20.79	34.64	23.33	21.42
PW	Gray seal	11.34	5.83	4.90	7.75	3.84	3.43	45.74	29.51	26.60
	Harbor seal	9.55	4.56	3.97	6.39	3.40	2.88	36.75	24.96	22.88
	Harp seal	10.97	5.49	4.72	7.48	3.61	3.13	45.58	29.45	26.46

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

Table H-51. Behavior: Monopile foundation (13 m diameter, 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	11.07	5.49	4.62	11.10	5.48	4.63	45.76	29.41	26.49
	Minke whale (migrating)	10.50	5.21	4.43	34.79	19.83	17.50	43.53	28.38	25.59
	Humpback whale	10.78	5.43	4.66	10.86	5.43	4.66	45.27	29.03	26.39
	North Atlantic right whale [c]	10.36	5.11	4.39	10.41	5.09	4.40	42.40	27.45	25.01
	Sei whale [c] (migrating)	11.10	5.43	4.61	35.23	20.78	18.60	45.13	29.02	25.99
MF	Atlantic white-sided dolphin	10.41	5.03	4.36	4.66	2.11	1.81	44.12	28.64	25.76
	Atlantic spotted dolphin	10.68	4.90	4.45	4.66	2.22	1.85	46.54	30.12	27.22
	Common dolphin	10.40	5.19	4.48	4.75	2.09	1.70	44.42	28.53	25.76
	Bottlenose dolphin, offshore	9.51	4.76	3.95	4.13	1.85	1.48	43.34	27.42	24.63
	Risso's dolphin	9.79	5.08	4.26	4.67	2.08	1.80	42.88	27.41	24.79
	Long-finned pilot whale	9.96	4.83	4.25	4.57	2.03	1.66	42.16	27.45	24.96
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	10.57	5.28	4.54	4.71	2.25	1.78	45.17	28.87	26.02
HF	Harbor porpoise (sensitive)	8.92	4.84	4.17	39.40	23.24	20.91	34.17	23.20	21.20
PW	Gray seal	11.36	5.78	4.88	7.81	3.97	3.44	45.85	29.53	26.63
	Harbor seal	9.41	4.69	4.05	6.52	3.33	2.82	36.64	24.58	22.59
	Harp seal	10.91	5.48	4.78	7.53	3.61	3.21	45.51	29.44	26.28

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

Table H-52. Behavior: jacket foundation (4 m diameter, 3500 kJ hammer, four piles per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Species		Impact						Vibratory		
		L_p [a]			L_p [b]			L_p [a]		
		Attenuation (dB)						Attenuation (dB)		
		0	10	12	0	10	12	0	10	12
LF	Fin whale [c]	8.43	4.63	4.15	8.41	4.65	4.16	39.43	27.74	25.83
	Minke whale (migrating)	7.93	4.22	3.67	23.72	14.48	13.16	38.54	26.94	24.85
	Humpback whale	8.28	4.70	4.10	8.27	4.74	4.11	39.09	27.43	25.57
	North Atlantic right whale [c]	7.94	4.47	3.84	7.96	4.48	3.85	36.15	25.66	23.87
	Sei whale [c] (migrating)	8.09	4.56	4.04	24.83	14.68	13.23	40.51	28.05	26.16
MF	Atlantic white-sided dolphin	8.07	4.41	3.84	4.62	2.29	1.94	38.97	27.16	25.04
	Atlantic spotted dolphin	7.82	4.50	4.00	4.87	2.37	1.85	41.77	29.06	27.08
	Common dolphin	7.87	4.46	3.87	4.73	2.28	1.97	38.91	27.04	25.13
	Bottlenose dolphin, offshore	7.29	4.09	3.52	4.24	1.97	1.68	37.25	25.85	23.94
	Risso’s dolphin	7.84	4.30	3.73	4.56	2.27	1.90	38.05	26.51	24.53
	Long-finned pilot whale	7.67	4.18	3.61	4.56	2.22	1.90	38.51	26.89	24.79
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0
	Sperm whale [c]	8.10	4.54	3.99	4.79	2.27	1.94	39.03	27.11	25.36
HF	Harbor porpoise (sensitive)	7.40	4.21	3.68	31.92	18.94	17.01	32.16	23.26	21.72
PW	Gray seal	8.63	4.98	4.42	6.55	3.63	3.25	38.69	27.41	25.51
	Harbor seal	7.31	4.11	3.60	6.00	3.31	2.78	32.47	23.55	22.23
	Harp seal	8.32	4.64	4.14	6.34	3.57	3.06	39.24	27.65	25.76

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

H.2.3.2. Sea Turtles

Table H-53. Monopile foundation (12 m diameter 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	1.04	0	0	0	0	0	0	0	0	2.53	0.86	0.56
Leatherback turtle [a]	1.62	0.30	0.26	0	0	0	0	0	0	3.40	1.35	0.94
Loggerhead turtle	1.11	0	0	0	0	0	0	0	0	3.02	1.15	1.05
Green turtle	0.98	0	0	0	0	0	0	0	0	2.90	1.03	0.70

[a] Listed as Endangered under the ESA.

Table H-54. Monopile foundation (12 m diameter 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	0.99	0	0	0	0	0	0	0	0	2.57	0.54	0.54
Leatherback turtle [a]	1.83	0.38	0.25	0	0	0	0	0	0	3.43	1.31	1.10
Loggerhead turtle	1.37	0	0	0	0	0	0	0	0	3.12	1.23	0.54
Green turtle	1.20	0	0	0	0	0	0	0	0	2.96	1.10	0.79

[a] Listed as Endangered under the ESA.

Table H-55. Monopile foundation (12 m diameter 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	1.06	0	0	0	0	0	0	0	0	2.63	1.37	1.04
Leatherback turtle [a]	1.62	0.30	0.26	0	0	0	0	0	0	3.68	1.47	1.26
Loggerhead turtle	1.25	0	0	0	0	0	0	0	0	3.39	1.43	0.95
Green turtle	0.99	0	0	0	0	0	0	0	0	3.39	1.29	0.99

[a] Listed as Endangered under the ESA.

Table H-56. Monopile foundation (12 m diameter 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	1.00	0	0	0	0	0	0	0	0	2.67	0.93	0.76
Leatherback turtle [a]	1.87	0.39	0.25	0	0	0	0	0	0	3.71	1.52	1.18
Loggerhead turtle	1.58	0.21	0	0	0	0	0	0	0	3.29	1.17	0.94
Green turtle	1.16	0	0	0	0	0	0	0	0	3.23	1.23	1.00

[a] Listed as Endangered under the ESA.

Table H-57. Monopile foundation (13 m diameter 5000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	0.85	0	0	0	0	0	0	0	0	2.41	0.39	0.23
Leatherback turtle [a]	1.58	0.25	0.24	0	0	0	0	0	0	3.74	1.34	1.14
Loggerhead turtle	1.46	0	0	0	0	0	0	0	0	3.30	1.39	0.93
Green turtle	1.13	0	0	0	0	0	0	0	0	3.33	1.21	0.67

[a] Listed as Endangered under the ESA.

Table H-58. Monopile foundation (13 m diameter 5000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	1.13	0	0	0	0	0	0	0	0	2.94	0.98	0.75
Leatherback turtle [a]	2.16	0.35	0.21	0	0	0	0	0	0	3.67	1.46	1.18
Loggerhead turtle	1.39	0	0	0	0	0	0	0	0	3.18	1.23	1.03
Green turtle	1.10	0.01	0.01	0	0	0	0	0	0	3.17	1.29	0.75

[a] Listed as Endangered under the ESA.

Table H-59. Monopile foundation (13 m diameter 6000 kJ hammer, one per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	1.19	0	0	0	0	0	0	0	0	2.71	1.16	0.99
Leatherback turtle [a]	1.69	0.28	0.28	0	0	0	0	0	0	3.95	1.54	1.23
Loggerhead turtle	1.55	0	0	0	0	0	0	0	0	3.55	1.39	0.97
Green turtle	1.19	0	0	0	0	0	0	0	0	3.52	1.22	1.02

[a] Listed as Endangered under the ESA.

Table H-60. Monopile foundation (13 m diameter 6000 kJ hammer, two per day): Vibratory and impact exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	0.93	0.27	0	0	0	0	0	0	0	3.55	1.20	0.74
Leatherback turtle [a]	2.18	0.41	0.21	0	0	0	0	0	0	3.97	1.51	1.27
Loggerhead turtle	1.72	0.31	0	0	0	0	0	0	0	3.54	1.43	1.16
Green turtle	1.44	0.01	0.01	0	0	0	0	0	0	3.53	1.45	1.07

[a] Listed as Endangered under the ESA.

Table H-61. Jacket foundation (4 m diameter, 3500 kJ hammer, 4 per day): Exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury									Behavior		
	Vibratory + Impact						Vibratory			Vibratory + Impact		
	L_E			L_{pk}			L_E			L_p		
	Attenuation (dB)			Attenuation (dB)			Attenuation (dB)			Attenuation (dB)		
	0	10	12	0	10	12	0	10	12	0	10	12
Kemp's ridley turtle [a]	1.98	0.28	0.24	0	0	0	0	0	0	3.05	1.09	0.80
Leatherback turtle [a]	4.08	1.48	1.16	0	0	0	0	0	0	3.58	1.28	1.10
Loggerhead turtle	2.50	0.58	0.50	0	0	0	0	0	0	3.25	1.30	0.99
Green turtle	2.17	0.38	0.26	0	0	0	0	0	0	3.17	1.24	0.89

[a] Listed as Endangered under the ESA.

H.3. Animal Densities

As described in Section 3.2, for vibratory setting of piles followed by impact pile driving and impact pile driving alone, densities were calculated within buffered polygons around the Lease Area perimeter for the following buffer ranges: 10, 25 and 50 km. The following section contains density values for those ranges.

H.3.1. Marine Mammals

Table H-62. Mean monthly marine mammal density estimates for all modeled species in a 25-km perimeter around New England Wind, used to calculate exposures above the 120 dB SPL behavioral threshold for vibratory setting followed by impact pile driving and impact pile driving alone.

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]	0.213	0.161	0.118	0.165	0.272	0.247	0.391	0.316	0.221	0.068	0.056	0.146	0.198	0.214
Minke whale	0.119	0.138	0.143	0.790	1.617	1.468	0.622	0.397	0.436	0.436	0.054	0.084	0.525	0.639
Humpback whale	0.034	0.026	0.044	0.146	0.271	0.284	0.156	0.107	0.147	0.202	0.174	0.035	0.135	0.172
North Atlantic right whale [a]	0.443	0.523	0.493	0.471	0.279	0.052	0.026	0.019	0.029	0.050	0.084	0.257	0.227	0.100
Sei whale [a]	0.036	0.022	0.045	0.115	0.186	0.053	0.013	0.010	0.017	0.035	0.080	0.066	0.056	0.058
Atlantic white-sided dolphin	2.062	1.314	0.913	1.383	3.179	2.994	1.368	0.644	1.532	2.246	1.741	2.357	1.811	2.008
Atlantic spotted dolphin	0.001	<0.001	<0.001	0.003	0.027	0.042	0.034	0.055	0.282	0.577	0.181	0.020	0.102	0.152
Common dolphin	7.388	2.799	2.212	3.612	6.556	13.827	10.602	13.820	23.538	24.395	12.882	11.716	11.112	14.667
Bottlenose dolphin, offshore	0.476	0.118	0.066	0.174	0.835	1.390	1.491	1.624	1.528	1.414	1.324	1.077	0.960	1.335
Risso's dolphin	0.051	0.006	0.003	0.021	0.112	0.070	0.092	0.170	0.223	0.122	0.128	0.174	0.098	0.136
Long-finned pilot whale [b]	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
Short-finned pilot whale [b]	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
Sperm whale [a]	0.030	0.012	0.012	0.003	0.013	0.028	0.038	0.115	0.059	0.042	0.029	0.021	0.034	0.043
Harbor porpoise	9.007	9.787	9.321	8.194	5.913	1.172	1.147	1.030	1.003	1.222	1.421	5.478	4.558	2.298
Gray seal [b]	5.553	5.401	3.946	3.485	5.109	1.750	0.315	0.296	0.497	0.881	2.108	4.485	2.819	1.930
Harbor seal [b]	8.329	8.101	5.919	5.227	7.664	2.625	0.473	0.443	0.745	1.322	3.161	6.728	4.228	2.895
Harp seal [b]	5.949	5.786	4.228	3.733	5.474	1.875	0.338	0.317	0.532	0.944	2.258	4.806	3.020	2.068

[a] Listed as Endangered under the ESA.
[b] Density adjusted by relative local abundance. Harp seal uses gray seal density.

Table H-63. Mean monthly marine mammal density estimates for all modeled species in a 50-km perimeter around New England Wind, used to calculate exposures above the 120 dB SPL behavioral threshold for vibratory setting followed by impact pile driving and impact pile driving alone.

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]	0.194	0.158	0.142	0.169	0.256	0.246	0.383	0.316	0.244	0.093	0.060	0.128	0.199	0.216
Minke whale	0.106	0.121	0.138	0.652	1.298	1.163	0.504	0.302	0.338	0.387	0.051	0.080	0.428	0.515
Humpback whale	0.037	0.030	0.044	0.167	0.270	0.300	0.158	0.096	0.124	0.177	0.164	0.041	0.134	0.166
North Atlantic right whale [a]	0.565	0.674	0.580	0.511	0.321	0.084	0.055	0.033	0.045	0.055	0.119	0.361	0.284	0.134
Sei whale [a]	0.030	0.024	0.045	0.123	0.181	0.059	0.016	0.009	0.014	0.034	0.076	0.058	0.056	0.056
Atlantic white-sided dolphin	2.430	1.744	1.187	1.652	3.170	3.373	1.468	0.508	1.265	2.153	1.732	2.428	1.926	2.012
Atlantic spotted dolphin	0.002	<0.001	<0.001	0.006	0.073	0.182	0.052	0.084	0.449	1.025	0.238	0.027	0.178	0.266
Common dolphin	10.202	5.127	4.047	5.422	8.950	18.237	13.103	14.754	22.465	30.637	18.664	15.127	13.895	17.742
Bottlenose dolphin, offshore	0.691	0.222	0.130	0.293	1.119	1.863	1.924	1.935	2.001	1.972	1.905	1.455	1.293	1.772
Risso's dolphin	0.110	0.023	0.009	0.040	0.230	0.227	0.299	0.488	0.642	0.322	0.190	0.218	0.233	0.327
Long-finned pilot whale [b]	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
Short-finned pilot whale [b]	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Sperm whale [a]	0.031	0.018	0.018	0.005	0.014	0.029	0.039	0.111	0.053	0.035	0.028	0.028	0.034	0.042
Harbor porpoise	6.731	7.481	7.192	6.632	4.590	1.481	1.388	1.038	0.852	1.130	1.383	4.273	3.681	2.017
Gray seal [b]	5.346	4.893	4.081	4.674	6.820	5.412	1.595	1.318	1.519	2.863	3.322	4.748	3.882	3.450
Harbor seal [b]	8.019	7.339	6.121	7.011	10.229	8.118	2.392	1.977	2.279	4.295	4.982	7.122	5.824	5.174
Harp seal [b]	5.728	5.242	4.372	5.008	7.307	5.798	1.709	1.412	1.628	3.068	3.559	5.087	4.160	3.696

[a] Listed as Endangered under the ESA.
[b] Density adjusted by relative local abundance. Harp seal uses gray seal density.

H.3.2. Sea Turtles

Table H-64. Sea turtle density estimates for all modeled species in a 25-km perimeter around New England Wind.

Species	Monthly densities (animals/100 km^2)[a]				Annual mean	May to Dec mean
	Spring	Summer	Fall	Winter		
Green sea turtle [b]	0.009	0.009	0.009	0.009	0.009	0.009
Leatherback sea turtle	0.024	0.630	0.873	0.024	0.388	0.570
Loggerhead sea turtle	0.105	0.206	0.633	0.105	0.262	0.341
Kemp's ridley sea turtle	0.009	0.009	0.009	0.009	0.009	0.009

[a] Density estimates are extracted from SERDP-SDSS NODE database within a 25 km perimeter of New England Wind, 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)

Table H-65. Sea turtle density estimates for all modeled species in a 50-km perimeter around New England Wind.

Species	Monthly densities (animals/100 km^2)[a]				Annual mean	May to Dec mean
	Spring	Summer	Fall	Winter		
Green sea turtle [b]	0.008	0.008	0.008	0.008	0.008	0.008
Leatherback sea turtle	0.027	0.630	0.873	0.027	0.389	0.570
Loggerhead sea turtle	0.105	0.206	0.633	0.105	0.262	0.341
Kemp's ridley sea turtle	0.008	0.008	0.008	0.008	0.008	0.008

[a] Density estimates are extracted from SERDP-SDSS NODE database within a 50 km perimeter of New England Wind, 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)

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H.4. Animat Seeding Areas

Exposure modeling seeding areas are set using each species' preferred depth range. The following maps show seeding areas for each species, overlaid on a density map, if available, displaying the highest density month (between May-December) for that species. If density surfaces are unavailable for a particular species, a surrogate may be used, and for some species, the density data source shown in the image may not coincide with the data source used in predicting exposures. Please refer to Section 3 for a detailed description of density sources and calculations.

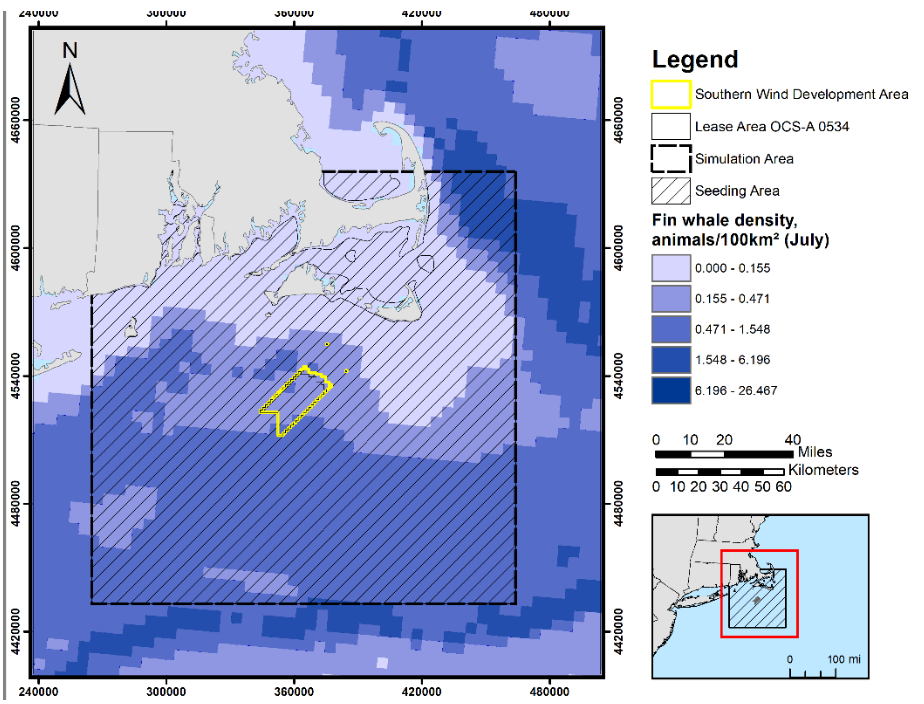

Figure H-1. Map of fin whale seeding area range for July, the month with the highest density.

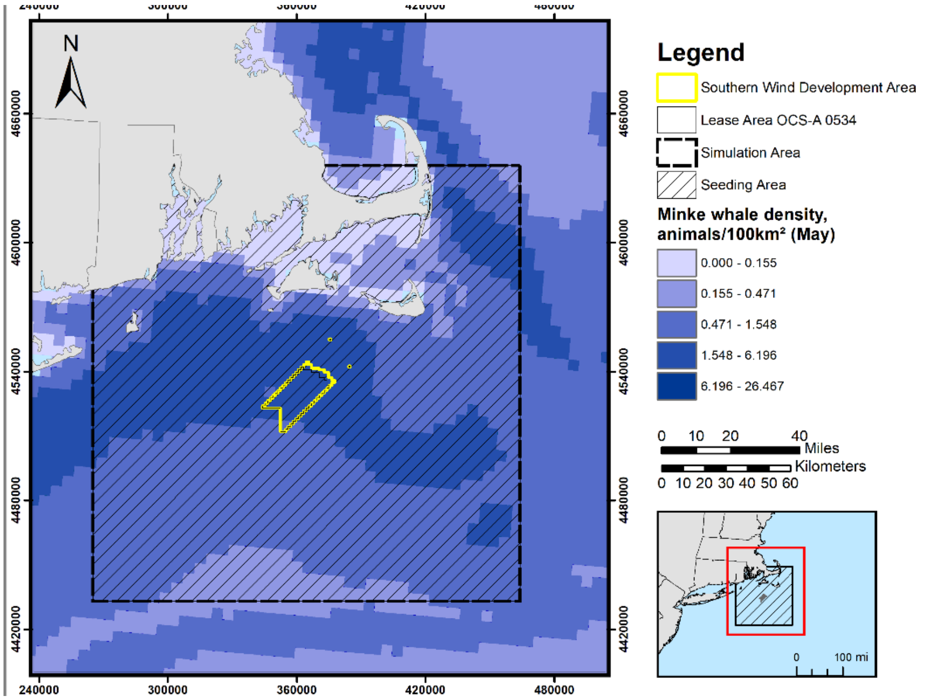

Figure H-2. Map of minke whale seeding area range for May, the month with the highest density.

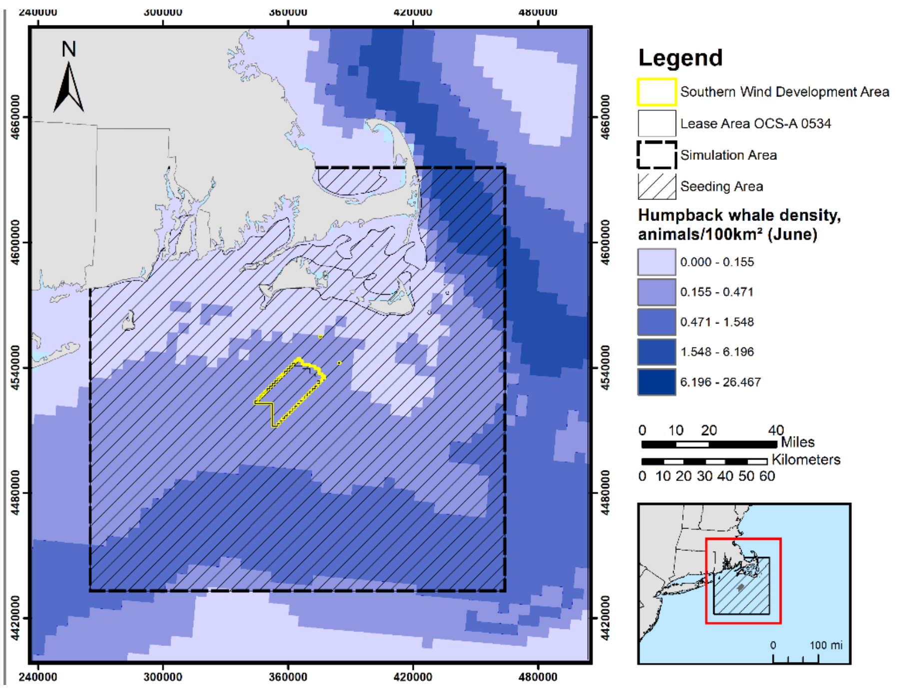

Figure H-3. Map of humpback whale seeding area range for June, the month with the highest density.

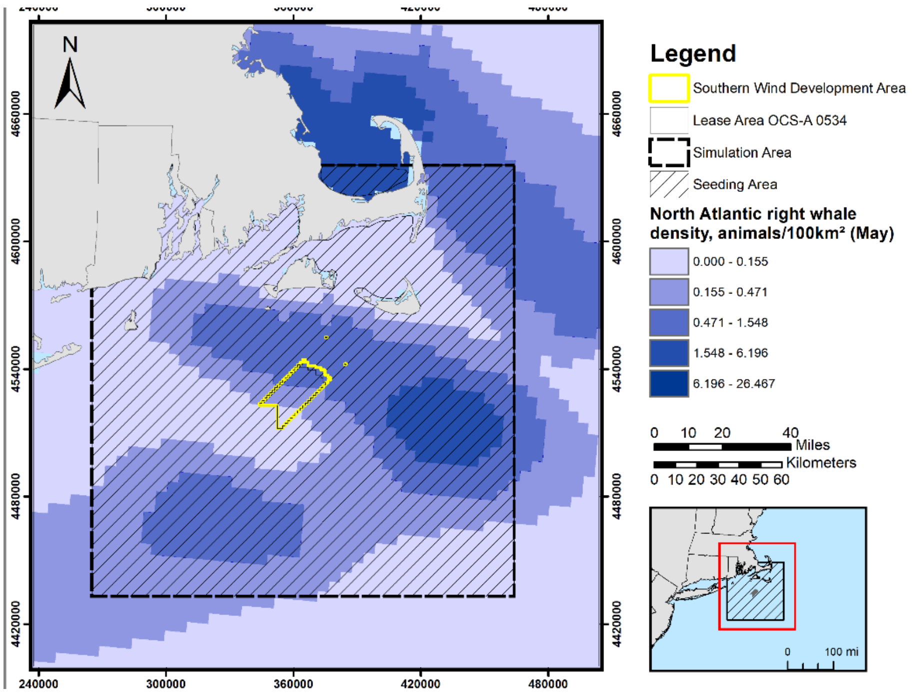

Figure H-4. Map of NARW seeding area range for May, the month with the highest density.

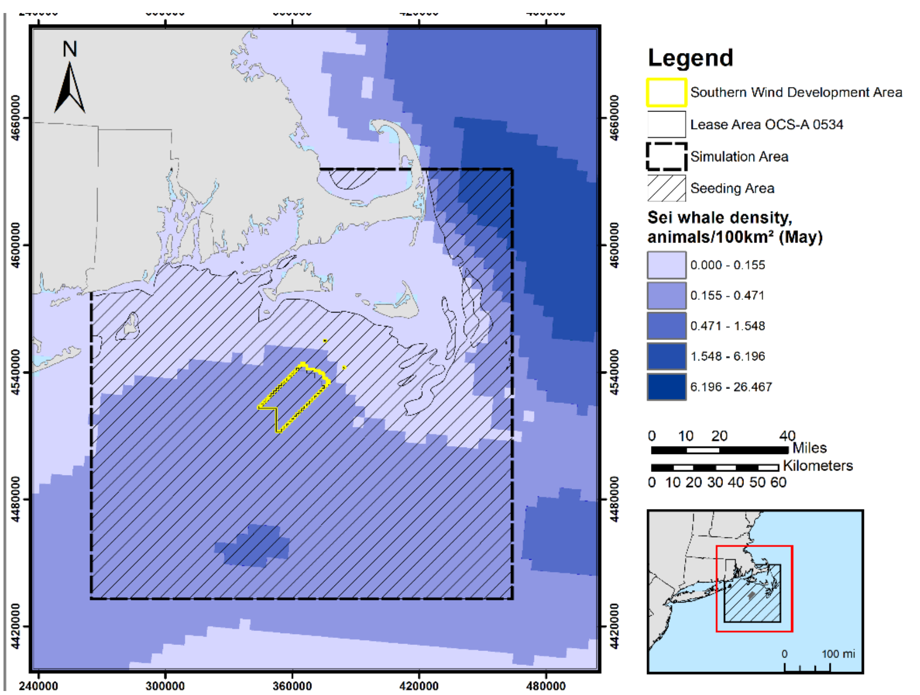

Figure H-5. Map of sei whale seeding area range for May, the month with the highest density.

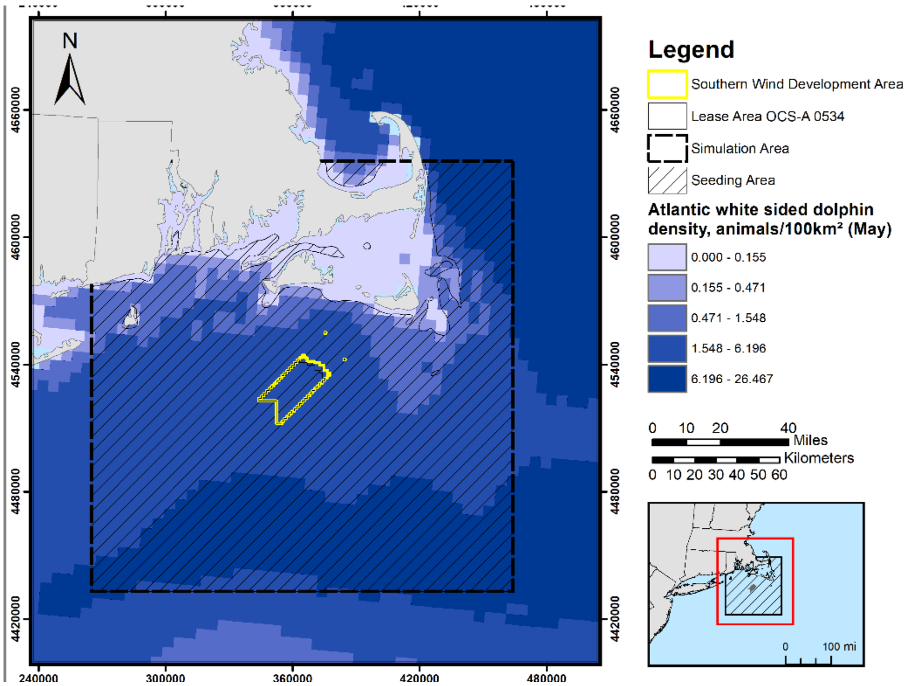

Figure H-6. Map of Atlantic white-sided dolphin seeding area range for May, the month with the highest density.

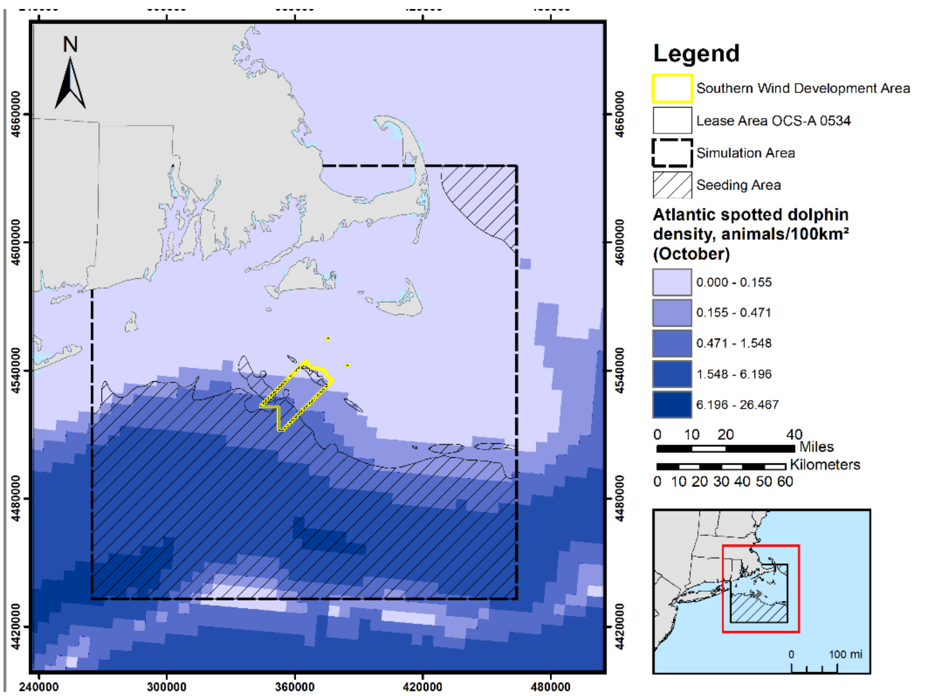

Figure H-7. Map of Atlantic spotted dolphin seeding area range for October, the month with the highest density.

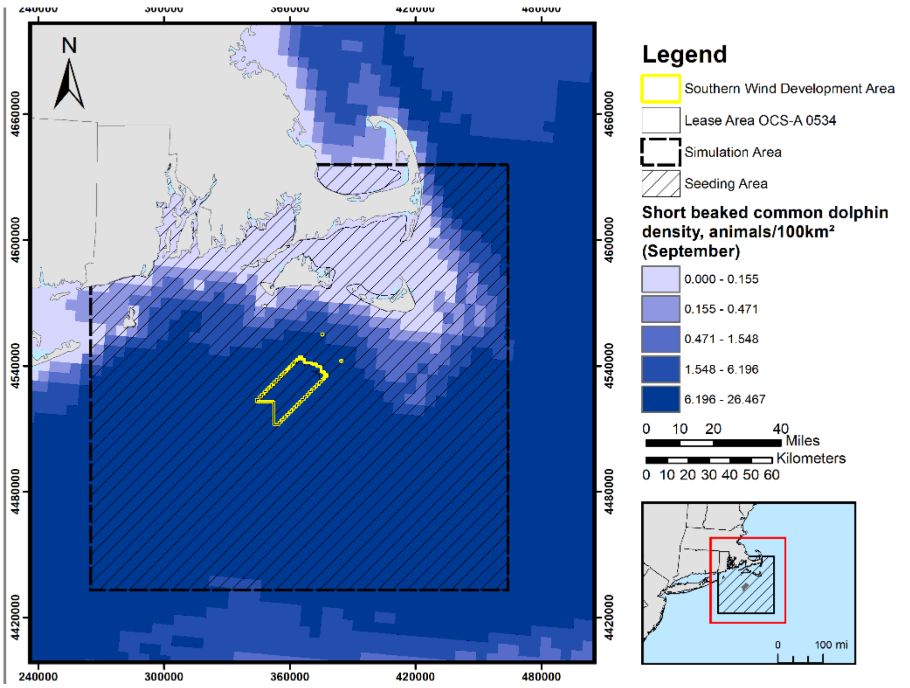

Figure H-8. Map of common dolphin seeding area range for September, the month with the highest density.

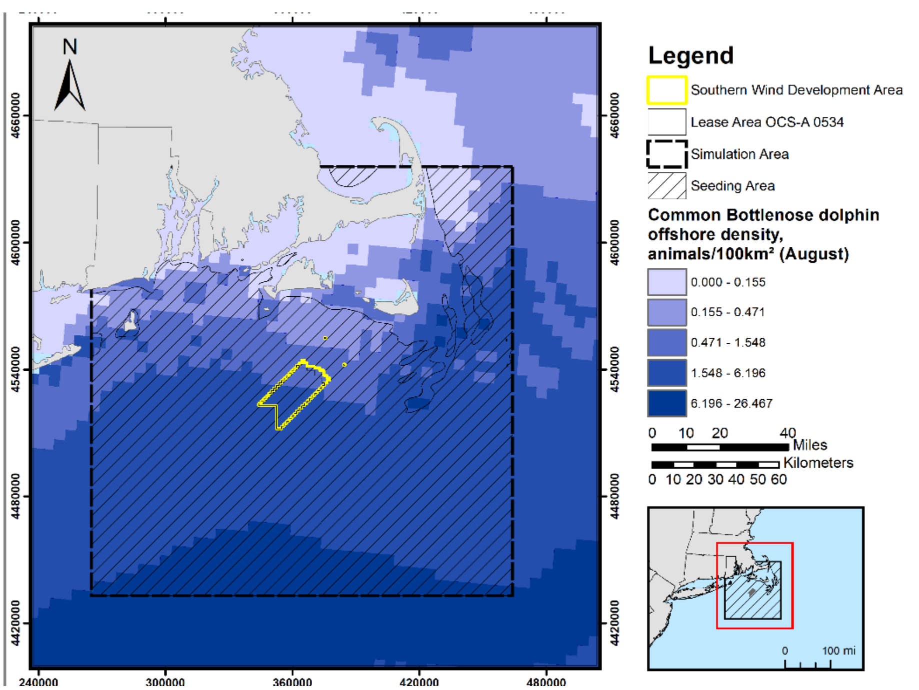

Figure H-9. Map of bottlenose dolphin seeding area range for August, the month with the highest density.

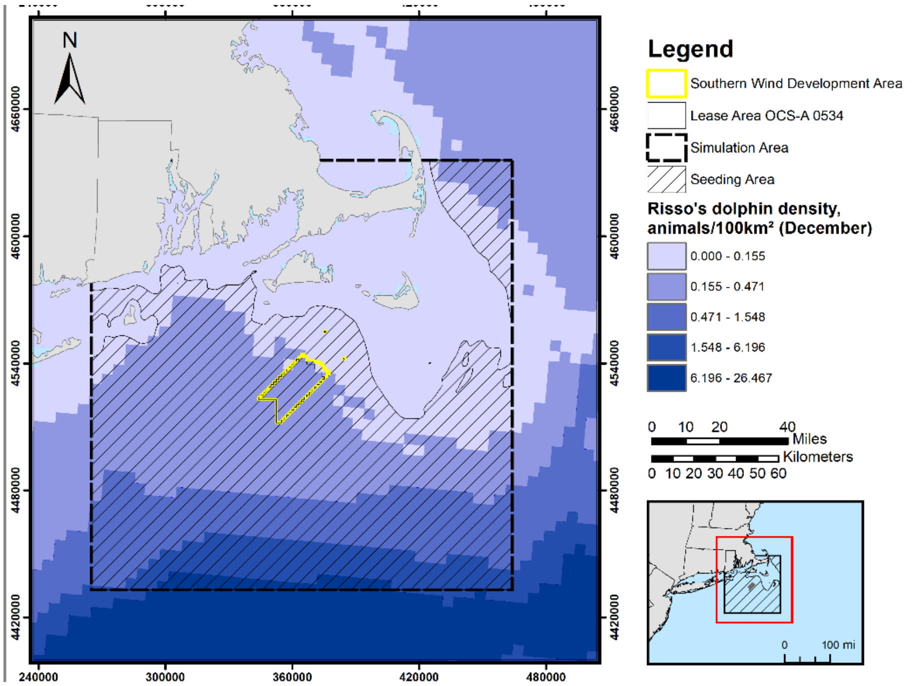

Figure H-10. Map of Risso's dolphin seeding area range for December, the month with the highest density.

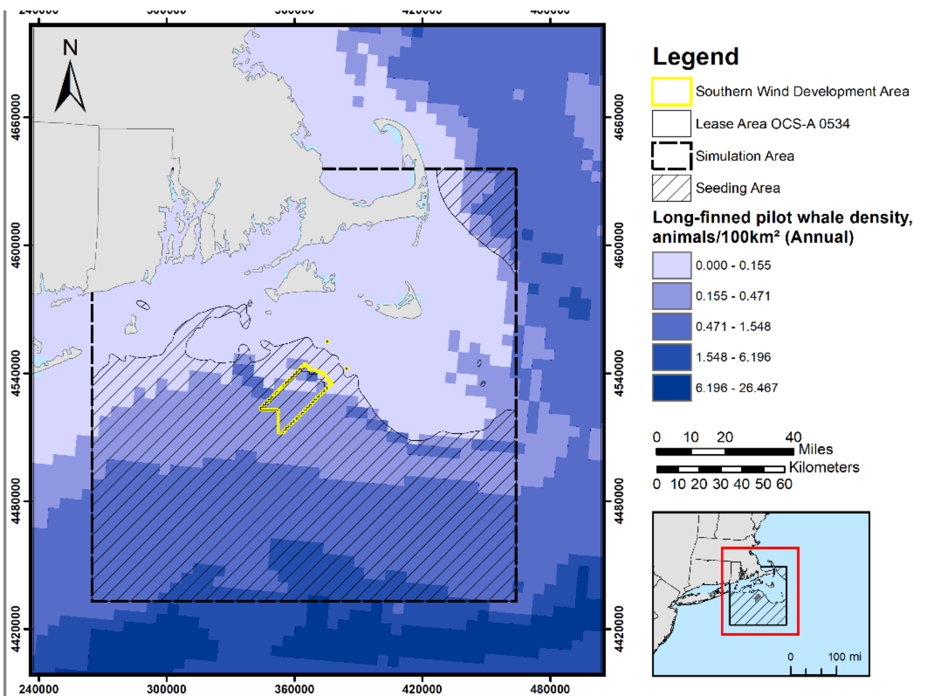

Figure H-11. Map of long-finned pilot whale seeding area range.

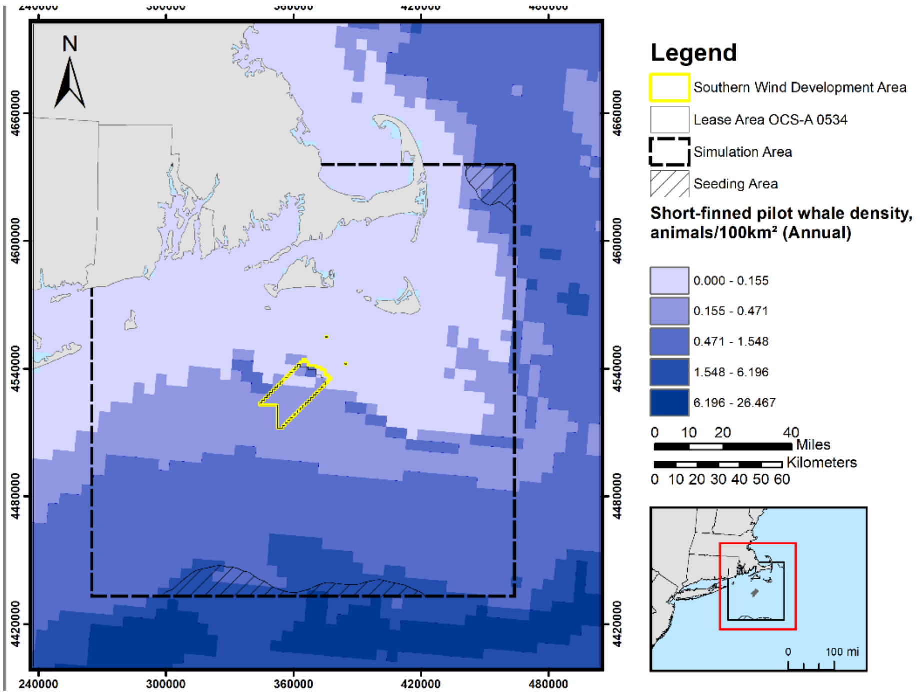

Figure H-12. Map of short-finned pilot whale seeding area range.

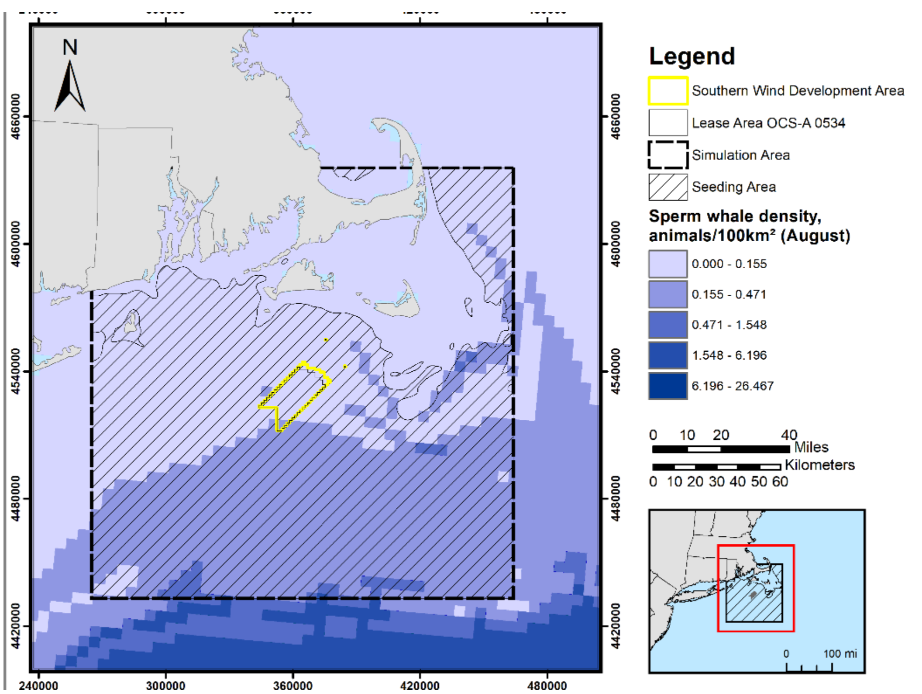

Figure H-13. Map of sperm whale seeding area range for August, the month with the highest density.

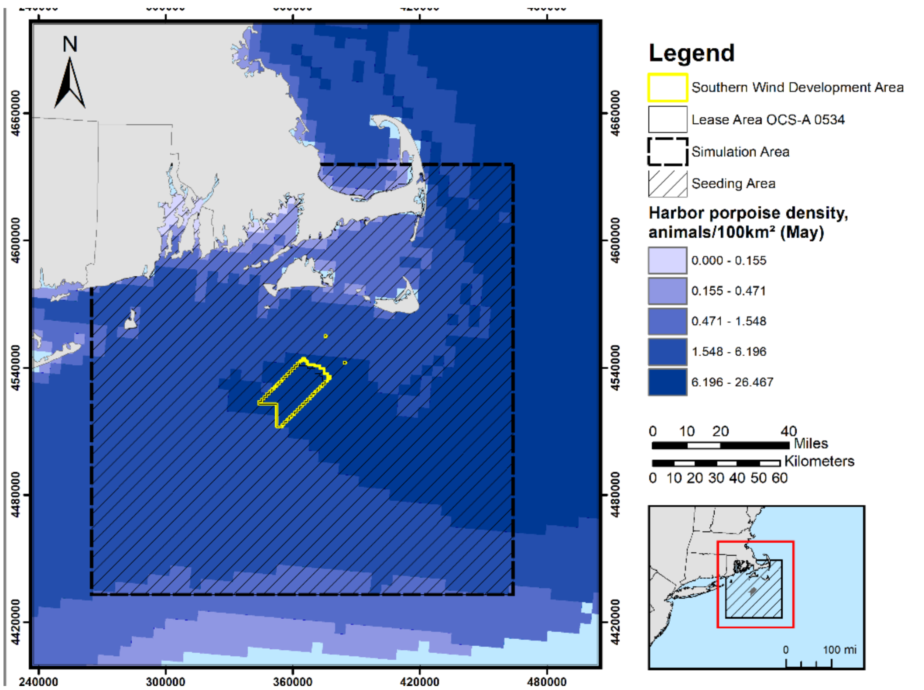

Figure H-14. Map of harbor porpoise seeding area range for May, the month with the highest density.

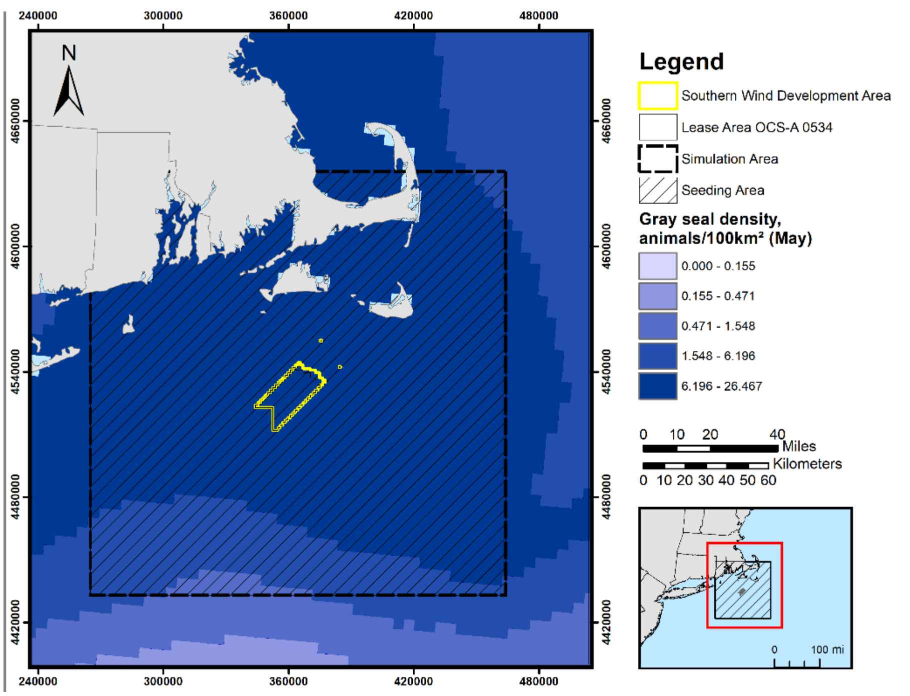

Figure H-15. Map of gray seal seeding area range for May, the month with the highest density.

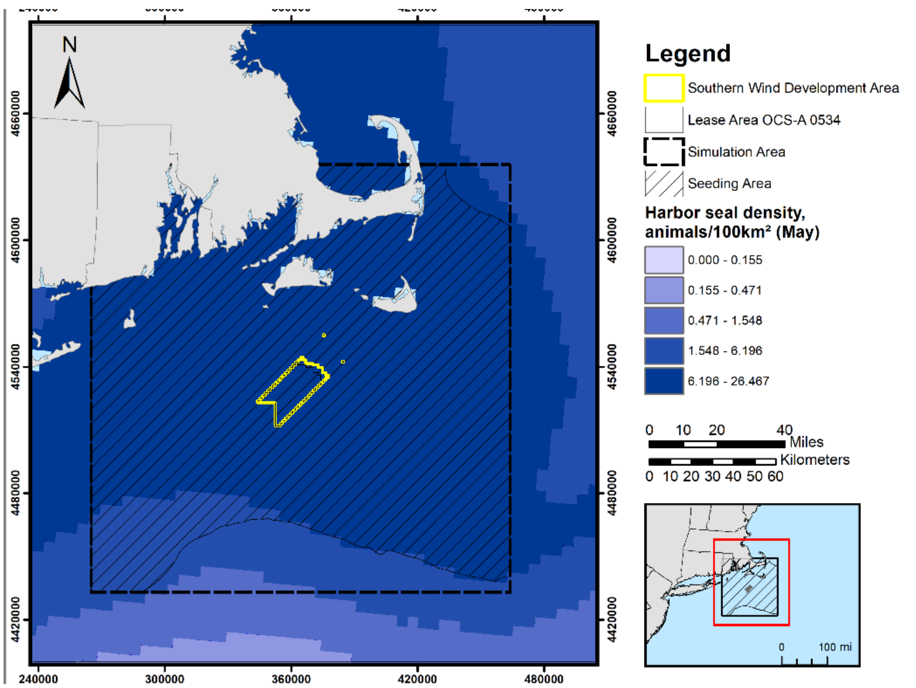

Figure H-16. Map of harbor seal seeding area range for May, the month with the highest density.

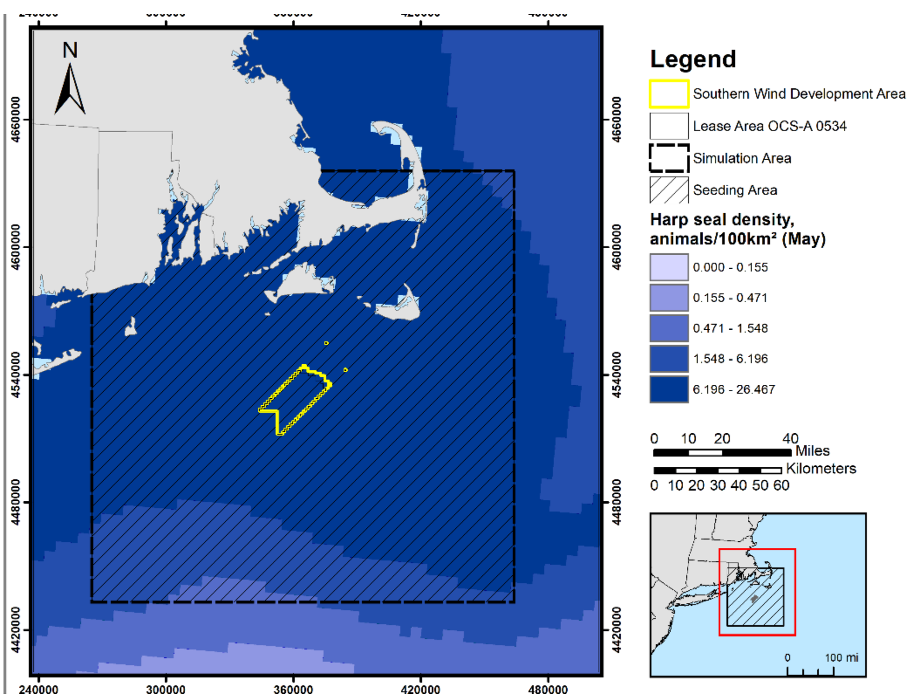

Figure H-17. Map of harp seal seeding area range for May, the month with the highest density

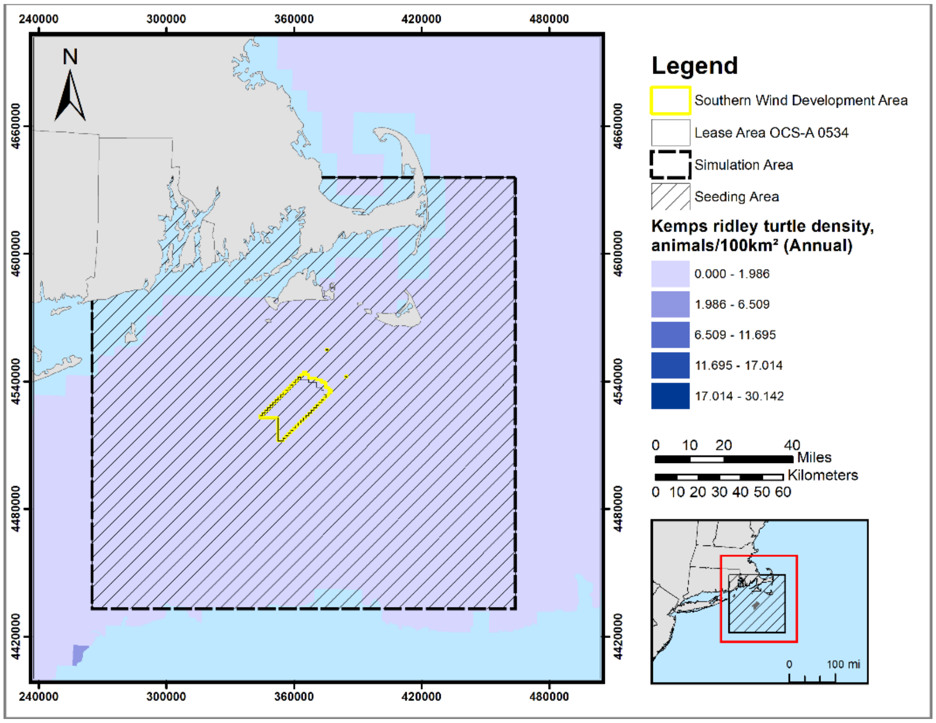

Figure H-18. Map of Kemp's ridley sea turtle seeding area range (DoN 2017). Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

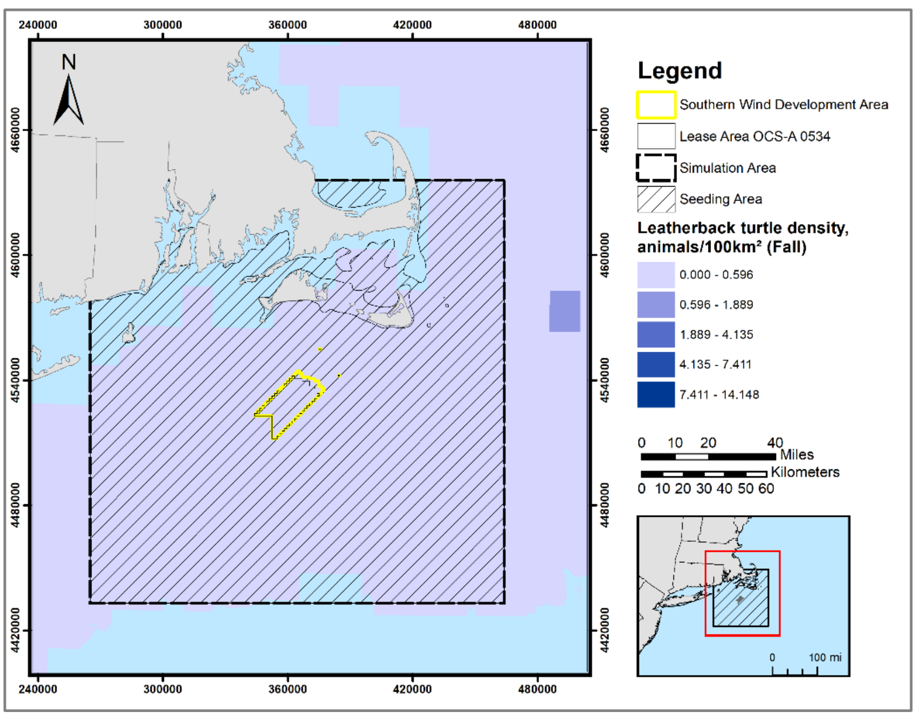

Figure H-19. Map of leatherback sea turtle seeding area range (DoN 2017). Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

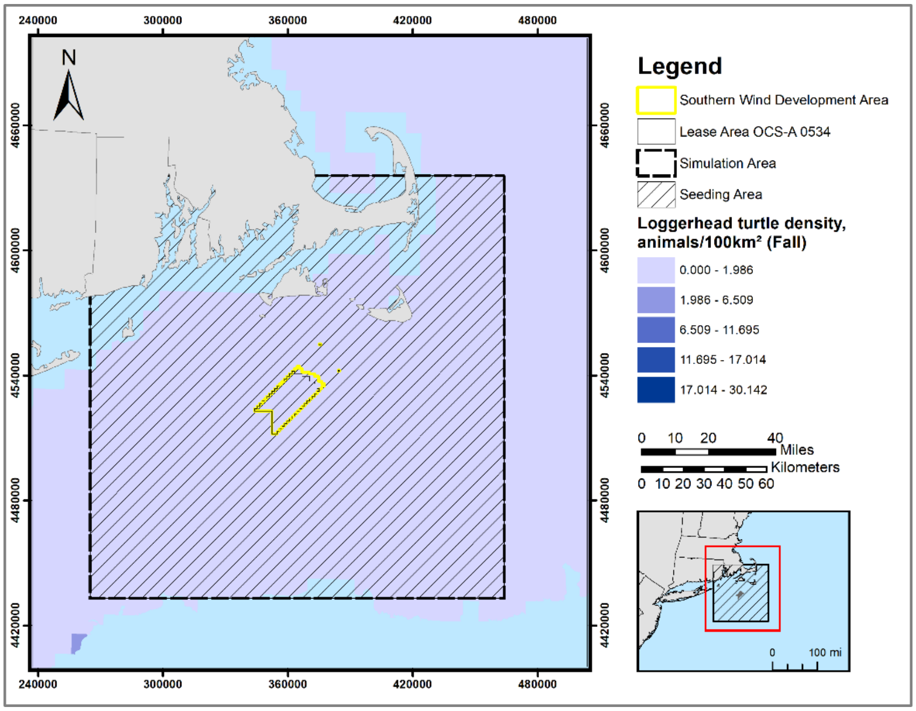

Figure H-20. Map of loggerhead sea turtle seeding area range (DoN 2017). Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

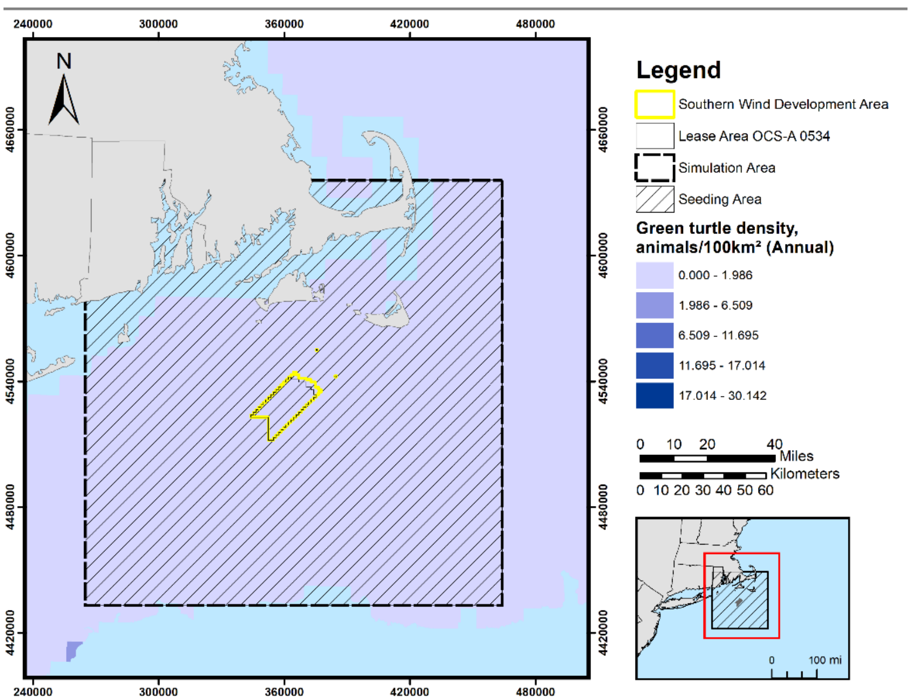

Figure H-21. Map of green sea turtle seeding area range (DoN 2017), showing Kemp's ridley sea turtle density as an example. Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

Appendix I. High-Resolution Geophysical Survey Exposure Analysis

JASCO APPLIED SCIENCES

8701 Georgia Avenue, Suite 410
Silver Spring, MD 20910 USA

Tel: +1-301-565-3500
www.jasco.com

Appendix I. Memo

DATE: 10 March 2023

Version: 4.0

FROM: Susan G. Dufault, Karlee E. Zammit, Madison E. Clapsaddle, and David G. 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. Sub-appendix I (which immediately follows this memo) details that modeling effort.

Table SA I-5 provides the model-predicted horizontal impact distances to Levels A and 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 I-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 I-1. Horizontal impact distances (in meters) to Levels A and 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 Sub-appendices I.1.2 and I.1.3.

I.1. Assumptions

HRG surveys will be conducted for New England Wind just prior to construction, during construction, and post-construction. Exposure calculations for HRG surveys assumed that there would be 25 days of surveying per year for each of the 5 years from 2025 to 2029 included in the Letter of Authorization (LOA) application; therefore, the total HRG survey days over the entire 5-year period would be 125 days. 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 the HRG surveys are currently unknown, as a conservative measure for each species, it was assumed that the 25 days of surveying in each year would occur during the highest density month for that species. Additional details of the density calculations are provided below.

I.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:

$$\mathrm{ZOI} = \left(\frac{\mathrm{distance}}{\mathrm{day}} \times 2r\right) + \pi r^2 \,, \tag{I-1}$$

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. Table I-2 provides the results of this calculation.

Table I-2. Zone of influence (ZOI; km^2) for the two modeled deep seismic profilers.

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

I.3. Density Calculations

Marine mammal densities in the potential impact area were estimated using the 2022 updated Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the US Atlantic (Roberts et al. 2022). Densities in the 2022 MGEL/Duke models are provided as the number of animals per 100 square kilometers (animals/100 km^2) and given for each 5 × 5 km cell in the US Atlantic.

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 I-1):

1. Phase 2 South Coast Variant Offshore Routing Envelope,
2. New England Wind Offshore Export Cable Corridor (OECC),
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 excluded, 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:

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned}+a_{long-finned}}\right), \quad \text{(I-2)}$$

where d is density and a is abundance. Also note that the MGEL/Duke model for the pilot whale guild (Roberts et al. 2022) provides only an annual, not monthly, density 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. 2022). The seals guild model is based primarily on harbor and gray seals. Harp seals, which are considered uncommon in the area, 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.

Table I-3 shows the monthly densities for each species used to estimate exposures above Level B acoustic thresholds during HRG surveys of New England Wind.

Table I-3. Maximum monthly density (animals/100 km^2) used to estimate exposures above acoustic thresholds during high-resolution geophysical (HRG) surveys for New England Wind.

Species	Maximum monthly density (animals/100 km^2)
Fin whale	0.436
Minke whale	1.704
Humpback whale	0.323
North Atlantic right whale	0.567
Sei whale	0.193
Atlantic white-sided dolphin	3.406
Atlantic spotted dolphin	0.404
Common dolphin	28.314
Bottlenose dolphin, offshore	1.753
Risso's dolphin	0.187
Long-finned pilot whale [a]	0.149
Short-finned pilot whale [a]	0.110
Sperm whale	0.111
Harbor porpoise	10.974
Gray seal [b]	27.901
Harbor seal [b]	62.687
Harp seal [b]	27.901

[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.

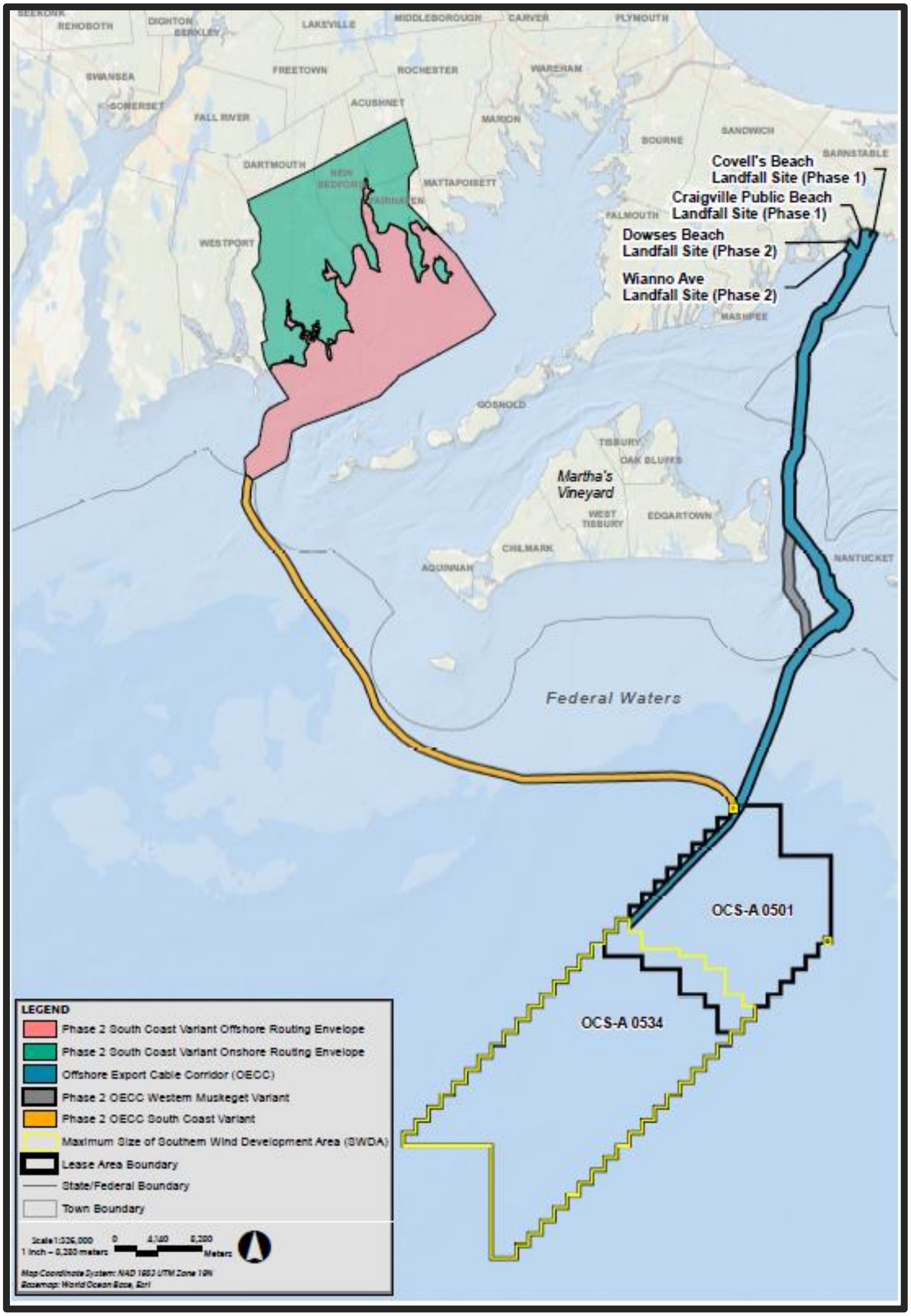

Figure I-1. Map showing two potential Phase 2 offshore export cable variants. The four areas of interest used in the HRG survey exposure calculations are: 1) Phase 2 South Coast Variant Offshore Routing Envelope, 2) New England Wind Offshore Export Cable Corridor (OECC), 3) Phase 2 OECC Western Muskeget Variant, and 4) Maximum size of the Southern Wind Development Area.

I.4. Estimated Exposures

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

$$\text{exposures} = \text{ZOI} \times (\text{days}) \times \text{density}\,, \qquad \text{(I-3)}$$

where ZOI is defined in Equation I-1, days = 25, and density is from Table I-3.

The results of these calculations are shown in Table I-4.

Table I-4. Estimated exposures: Number of animals of each species estimated to receive sound levels above the Level B threshold annually during high-resolution geophysical (HRG) surveys of New England Wind.

Species	Applied Acoustics AA251 Boomer	GeoMarine Geo Spark 2000
Fin whale [a]	3.11	2.47
Minke whale	12.17	9.64
Humpback whale	2.31	1.83
North Atlantic right whale [a]	4.05	3.21
Sei whale [a]	1.38	1.09
Atlantic white-sided dolphin	24.34	19.26
Atlantic spotted dolphin	2.88	2.28
Common dolphin	202.30	160.13
Bottlenose dolphin, offshore	12.53	9.92
Risso's dolphin	1.34	1.06
Long-finned pilot whale	1.06	0.84
Short-finned pilot whale	0.78	0.62
Sperm whale [a]	0.79	0.62
Harbor porpoise	78.41	62.07
Gray seal	199.35	157.80
Harbor seal	447.89	354.54
Harp seal	199.35	157.80

[a] Listed as Endangered under the ESA.

Literature Cited

Roberts, J.J., T.M. Yack, and P.N. Halpin. 2022. *Habitat-based marine mammal density models for the U.S. Atlantic.* (web page). https://seamap.env.duke.edu/models/Duke/EC/.

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.

Sub-appendix I. Distance to Acoustic Thresholds for High-Resolution Geophysical Sources

SA 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 SA I-1). The larger of these two is reported.

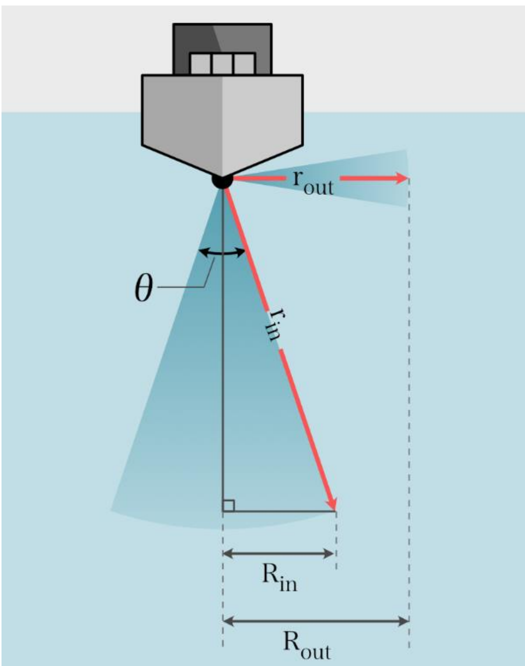


Figure SA I-1. Geometry used in computing horizontal impact ranges based on in-beam and out-of-beam energy.

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.

Sub-appendix I.1.1 provides an overview of calculations. Sub-appendices I.1.2 and I.1.3 describe how Level A and B ranges are determined.

SA I.1.1. Calculation Summary

Propagation Loss

The sonar equation is used to calculate the received sound pressure level:

$$SPL(r) = SL - PL(r)\,, \tag{SA I-1}$$

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:

$$PL(r) = 20\log_{10}\left(\frac{r}{1\text{ m}}\right)\text{ dB} + \alpha(f)\cdot r/1000\,, \tag{SA I-2}$$

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):

$$\alpha(f) \approx 0.000339f^2 + 48.5f^2/(75.6^2 + f^2)\,. \tag{SA I-3}$$

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 SA 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:

$$R_{in} = r_{in}\cdot\sin\left(\frac{\delta\theta}{2}\right), \tag{SA I-4}$$

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 SA 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:

$$R_{out} = r_{out}\,. \tag{SA I-5}$$

The larger of the two horizontal range estimates was then selected for assessing impact distance (presented in Sub-appendix I.4):

$$R = \max(R_{in}, R_{out})\,. \tag{SA I-6}$$

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:

$$b(u) = (2\ J_1(u)/u)^2, \qquad \text{(SA I-7)}$$

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) $\delta\theta$

$$u = u_0 \frac{\sin\theta}{\sin\frac{\delta\theta}{2}}, \qquad \text{(SA I-8)}$$

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)

$$B_{\max} = -17.6\ \mathrm{dB}\,. \qquad \text{(SA I-9)}$$

For the lower limit we consider the asymptotic behavior of the beam pattern in the horizontal direction

$$J_1(u) \sim \sqrt{\frac{2}{\pi u}} \cos\left(u - \frac{3\pi}{4}\right), \qquad \text{(SA I-10)}$$

where

$$u = \frac{u_0}{\sin\frac{\delta\theta}{2}}. \qquad \text{(SA I-11)}$$

In this way we obtain the lower limit as

$$B_{\min} = 10\log_{10}\left(\frac{8}{\pi\, u_0^3}\sin^3\frac{\delta\theta}{2}\right)\mathrm{dB}\,. \qquad \text{(SA I-12)}$$

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 SA I-2. Note that narrower beam sources have a larger reduction in side lobe levels than wider beam sources.

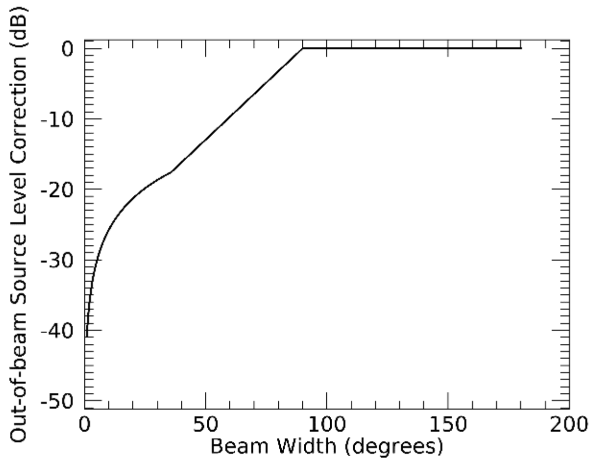


Figure SA I-2. Correction for calculating out-of-beam source level (i.e., in the horizontal direction) from in-beam source level, as a function of main lobe beam width.

The out-of-beam source level for a given HRG source was calculated by adding the dB correction (Figure SA I-2) to the in-beam source level. The corrections computed for the sources considered in this study can be found in Table SA I-4.

SA 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 SA 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 SA 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 SA I-1 to SA 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 SA I-2), and then using the appropriate (in beam or out of beam) weighted source level and pulse length (Figure SA I-2 and Table SA 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 SA 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:

$$T = 10^{(ESL-SL)/10}. \qquad \text{(SA I-13)}$$

SA 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).

SA 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 SA I-1) and Level B (160 dB re 1 µPa) thresholds were computed for each source by applying the methods from Sub-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.

SA I.3. Overview of Source Properties

Table SA 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 SA I-3 provides the accompanying data source reference.

Table SA 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 SA 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 (Sub-app 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 (Sub-app 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 (Sub-app 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 (Sub-app 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.

SA I.3.1. Derived Out-of-beam Levels

Table SA I-4 lists the corrections applied to obtain out-of-beam source levels.

Table SA 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

SA I.4. Distances

Table SA I-5 lists the geophysical survey sources and the horizontal impact distances to the Levels A and B criteria that were obtained by applying the methods from Sub-appendix I with the source parameters in Sub-appendix I.3.

Table SA I-5. Horizontal distance to Levels A and B impact thresholds.

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.

SA I.5. Equipment Specification Reference Sheets

SA 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.

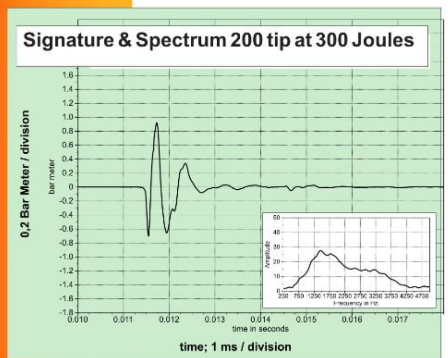
Efficient & Cost Effective
With the Geo-Spark HV power supplies you will save a lot of time and money, since the electrodes do NOT burn off like in all other systems.

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



Maintenance free electrodes, no trimming, stable signature

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

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

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

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Appendix J. Unexploded Ordnance Exposure Analysis

8701 Georgia Avenue, Suite 410
Silver Spring, MD 20910 USA

Tel: +1-301-565-3500
www.jasco.com

Appendix J. Memo

DATE: 5 December 2023

Version: 4.0

FROM: David E. Hannay, Madison E. Clapsaddle, and David G. Zeddies
(JASCO Applied Sciences [USA] Inc.)

TO: Park City Wind LLC

Subject: Marine Mammal Levels A and 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 an alternative combustive removal technique (e.g., deflagration) are infeasible 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 are unknown at this time. Initial survey data, however, suggest that there are potential areas of moderate risk for UXO presence (Figure J-1, see Section J.1 for a further description of the UXO risk evaluation). Water depths 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 Construction and Operations Plan (COP) development and will be further matured as the project timeline progresses towards construction.

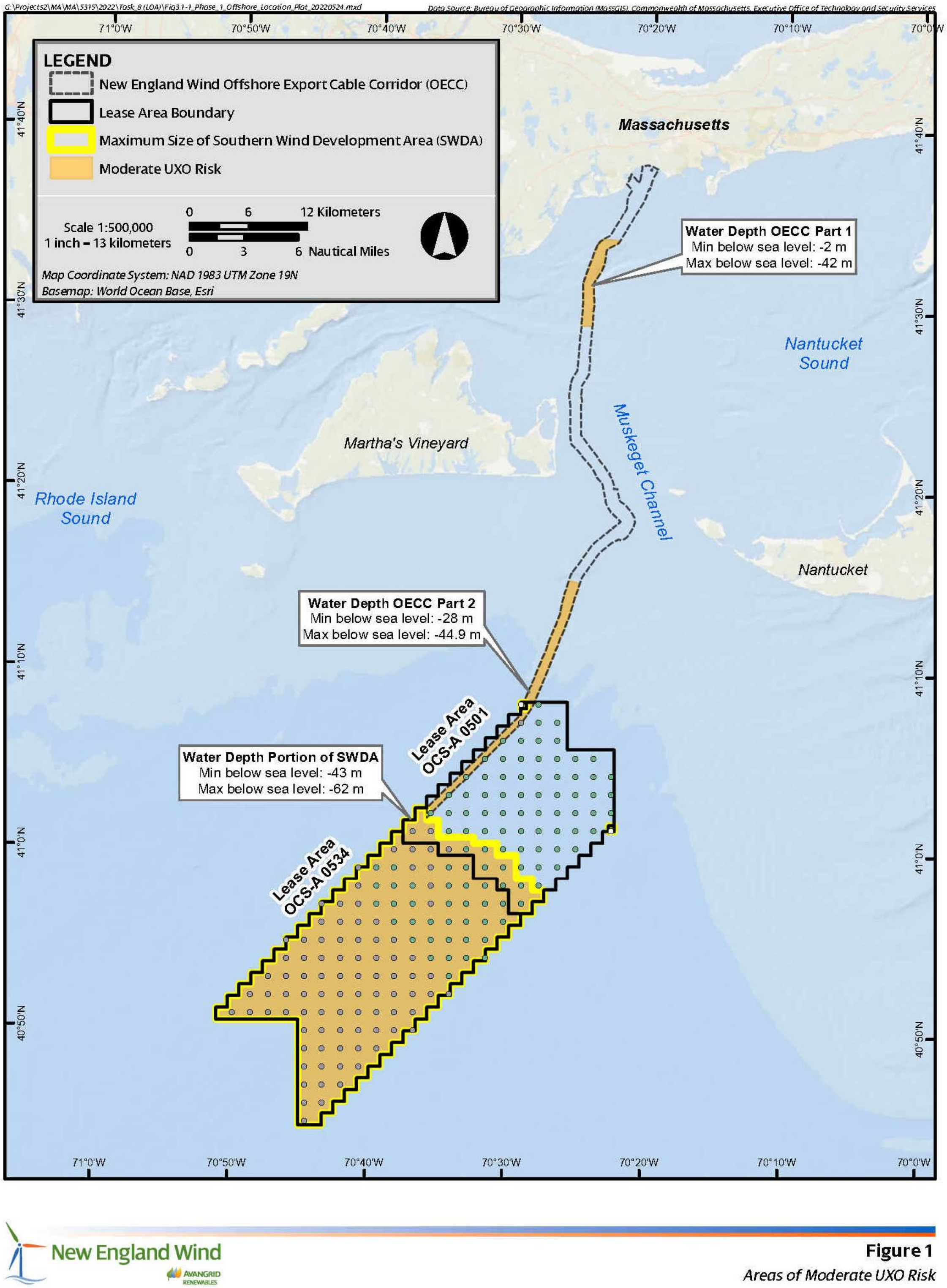

Figure J-1. Potential areas of moderate risk for unexploded ordnance (UXO) presence. Source: Figure 1 of Mills (2021).

J.1. Baseline Threat Assessment and Risk Level Identification

Park City Wind has commissioned a UXO desktop study in which a comprehensive historic analysis of all activities that may have contributed to potential UXO-related contamination have been considered and are summarized. Tables J-1 and J-2 present the conclusion of this historical research. 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	
		Grade	**Probability level**
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 baseline threat assessment was used to assign a risk level to the different geographic areas within New England Wind. Areas of moderate risk are shown on Figure J-1 (all other areas of New England Wind are low risk). A moderate risk is identified when evidence suggests that there is UXO present in the area (i.e., when there is a possibility of encountering UXO), activities may result in UXO detonation, and present receptors are at risk of experiencing an adverse response following detonation. Proactive UXO Mitigation is required for moderate risk (see Table J-3**Error! Reference source not found.**).

Table J-3. Risk level definitions.

Risk level	Definition
High	Indisputable evidence that there is a risk from this type of UXO in the area. Proactive UXO Mitigation is required.
Moderate	Evidence suggests that there is a risk from this type of UXO in the area. Proactive UXO Mitigation is required.
Low	Some evidence suggests that there is a risk from this type of UXO in the area or wider region. Reactive mitigation may be required.
Negligible	No evidence suggesting that there is a risk from this type of UXO in the area or wider region. No further mitigation is required.

J.2. Acoustic Modeling Methodology and Assumptions

An acoustic modeling study (Hannay and Zykov 2022) of peak pressure, acoustic impulse, and sound exposure level (SEL) from UXO detonation was performed recently for the Revolution Wind project, an Ørsted and Eversource Investment joint venture, 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 Ørsted'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 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 that 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 water depths (12, 20, 30, and 45 m) within the Revolution Wind project area and for five UXO charge weight bins (E4 [2.3 kg], E6 [9.1 kg], E8 [45.5 kg], E10 [227 kg], and E12 [454 kg]; Table J-4) (Hannay and Zykov 2022). The modeling locations were chosen at two sites along the Revolution Wind subsea export cable route in Narragansett Bay in 12 and 20 m water depths, and two sites within the Revolution Wind lease area at 30 and 45 m water depths.

Table J-4. Navy 'bins' and corresponding maximum unexploded ordnance (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 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, which could affect the maximum submersion depth of nearby animals. These results are independent of 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 sites of similar depth within New England Wind's project area, with the possible exception of the shallowest site (12 m), which 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 water 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 is gently sloping, but some non-uniform bathymetry features were 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 water depths expected to be encountered in the project area, estimating two UXOs at 12 m, three UXOs at 20 m, three UXOs at 30 m, and two 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-5 presents SEL-based $R_{95\%}$ PTS (Level A) and TTS (Level B) isopleths and their equivalent areas, which include results with no attenuation and results with an assumed 10 dB of attenuation due to the use of NMS (Bellmann 2021). New England Wind will use NMS with an expected 10 dB of attenuation (Bellmann 2021).

Injury to fish from exposures to blast pressure waves is attributed to compressive damage to tissues surrounding the swim bladder and gastrointestinal tract, which may contain small gas bubbles. Effects of detonation pressure exposures to fish have been assessed according to the L_{pk} limits for onset of mortality or injury leading to mortality due to explosives, as recommended by the American National Standards Institute (ANSI) expert working group (Popper et al. 2014). The injurious effects thresholds for all fish species groups are the same: L_{pk} = 229–234 dB re 1 µPa. Applying the lower range value of L_{pk} = 229 dB re 1 µPa, the unmitigated range to injury onset for fish is estimated to be 852 m for UXO in bin E12. The mitigated range to injury onset for fish is 292 m assuming 10 dB mitigation. This estimate includes an explosion of a donor charge with mass equal to 2% of the UXO mass.

Table J-5. SEL-based criteria ranges (m) and equivalent areas (km²) to PTS- and TTS-onset ($R_{95\%}$) for various water depths assuming no attenuation and 10 dB attenuation.

Hearing group	Threshold (dB re 1 µPa²s)	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 2022 Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the US Atlantic (Roberts et al. 2022). Densities in the 2022 MGEL/Duke models are provided as the number of animals per 100 square kilometers (animals/100 km²) and given for each 5 × 5 km cell in the US Atlantic.

The UXO desktop study (Mills 2021) identified the following three areas as moderate UXO risk within the project area (see Figure J-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 two UXOs would be assumed at the 12 m water depth location, three UXOs at 20 m, three UXOs at 30 m, and two UXOs at 40 m, monthly density was calculated for each species at the shallow portion of the OECC (representing the 12 m water depth location) and the combined deepwater segment of the OECC and SWDA (20–62 m water depths). To capture all density data within the highest impact area, the largest SEL-based TTS-onset acoustic ranges (see Table J-5) across all hearing groups was applied to the moderate UXO risk areas. Figure J-2 shows the density perimeters used in these calculations. These areas are used to calculate the maximum monthly marine mammal densities in this document (Table J-6). As a conservative measure, the month with the highest density among the areas of interest for each species was applied 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:

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

where d is density and a is abundance. Also note that the MGEL/Duke model for the pilot whale guild (Roberts et al. 2022) provides 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. 2022). 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 Levels A and B acoustic thresholds during potential UXO detonations for New England Wind are shown in Table J-6.

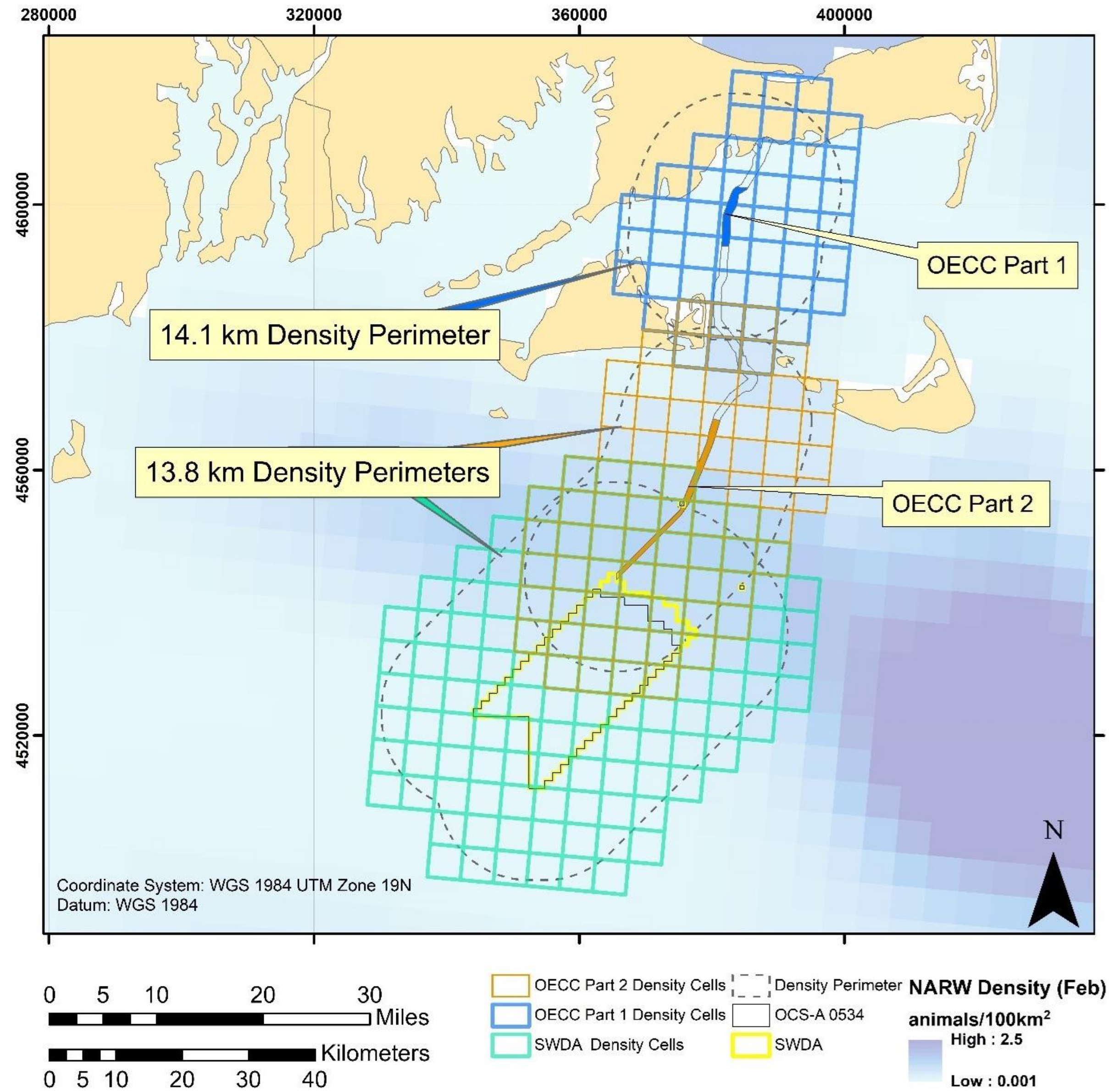

Figure J-2. Marine mammal (e.g., NARW) density map (Roberts et al. 2022) showing highlighted grid cells used to calculate mean monthly species density estimates within 13.8 and 14.1 km perimeters around New England Wind's Offshore Export Cable Corridors (OECCs), used to estimate exposures to detonation sounds above the US Navy's TTS criterion by SEL (Finneran et al. 2017). Note that the modeled densities are in units of animals/100 km^2, even when grid cells are 5 × 5 km.

Table J-6. Maximum monthly density (animals/100 km^2) at the moderate UXO risk areas used to estimate exposures above the Levels A and 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]	0.007	0.425
	Minke whale	0.129	1.720
	Humpback whale	0.040	0.297
	North Atlantic right whale [a]	0.116	0.707
	Sei whale [a]	0.034	0.191
MF	Atlantic white-sided dolphin	0.051	3.278
	Atlantic spotted dolphin	0.013	0.448
	Common dolphin	0.350	24.845
	Bottlenose dolphin, offshore	0.158	1.631
	Risso's dolphin	0.010	0.176
	Long-finned pilot whale [b]	0.000	0.135
	Short-finned pilot whale [b]	0.000	0.100
	Sperm whale [a]	0.002	0.112
HF	Harbor porpoise	1.772	10.608
PPW	Gray sea [c]	24.506	13.647
	Harbor seal [c]	55.059	30.662
	Harp seal [c]	24.506	13.647

[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-6 were multiplied by the highest monthly species density in the deepwater OECC segment and the SWDA for the 20–45 m water depths, and by the highest monthly species density in the shallow water OECC segment for the 12 m water depth. The result of the areas multiplied by the densities were then multiplied by the number of UXOs estimated at each of the water depths to calculate total estimated exposures. The ten potential UXO detonations as described above could occur over two years, as shown in the predicted schedule in Table J-7, and thus yearly exposures are estimated. 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.

Table J-7. Potential unexploded ordnance (UXO) detonation schedule.

Year 1 (2025)	Year 2 (2026)
2 UXOs at 12 m	0 UXOs at 12 m
3 UXOs at 20 m	0 UXOs at 20 m
1 UXOs at 30 m	2 UXOs at 30 m
0 UXOs at 40 m	2 UXOs at 40 m
Total UXOs = 10	

J.6. Estimated Level A Exposures

Table J-8 lists the SEL-based PTS exposures for potential UXO detonations as Level A exposures. Level A exposures are unlikely, but possible, during UXO detonation. Table J-8 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. Using NMSs is expected to achieve a broadband attenuation level of 10 dB (Bellmann et al. 2020, Bellmann 2021) and will minimize the size of the ensonified zones, thereby reducing the number of potential marine mammal PTS exposures.

Table J-8. Estimated potential maximum Level A exposures of marine mammals resulting from the possible detonations of up to 10 total unexploded ordnances (UXOs) occurring in 2025 and 2026, assuming no attenuation and 10 dB of attenuation.

Species		Estimated Level A Exposures (PTS SEL)			
		No attenuation [c]		10 dB of attenuation	
		Year 1 (2025) [d]	Year 2 (2026) [e]	Year 1 (2025) [d]	Year 2 (2026) [e]
LF	Fin whale [a]	4.08	3.85	0.75	0.70
	Minke whale	16.88	15.58	3.10	2.82
	Humpback whale	2.98	2.69	0.55	0.49
	North Atlantic right whale [a,b]	7.17	6.40	1.32	1.16
	Sei whale [a]	1.94	1.73	0.36	0.31
MF	Atlantic white-sided dolphin	0.88	0.86	0.06	0.07
	Atlantic spotted dolphin	0.12	0.12	0.01	0.01
	Common dolphin	6.69	6.52	0.49	0.53
	Bottlenose dolphin, offshore	0.46	0.43	0.03	0.03
	Risso's dolphin	0.05	0.05	0.00	0.00
	Long-finned pilot whale	0.04	0.04	0.00	0.00
	Short-finned pilot whale	0.03	0.03	0.00	0.00
	Sperm whale [a]	0.03	0.03	0.00	0.00
HF	Harbor porpoise	374.31	345.46	55.36	50.83
PPW	Gray seal [b]	63.54	34.50	7.51	3.44
	Harbor seal [b]	142.75	77.51	16.87	7.73
	Harp seal [b]	63.54	34.50	7.51	3.44

[a] Listed as Endangered under the ESA.
[b] Level A exposures were estimated for this species, but due to mitigation measures, no Level A takes are expected or requested.
[c] Although the Proponent intends to use mitigation during all potential UXO detonations, values assuming no attenuation are presented here for comparison.
[d] Year 1 (2025) exposures are calculated under the assumption that 2 UXOs would be detonated at the 12 m water depth location, 3 UXOs at 20 m, 1 UXO at 30 m, and 0 UXOs at 40 m. A total of 6 UXOs are assumed in this year.
[e] Year 2 (2026) exposures are calculated under the assumption that 0 UXOs would be detonated at the 12 m water depth location, 0 UXOs at 20 m, 2 UXOs at 30 m, and 2 UXOs at 40 m. A total of 4 UXOs are assumed in this year.

J.7. Estimated Level B Exposures

Table J-9 lists the SEL-based TTS exposures for potential UXO detonations as Level B exposures. 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-9. Estimated potential maximum Level B exposures of marine mammals resulting from the possible detonations of up to 10 total unexploded ordnances (UXOs) occurring in 2025 and 2026, assuming no attenuation and 10 dB of attenuation.

Species		Estimated Level B Exposures (TTS SEL)			
		No Attenuation [b]		10 dB of Attenuation	
		Year 1 (2025)[c]	Year 2 (2026)[d]	Year 1 (2025)[c]	Year 2 (2026)[d]
LF	Fin whale [a]	15.82	15.75	6.75	6.56
	Minke whale	65.73	63.69	27.98	26.52
	Humpback whale	11.65	10.99	4.95	4.58
	North Atlantic right whale [a]	35.27	32.57	13.25	12.06
	Sei whale [a]	7.63	7.07	3.24	2.94
MF	Atlantic white-sided dolphin	13.31	13.12	2.41	2.46
	Atlantic spotted dolphin	1.83	1.79	0.33	0.34
	Common dolphin	100.82	99.41	18.28	18.67
	Bottlenose dolphin, offshore	6.89	6.52	1.25	1.23
	Risso's dolphin	0.73	0.70	0.13	0.13
	Long-finned pilot whale	0.54	0.54	0.10	0.10
	Short-finned pilot whale	0.40	0.40	0.07	0.07
	Sperm whale [a]	0.46	0.45	0.08	0.08
HF	Harbor porpoise	1031.91	952.37	216.13	192.18
PPW	Gray seal [b]	503.19	257.67	145.91	79.64
	Harbor seal [b]	1130.53	578.92	327.81	178.93
	Harp seal [b]	503.19	257.67	145.91	79.64

[a] Listed as Endangered under the ESA.
[b] Although the Proponent intends to use mitigation during all potential UXO detonations, values assuming no attenuation are presented here for comparison.
[c] Year 1 (2025) exposures are calculated under the assumption that 2 UXOs would be detonated at the 12 m water depth location, 3 UXOs at 20 m, 1 UXO at 30 m, and 0 UXOs at 40 m. A total of 6 UXOs are assumed in this year.
[d] Year 2 (2026) exposures are calculated under the assumption that 0 UXOs would be detonated at the 12 m water depth location, 0 UXOs at 20 m, 2 UXOs at 30 m, and 2 UXOs at 40 m. A total of 4 UXOs are assumed in this year.

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Appendix K. Drilling Exposure Analysis

Appendix K. Memo

DATE: 9 January 2024

Version: 2.0

FROM: Chinaemerem Kanu, Emma Ozanich, Kaylyn Terry, Elizabeth Küsel, and David Zeddies

TO: Maria Hartnett (Epsilon)

Subject: Underwater Acoustic Modeling of Drilling Activities During Pile Installation for New England Wind

K.1. Introduction

Park City Wind (the Proponent) is planning on the use of drilling to aid in foundation installation for the New England Wind Project. The Proponent has assessed the potential for impacts to marine fauna (marine mammals, sea turtles, and fish) from drilling activities during pile installation, and found impacts to fish to be unlikely, but impacts to marine mammals and sea turtles a possibility.

It is unclear whether the sound emitted by marine drilling activities is likely to impact the behavior of fish. McCauley (1998) determined that any effects to fish from sounds produced by 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). The available literature suggests that continuous sound produced by drilling operations may mask acoustic signals of fish that convey important environmental information (McCauley 1994, Popper et al. 2014). Recordings of planktivorous fish choruses showed that the fish 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 to support a clear link between anthropogenic sound and permanent injury or mortality in fish, particularly with non-impulsive sound sources (Popper and Hawkins 2019). Continuous sound has been linked to temporary threshold shift (TTS) in some species of fish; however, exposure times to these sounds were at least 12 hours (Amoser and Ladich 2003, Smith et al. 2006). The sounds emitted by marine drilling operations for wind farm construction are expected to be short-term and intermittent. It is therefore unlikely that the acoustic characteristics of this source will cause prolonged acoustic masking to fish, and the risk of impact from this activity is expected to be low.

Potential impacts to marine mammals and sea turtles from underwater sound exposure produced by drilling operations could include changes in behavior and auditory injury (permanent threshold shift [PTS]) at distances close to the sound source. This Memo provides a quantitative assessment of these potential impacts from drilling activity during pile installation for New England Wind.

K.2. Methods

K.2.1. Modeled Locations

Sound fields from drilling activities were modeled at three representative locations in the Lease Area (M1, M2, and J1) as depicted in Figure 1 and Table 1. These modeling locations were selected as they represent the range of water depths in the Lease Area. Acoustic modeling assumed that drilling activity could occur for a full 24 hours during any given day. Although it is not expected that drilling would be required up to 24 hours, all modeling results in this report reflect this duration and is assumed to be most conservative.

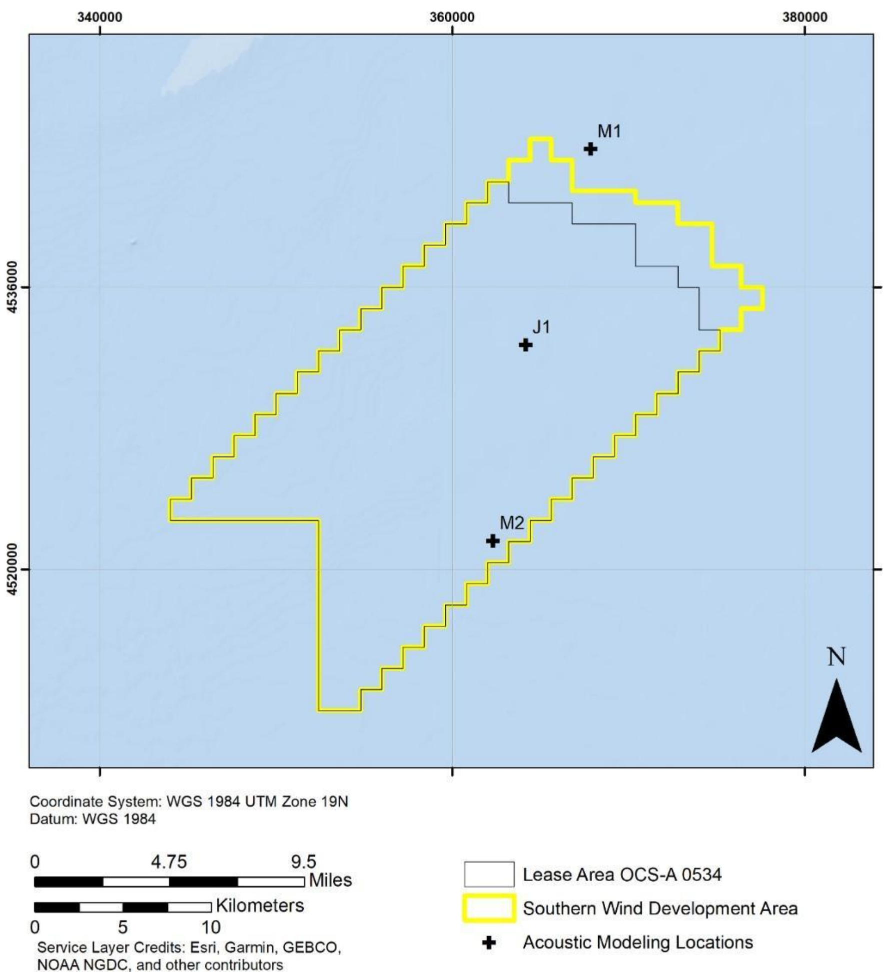

Figure 1. Drilling acoustic modeling locations relative to the Lease Area OCS-A 0534 and the Southern Wind Development Area (SWDA).

Table 1. Propagation modeling sampling locations used for drilling activity.

Modeling location[1, 2]	Latitude	Longitude	Depth (m)
M1	41.035501217	−70.571798180	44
M2	40.834461320	−70.632933892	52
J1	40.934831948	−70.613405411	53

[1] These drilling acoustic modeling locations correspond to the locations that were also used for modeling of impact pile driving. M1 and M2 represent monopile locations and J1 represents a jacket foundation location.

K.2.2. Evaluation Criteria

Injury to the hearing apparatus of marine mammals may result from a fatiguing stimulus measured in terms of the sound exposure level (SEL), which considers the sound level and duration of the exposure signal. A permanent threshold shift (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, however, data that indicate the received sound levels at which temporary threshold shift (TTS) occurs, and PTS onset can be extrapolated from TTS onset level and an assumed growth function (Southall et al. 2007). In 2018, the National Oceanographic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) issued a Technical Guidance document (NMFS 2018) that incorporated the best available science to estimate PTS onset thresholds in marine mammals from sound energy, SEL, accumulated over 24 hours.

NMFS (2018) also provided guidance on using weighting functions to adjust the received sound levels according to the hearing sensitivity of the animals. Acoustic criteria and weighting function application are divided into functional hearing groups (low-, mid-, and high-frequency cetaceans and phocid pinnipeds) that species are assigned to base on their respective hearing frequency ranges. Table 2 shows hearing group frequency ranges that are used to define the auditory weighting function, and Table 3 shows the hearing group thresholds.

After numerous studies on marine mammal behavioral responses to sound exposure there is still no consensus in the scientific community regarding the appropriate metric for assessing behavioral reactions. NMFS currently uses behavioral response thresholds of 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, 1990).

Injury 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). 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).

Marine mammals and sea turtles were considered static receivers. Acoustic distances where sound levels could exceed marine mammal (NMFS 2018) and sea turtle (Finneran et al. 2017) thresholds were determined using a maximum-over-depth approach.

Table 2. Marine mammal hearing groups and frequency ranges (Sills et al. 2014, NMFS 2018).

Faunal group	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

[a] The generalized hearing range is for all species within a group. Individual hearing will vary.

Table 3. Summary of permanent threshold shift onset acoustic thresholds for marine mammals exposed to continuous sound sources (NMFS 2018).

Faunal group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)
Low-frequency (LF) cetaceans	199
Mid-frequency (MF) cetaceans	198
High-frequency (HF) cetaceans	173
Phocid pinnipeds in water (PPW)	201
Sea turtles	220

K.2.3. Source and Propagation Modeling

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 sound pressure level (SPL) for three mobile drilling units at 1000 m and estimated their broadband source levels. Here, the average source level of these mobile drilling units is used as representative source spectrum of broadband drilling activity.

The mudline cellar drilling in the Chukchi Sea was measured at a site with a 46 m water depth, which is similar to the average depth of the New England Wind area. Seabed sediment geoacoustic properties differ: the Chukchi Sea drilling site had softer surface sediments with a 14.5 m thick top layer of a constant sound speed of 1630 m/s and a density of 1.45 g/cm^3, overlying more consolidated sediments with a sound speed of 2384 m/s and a density of 2.32 g/cm^3. By comparison, New England Wind surficial sediments are expected to be predominantly sand, based on samples from nearby study sites. Table 5 shows the sediment layer geoacoustic property profile based on the sediment type derived from measurements of geoacoustic parameters and determined empirical relationships between them (Ainslie 2010). Overall, the Chukchi Sea surface sediments have a slightly lower sound speed and lower density than the New England Wind site, with similar sound speeds at depth. Overall, the acoustic reflectivity at lower frequencies is expected to be similar between these sites. The ocean sound speed profiles at both the Chukchi and New England Wind sites are slightly downward refracting in summer (which is when the measurements were taken for Austin et al. (2018)).

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 drill site on dynamic positioning.

We assumed that pile installation drilling produces similar sound levels as mudline cellar drilling, and, as a conservative measure, we averaged the three representative source levels estimated by Austin et al. (2018) for the 10–32,000 Hz band.' The average source level shown below have a broadband level of 191.6 dB re 1 µPa^2·s m^2.

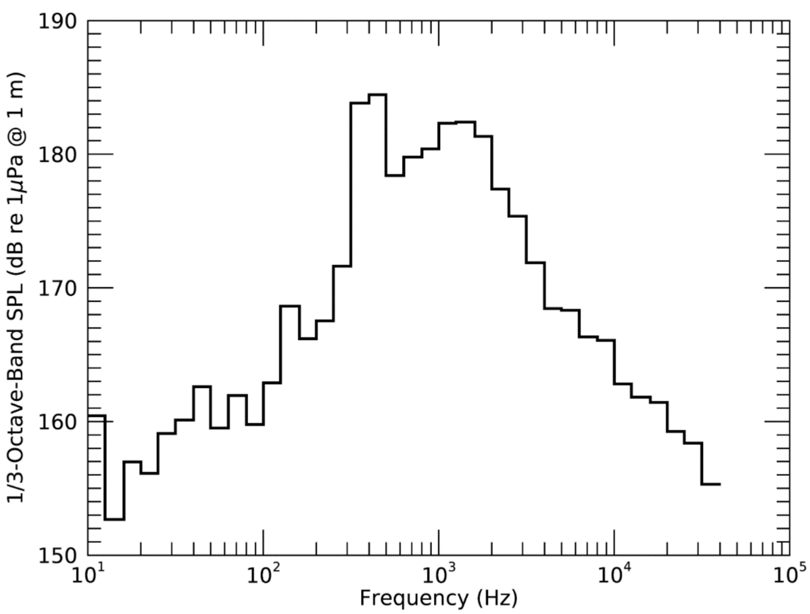

Figure 2. Decidecade band source levels averaged across three sources for drilling and excavation of mudline cellars (Austin et al. 2018).

JASCO's Marine Operations Noise Model (MONM) was used to predict SEL and SPL sound fields up to 1 kHz at a representative location near the proposed drilling sites considering the influence of bathymetry, seabed, water sound speed, and water attenuation. 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). From 1 to 25 kHz, the Bellhop ray tracing model (Porter and Liu 1994) was used to predict sound fields at the same representative location using from 2512 to 5012 geometric beams, increasing the beam coverage with frequency. The total sound energy transmission loss was computed at the center frequencies of decidecade bands as a function of range and depth from the source. Bellhop-MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is important for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results. The drill was represented as a point source in mid-water column at each site. The mid-water depth is a conservative representation of the noise source across the drill bit. The acoustic field in three dimensions was generated by modeling two-dimensional (2-D) vertical planes radially spaced at 2.5° in a 360° swath around the source (*N* x 2-D). Composite broadband received SEL were computed by summing the received decidecade band levels across frequency and taking the maximum-over-depth. Major modeling assumptions are listed in Table 4 and the estimated geoacoustic properties used for modeling are listed in Table 5.

Table 4. Major assumptions used in underwater acoustic modeling of relief drilling during piling.

Parameter	Value	Reference (if applicable)
JASCO Applied Sciences		
Drill	6 m drill bit, mudline cellar excavation	Austin et al. (2018)
New England Wind		
Bathymetry		US Coastal Relief Model, National Centers for Environmental Information NOAA (September 2010). (NGDC 2003)
Sound speed	Regionally and seasonally [a] averaged profiles	GDEM v-3.0 (NAVO 2003)
Geoacoustics	Elastic seabed properties based on client-supplied description of seabed layering	Ainslie (2010). See Table 5.

[a] Sound speed was converted to mean summer (June to August) profile.

Table 5. Estimated geoacoustic properties used for modeling, as a function of depth. Within an indicated depth range, the parameter varies linearly within the stated range.

Depth below seafloor (m)	Material	Density (g/cm³)	Compressional wave			Shear wave
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5.0	Sand	2.086–2.093	1761–1767	0.88–0.879	300	3.65
5.0–10.0		2.093–2.099	1767–1774	0.879–0.877		
10.0–15		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	0.843–0.790		
240–365		2.382–2.513	2034–2150	0.790–0.730		
365-615		2.513-2.719	2150-2342	0.730-0.616		
615-865		2.719-2.845	2342-2500	0.616-0.541		
>865		2.845	2500	0.541		

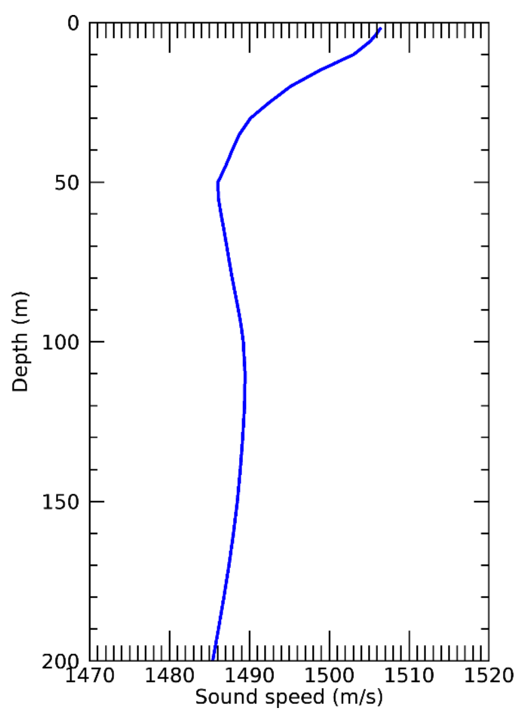

Figure 3. Mean Sound speed profile up to 200 m for the summer months for New England Wind. The mean profile used in the modeling was obtained by taking the average of all profiles for June through August.

K.2.4. Exposure Estimates for Marine Animals

Exposures were calculated for one day of drilling. Drilling was modeled at each of the three site locations (J1, M1, M2). Exposures were calculated for each of these locations individually and also for the maximum potential exposures using the maximum ensonified area for each threshold. Exposures were estimated using the monthly animal densities from May to December.

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 US Atlantic (Roberts et al. 2016, 2022). 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 5 × 5 km cell in the US Atlantic for all species. 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).

To calculate marine mammal densities for the potential drilling impact area, it was assumed that the surveys would occur in three areas of interest: J1, M1, and M2. The density perimeter was determined using the longest 10-dB attenuated 95th percentile acoustic range to the behavioral threshold ($R_{95\%}$) for all locations, rounded up to the nearest 5 km, and then applied around the entire lease area (i.e., 7.1 km rounded up to 10 km). Monthly densities were calculated for each species as the average of the densities from all MGEL/Duke model grid cells that overlap partially or completely with the area of interest. Cells entirely on land were not included, but cells that overlap only partially with land were included.

There are two cases in this study for which the MGEL/Duke models report densities for species guilds: seals and pilot whales. When calculating exposures for individual pilot whale and seal species, the guild densities provided by Roberts et al. (2016a, 2022) were scaled by the relative abundances of the two species in each guild, using the best available estimates of local abundance, to get species-specific density estimates for the project area. In estimating local abundances, all distribution data from the two pilot whale species and three seal species were downloaded from the Ocean Biodiversity Information System (OBIS) data repository (available at https://obis.org/). After reviewing the available datasets, it was deemed that data available in OBIS in Rhode Island and Massachusetts waters are the best available for the three seals species because of their overlap with the project area. For seals, OBIS reported 86 observations of gray seals, 129 observations of harbor seals, and 93 observations of harp seals. Therefore, the proportions of 0.28 (86/308), 0.42 (129/308), and 0.30 (93/308) were used to scale the seals guild densities for the three seal species, respectively. The best data available for pilot whales came from AMAPPS data in Rhode Island and Massachusetts waters. The proportions of 0.80 for long-finned and 0.20 for short-finned pilot whales were used (Palka et al 2021.)

The monthly densities were calculated for May to December. The resulting densities are included in Table 6 and Figure 4. Figure 4 shows the data cells included in the density average for distances to injury and behavior thresholds, respectively.

Table 6. Average monthly marine mammal density estimates for all modeled species in a 10-km perimeter around the Southern Wind Development Area (SWDA).

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]	0.215	0.166	0.107	0.164	0.272	0.256	0.438	0.366	0.227	0.057	0.051	0.141	0.205	0.226
Minke whale	0.113	0.137	0.136	0.806	1.728	1.637	0.700	0.471	0.516	0.465	0.052	0.077	0.570	0.706
Humpback whale	0.031	0.023	0.043	0.149	0.294	0.307	0.172	0.120	0.167	0.236	0.190	0.030	0.147	0.189
North Atlantic right whale [a]	0.387	0.461	0.456	0.478	0.295	0.050	0.022	0.018	0.028	0.052	0.068	0.197	0.209	0.091
Sei whale [a]	0.039	0.021	0.044	0.112	0.192	0.052	0.013	0.011	0.019	0.036	0.079	0.065	0.057	0.058
Atlantic white-sided dolphin	2.049	1.230	0.850	1.313	3.322	3.003	1.392	0.730	1.654	2.431	1.791	2.440	1.850	2.095
Atlantic spotted dolphin	0.001	0.000	0.001	0.003	0.018	0.025	0.031	0.054	0.273	0.431	0.179	0.018	0.086	0.128
Common dolphin	7.130	2.455	1.884	3.258	6.254	13.905	10.533	14.446	25.703	22.676	11.103	10.774	10.844	14.424
Bottlenose dolphin, offshore	0.495	0.111	0.059	0.156	0.814	1.358	1.479	1.659	1.483	1.337	1.255	1.101	0.942	1.311
Risso’s dolphin	0.043	0.004	0.002	0.018	0.096	0.048	0.068	0.128	0.158	0.087	0.120	0.179	0.079	0.111
Long-finned pilot whale [b]	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189
Short-finned pilot whale [b]	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
Sperm whale [a]	0.031	0.011	0.013	0.003	0.014	0.028	0.038	0.107	0.070	0.057	0.031	0.020	0.035	0.046
Harbor porpoise	10.007	10.784	10.277	8.914	6.741	0.960	0.880	0.848	0.988	1.271	1.418	5.812	4.908	2.365
Gray seal [c]	5.395	5.603	4.176	3.203	4.716	0.806	0.088	0.094	0.226	0.500	1.768	4.534	2.592	1.591
Harbor seal [c]	8.093	8.404	6.265	4.804	7.074	1.209	0.132	0.140	0.339	0.750	2.652	6.802	3.889	2.387
Harp seal [c]	5.781	6.003	4.475	3.432	5.053	0.864	0.094	0.100	0.242	0.535	1.894	4.858	2.778	1.705

[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.

Table 7. 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]	0.015	0.015	0.015	0.015
Leatherback sea turtle	0.023	0.630[c]	0.873[c]	0.023
Loggerhead sea turtle	0.107	0.206[d]	0.633[d]	0.107
Kemp's ridley sea turtle	0.015	0.015	0.015	0.015

[a] Density estimates are extracted from SERDP-SDSS NODE database within a 10 km perimeter 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).

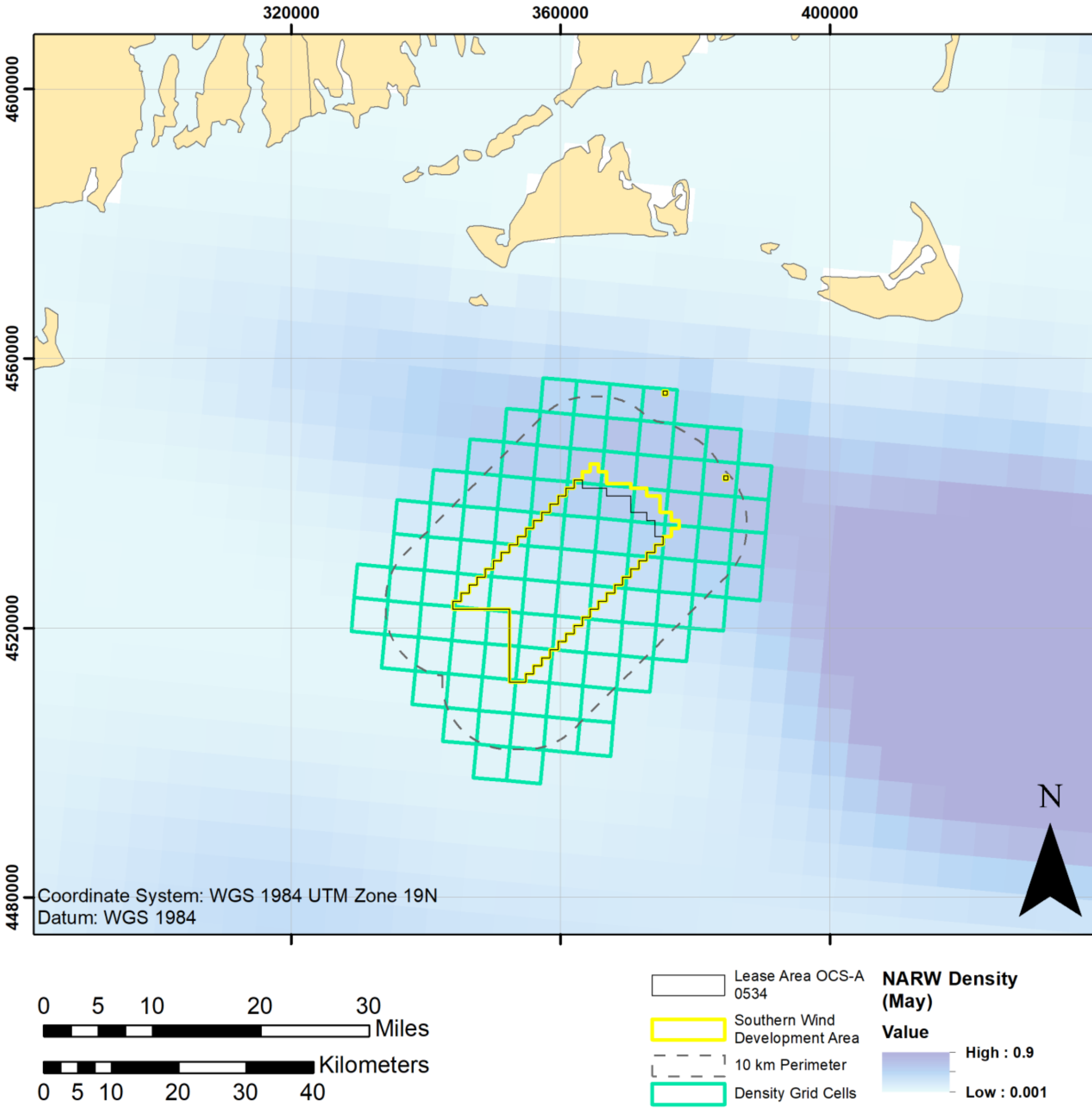

Figure 4. Marine mammal (e.g., NARW) density showing highlighted grid cells used to calculate monthly species density estimates within a 10 km perimeter around Lease Area OCS-A 0534 ((Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b).

K.3.Results

K.3.1. Acoustic Ranges

Assuming up to 24 hours of drilling could occur during a 24-hour period, the frequency-weighted distances to potential injury for the marine mammal hearing groups are shown in Table 6 through Table 17 for the modeled locations. While we are not aware of any studies of noise attenuation systems (NAS) used with very large rotational drills, the Proponent expects to employ the same NAS during all drilling activity of WTG and ESP foundations as used during impact driving. Drilling produces sound of similar frequency content as impact pile driving, so the NAS performance, at sufficient distance to attenuate sound entering the water from the substrate, would be expected to have essentially the same performance for during drilling as impact pile driving. For this reason, results with attenuations of 10 dB and 12 dB during the summer are also included. The acoustic ranges to the marine mammal PTS injury are less than 100 m at the three sites for all hearing groups, except for low-frequency and high-frequency animals (FHWG 2008) whose predicted maximum $R_{95\%}$ acoustic ranges are ~300 m.

The acoustic ranges to the behavioral thresholds for marine mammal hearing groups sounds SPL 120 dB re 1 µPa threshold (NMFS 2018) and sea turtles SPL 175 dB re 1 µPa threshold, without frequency weighting, are shown in Table 18 through Table 20 for the modeled locations and attenuations (0 dB, 10 dB, 12 dB) during the summer. The maximum, unweighted, unattenuated, marine mammal behavioral acoustic ranges were found to extend to 20.73 km at J1, 21.65 km at M1, and 25.37 km at M2 location. Excluding 5% of the farthest points (R95%), the behavioral threshold ranges were 17.76 km at J1, 16.62 km at M1 and 19.67 at M2 location. The unweighted SPL levels at 750 m are 145.25 dB re 1 µPa, 146.33 dB re 1 µPa and 145.44 dB re 1 µPa for J1, M1, and M2, respectively during the summer. The corresponding unweighted cumulative SEL levels at 750m are 195.24 dB re 1 µPa2·s, 195.07 dB re 1 µPa2·s, and 194.10 dB re 1 µPa2·s for J1, M1, and M2, respectively during the summer, At all sites, the behavioral threshold ranges were approximately equidistant in all directions (Figure 1). Propagation extent and shoreline were determined using global bathymetry data (STRM15+ referenced vertically to the EGM96 geoid).

Table 8. Site J1 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 0 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling 24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	0.315	0.309	0.320
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	0.261	0.251	0.207
Phocid pinnipeds in water (PPW)	201	0.057	0.057	0.015
Sea turtles	220	-	-	-

Table 9. Site M1 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 0 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling 24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	0.317	0.312	0.318
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	0.276	0.273	0.243
Phocid pinnipeds in water (PPW)	201	0.067	0.067	0.015
Sea turtles	220	-	-	-

Table 10. Site M2 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 0 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling 24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	0.323	0.296	0.285
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	0.255	0.248	0.207
Phocid pinnipeds in water (PPW)	201	0.065	0.065	0.012
Sea turtles	220	-	-	-

Table 11. Site J1 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 10 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling		
		24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	0.057	0.057	0.015
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	0.057	0.057	0.015
Phocid pinnipeds in water (PPW)	201	-	-	-
Sea turtles	220	-	-	-

Table 12. Site M1 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 10 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling		
		24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	0.065	0.065	0.012
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	<0.05	<0.05	0.010
Phocid pinnipeds in water (PPW)	201	-	-	-
Sea turtles	220	-	-	-

Table 13. Site M2 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 10 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling		
		24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	<0.05	<0.05	0.010
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	<0.05	<0.05	0.010
Phocid pinnipeds in water (PPW)	201	-	-	-
Sea turtles	220	-	-	-

Table 14. Site J1 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 12 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling		
		24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	<0.05	<0.05	<0.05
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	<0.05	<0.05	<0.05
Phocid pinnipeds in water (PPW)	201	-	-	-
Sea turtles	220	-	-	-

Table 15. Site M1 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 12 dB

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling		
		24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	<0.05	<0.05	0.005
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	<0.05	<0.05	0.005
Phocid pinnipeds in water (PPW)	201	-	-	-
Sea turtles	220	-	-	-

Table 16. Site M2 (Summer): Distances to PTS onset for marine mammal hearing groups (NMFS 2018) thresholds for continuous sounds generated by relief drilling during piling for attenuation 12 dB.

Hearing group	Frequency-weighted $L_{E,24hr}$ (dB re 1 µPa²·s)	Drilling		
		24hr		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Low-frequency (LF) cetaceans	199	<0.05	<0.05	0.005
Mid-frequency (MF) cetaceans	198	-	-	-
High-frequency (HF) cetaceans	173	<0.05	<0.05	0.005
Phocid pinnipeds in water (PPW)	201	-	-	-
Sea turtles	220	-	-	-

Table 17. Site J1 (Summer): Distances to behavioral thresholds for marine mammal hearing groups (NMFS 2018) and sea turtles for continuous sounds generated by relief drilling during piling.

Hearing group	Unweighted L_P (dB re 1 µPa)	0 dB			10 dB			12 dB		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Marine mammals	120	20.73	17.76	972.5	7.498	7.054	162.8	6.003	5.517	100.6
Fish	150	0.33	0.32	0.34	0.06	0.06	0.02	0.03	0.03	0.01
Sea turtles	175 [b]	-	-	-	-	-	-	-	-	-

[a] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).
[b] McCauley et al. (2000).

Table 18. Site M1 (Summer): Distances to behavioral thresholds for marine mammal hearing groups (NMFS 2018) and sea turtles for continuous sounds generated by relief drilling during piling.

Hearing group	Unweighted L_P (dB re 1 µPa)	0 dB			10 dB			12 dB		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Marine mammals	120	21.65	16.62	877.2	7.830	6.853	151.1	6.089	5.435	94.62
Fish	150	0.35	0.33	0.36	0.07	0.07	0.02	0.05	0.05	0.01
Sea turtles	175 [b]	-	-	-	-	-	-	-	-	-

[a] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).
[b] McCauley et al. (2000).

Table 19. Site M2 (Summer): Distances to behavioral thresholds for marine mammal hearing groups (NMFS 2018) and sea turtles for continuous sounds generated by relief drilling during piling.

Hearing group	Unweighted L_P (dB re 1 µPa)	0 dB			10 dB			12 dB		
		R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Marine mammals	120	25.37	19.67	>1000	7.641	6.884	152.1	6.051	5.495	95.79
Fish	150	0.34	0.32	0.33	0.05	0.05	0.01	0.03	0.03	0.01
Sea turtles	175 [b]	-	-	-	-	-	-	-	-	-

[a] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).
[b] McCauley et al. (2000).

Table 20. Site J1 (Summer): Distances to fish and sea turtle injury thresholds for continuous sounds generated by drilling during piling.

Faunal group	Metric	Threshold (dB)	Attenuation								
			0 dB			10 dB			12 dB		
			R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)	R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)	R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)
Sea turtles	L_E	220	-	-	-	-	-	-	-	-	-
Fish without swim bladder	L_E	216	-	-	-	-	-	-	-	-	-
Fish with swim bladder not involved in hearing	L_E	203	0.18	0.17	0.10	0.03	0.03	0.01	-	-	-
Fish with swim bladder involved in hearing	L_E	203	0.18	0.17	0.10	0.03	0.03	0.01	-	-	-
Fish greater than or equal to 2 g	L_E	187	2.89	2.78	25.57	0.56	0.53	0.94	0.35	0.34	0.38
Fish less than 2 g	L_E	183	4.81	4.59	69.72	1.08	1.04	3.58	0.97	0.94	2.91

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 21. Site M1 (Summer): Distances to fish and sea turtle injury thresholds for continuous sounds generated by drilling during piling.

Faunal group	Metric	Threshold (dB)	Attenuation 0 dB R_{max} (km)	0 dB $R_{95\%}$ (km)	0 dB Area (km²)	10 dB R_{max} (km)	10 dB $R_{95\%}$ (km)	10 dB Area (km²)	12 dB R_{max} (km)	12 dB $R_{95\%}$ (km)	12 dB Area (km²)
Sea turtles	L_E	220	-	-	-	-	-	-	-	-	-
Fish without swim bladder	L_E	216	-	-	-	-	-	-	-	-	-
Fish with swim bladder not involved in hearing	L_E	203	0.19	0.19	0.11	0.03	0.03	0.01	-	-	-
Fish with swim bladder involved in hearing	L_E	203	0.19	0.19	0.11	0.03	0.03	0.01	-	-	-
Fish greater than or equal to 2 g	L_E	187	3.16	3.03	24.51	0.76	0.74	1.27	0.36	0.35	0.40
Fish less than 2 g	L_E	183	4.89	4.60	65.12	1.45	0.98	3.18	0.88	0.86	2.42

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa²·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table 22. Site M2 (Summer): Distances to fish and sea turtle injury thresholds for continuous sounds generated by drilling during piling.

Faunal group	Metric	Threshold (dB)	Attenuation 0 dB R_{max} (km)	0 dB $R_{95\%}$ (km)	0 dB Area (km²)	10 dB R_{max} (km)	10 dB $R_{95\%}$ (km)	10 dB Area (km²)	12 dB R_{max} (km)	12 dB $R_{95\%}$ (km)	12 dB Area (km²)
Sea turtles	L_E	220	-	-	-	-	-	-	-	-	-
Fish without swim bladder	L_E	216	-	-	-	-	-	-	-	-	-
Fish with swim bladder not involved in hearing	L_E	203	0.18	0.17	0.09	0.02	0.02	<0.005	-	-	-
Fish with swim bladder involved in hearing	L_E	203	0.18	0.17	0.09	0.02	0.02	<0.005	-	-	-
Fish greater than or equal to 2 g	L_E	187	3.08	2.85	24.86	0.53	0.48	0.77	0.37	0.34	0.38
Fish less than 2 g	L_E	183	5.09	4.56	63.42	1.11	1.05	3.58	1.01	0.95	2.67

L_{pk} = unweighted peak sound pressure (dB re 1 µPa); L_E = unweighted sound exposure level (dB re 1 µPa²·s); L_p = unweighted sound pressure level (dB re 1 µPa).

Table 23. Site J1 (Summer): Distances to behavioral thresholds for fish and sea turtles for continuous sounds generated by relief drilling during piling.

Hearing group	Unweighted L_P (dB re 1 µPa)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)
		0 dB			10 dB			12 dB		
Fish	150 [a]	0.33	0.32	0.34	0.06	0.06	0.02	0.03	0.03	0.01
Sea turtles	175 [b]	-	-	-	-	-	-	-	-	-

[a] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).
[b] McCauley et al. (2000).

Table 24. Site M1 (Summer): Distances to behavioral thresholds for fish and sea turtles for continuous sounds generated by relief drilling during piling.

Hearing group	Unweighted L_P (dB re 1 µPa)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)
		0 dB			10 dB			12 dB		
Fish	150 [a]	0.35	0.33	0.36	0.07	0.07	0.02	0.05	0.05	0.01
Sea turtles	175 [b]	-	-	-	-	-	-	-	-	-

[a] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).
[b] McCauley et al. (2000).

Table 25. Site M2 (Summer): Distances to behavioral thresholds for fish and sea turtles for continuous sounds generated by relief drilling during piling.

Hearing group	Unweighted L_P (dB re 1 µPa)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)	R_{max} (m)	$R_{95\%}$ (m)	Area (km²)
		0 dB			10 dB			12 dB		
Fish	150 [a]	0.34	0.32	0.33	0.05	0.05	0.01	0.03	0.03	0.01
Sea turtles	175 [b]	-	-	-	-	-	-	-	-	-

[a] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).
[b] McCauley et al. (2000).

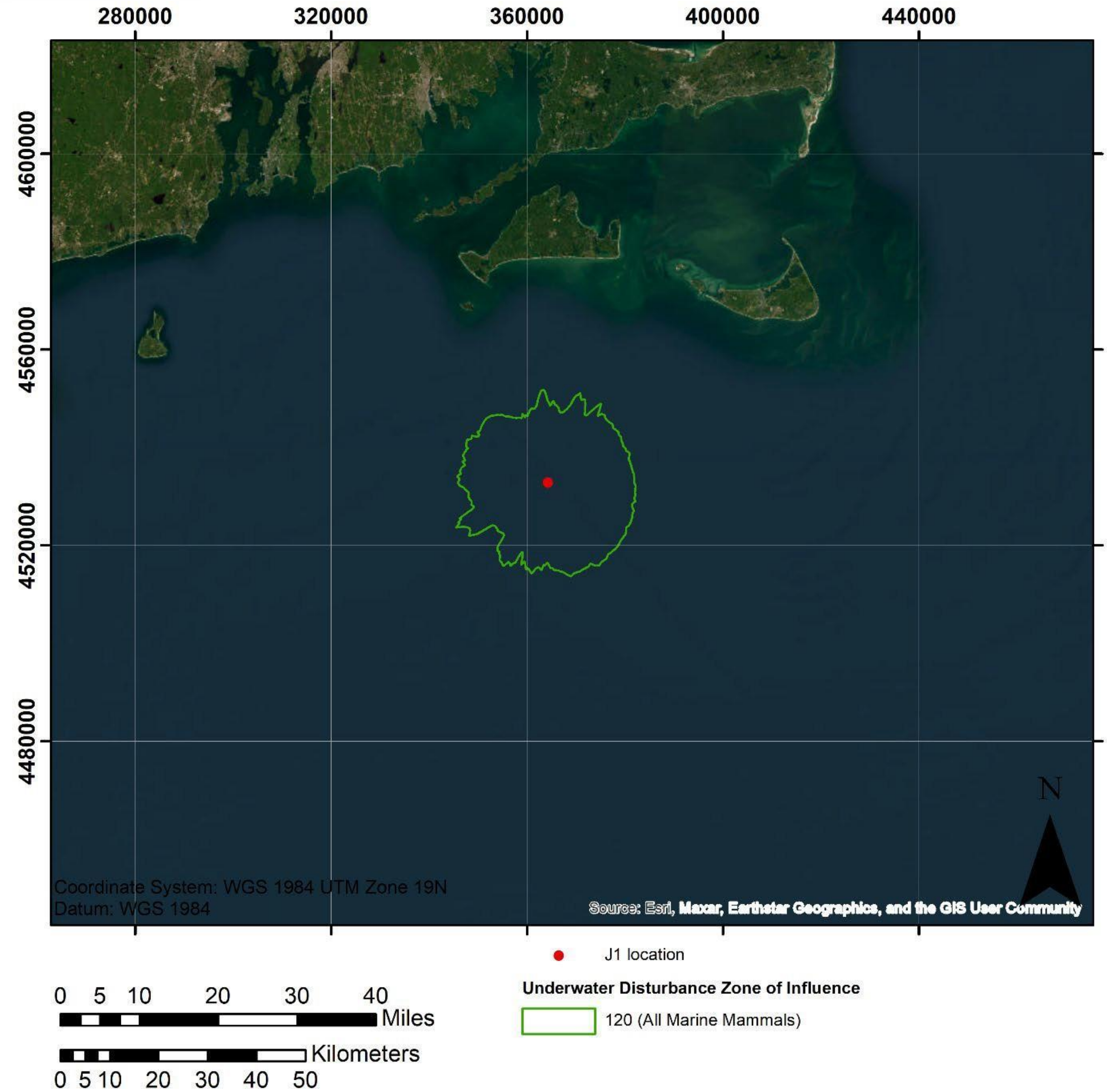

Figure 5. Location J1 – Underwater disturbance zone of influence for marine mammals for 24 hours of drilling.

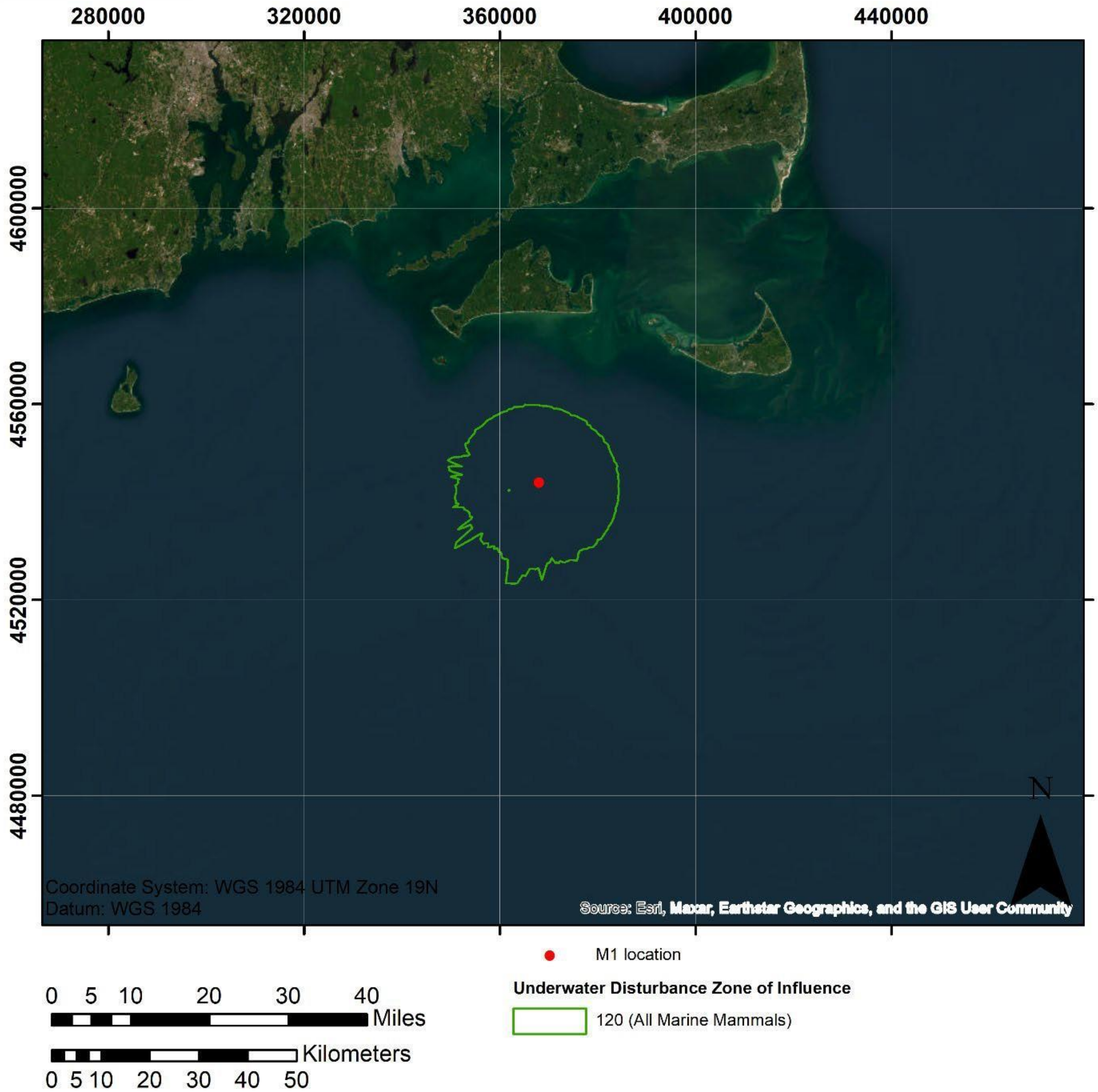

Figure 6. Location M1 – Underwater disturbance zone of influence for marine mammals for 24 hours of drilling

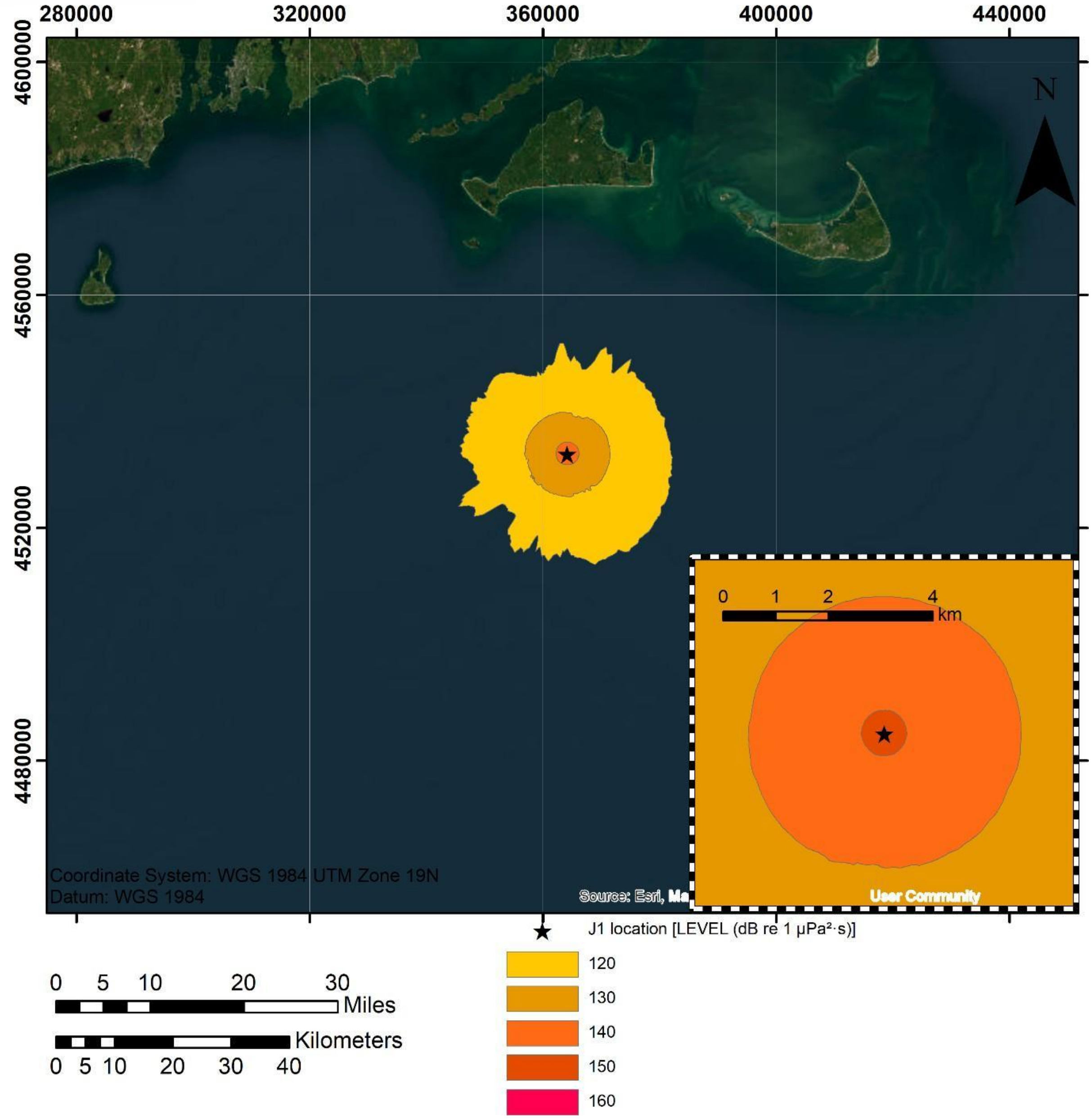

Figure 7. Location J1 – Modeled unweighted sound exposure level for 24 hours of drilling.

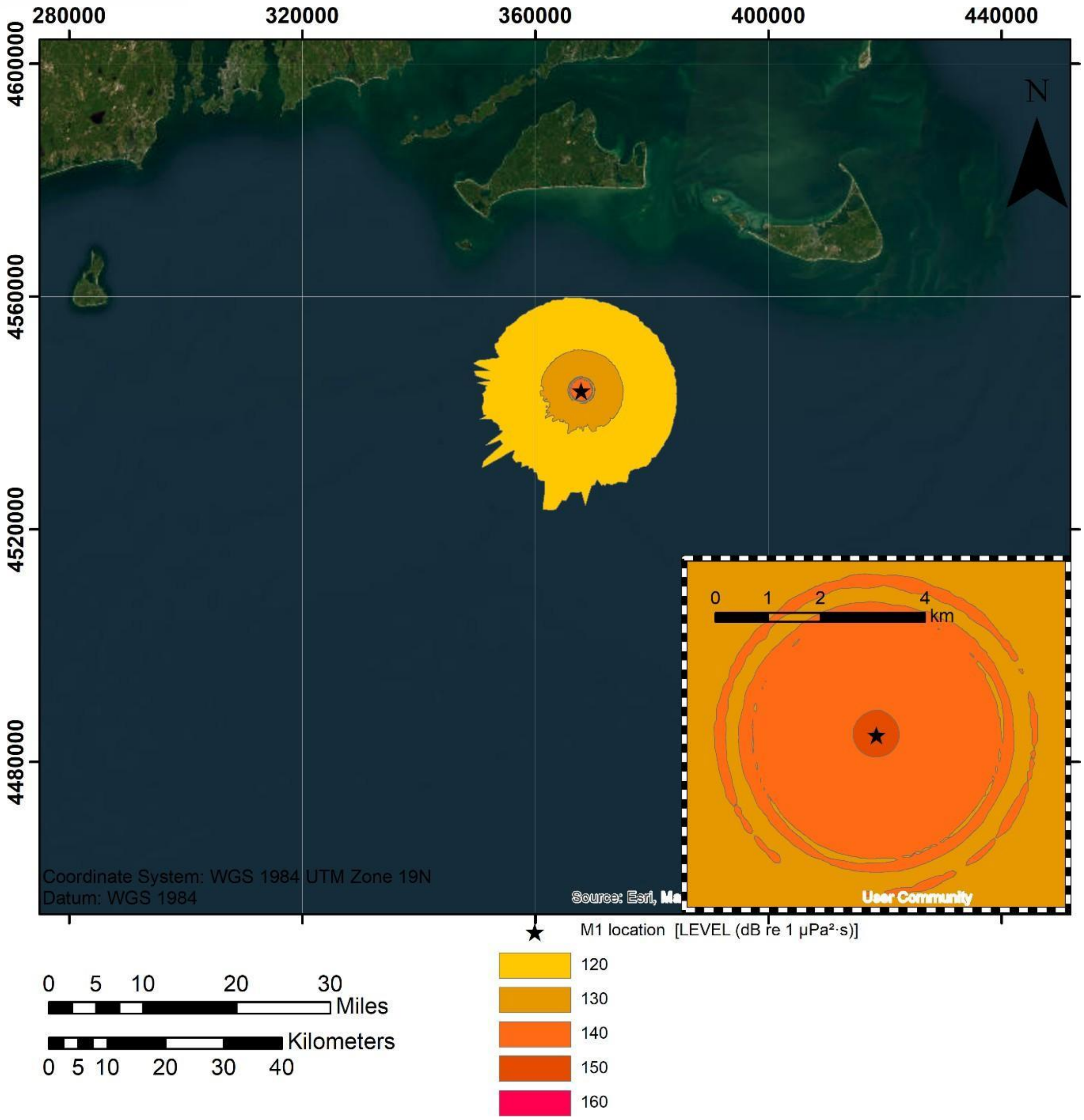

Figure 8. Location M1 – Modeled unweighted sound exposure level for 24 hours of drilling.

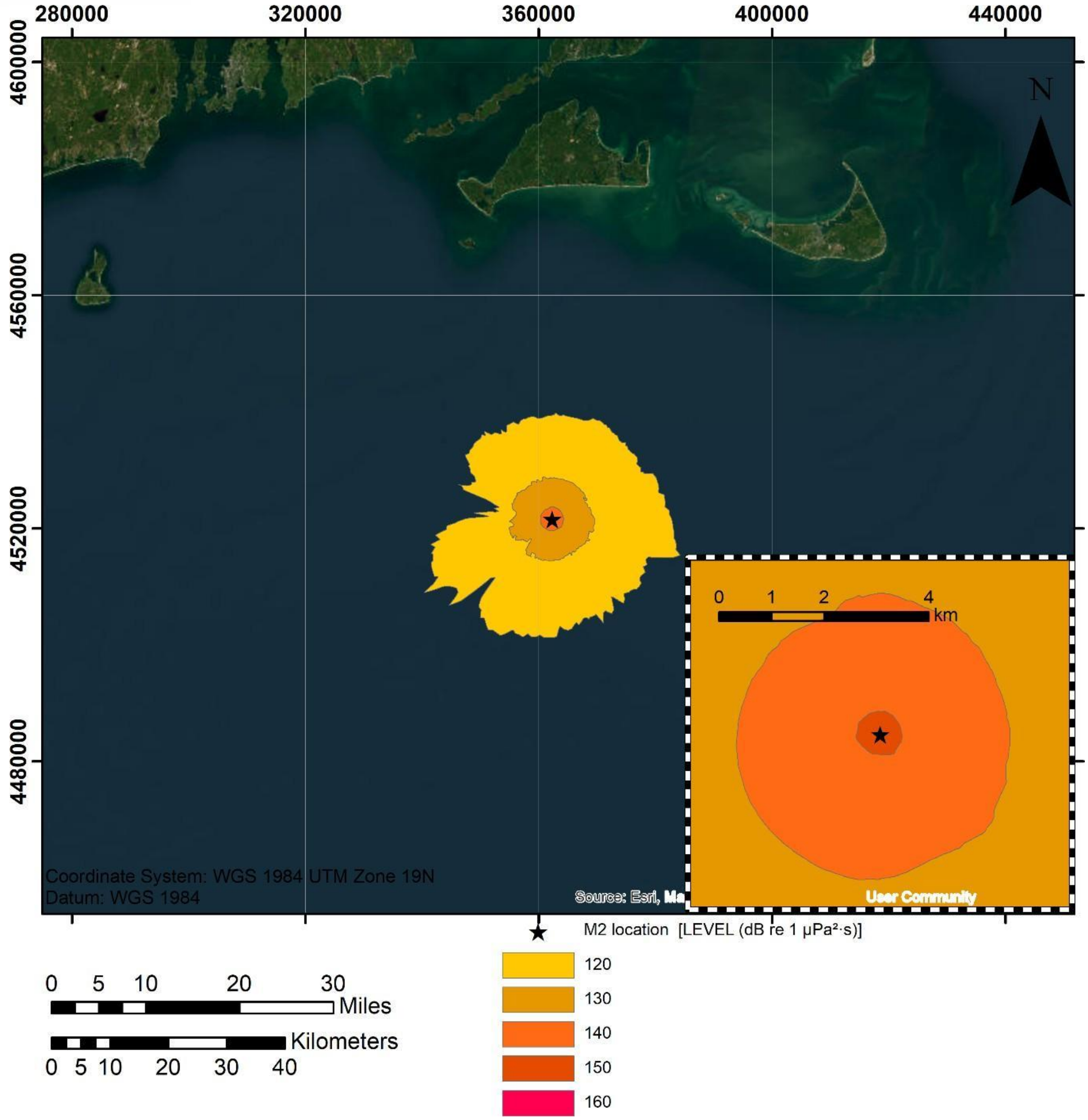

Figure 9. Location M2 – Modeled unweighted sound exposure level for 24 hours of drilling.

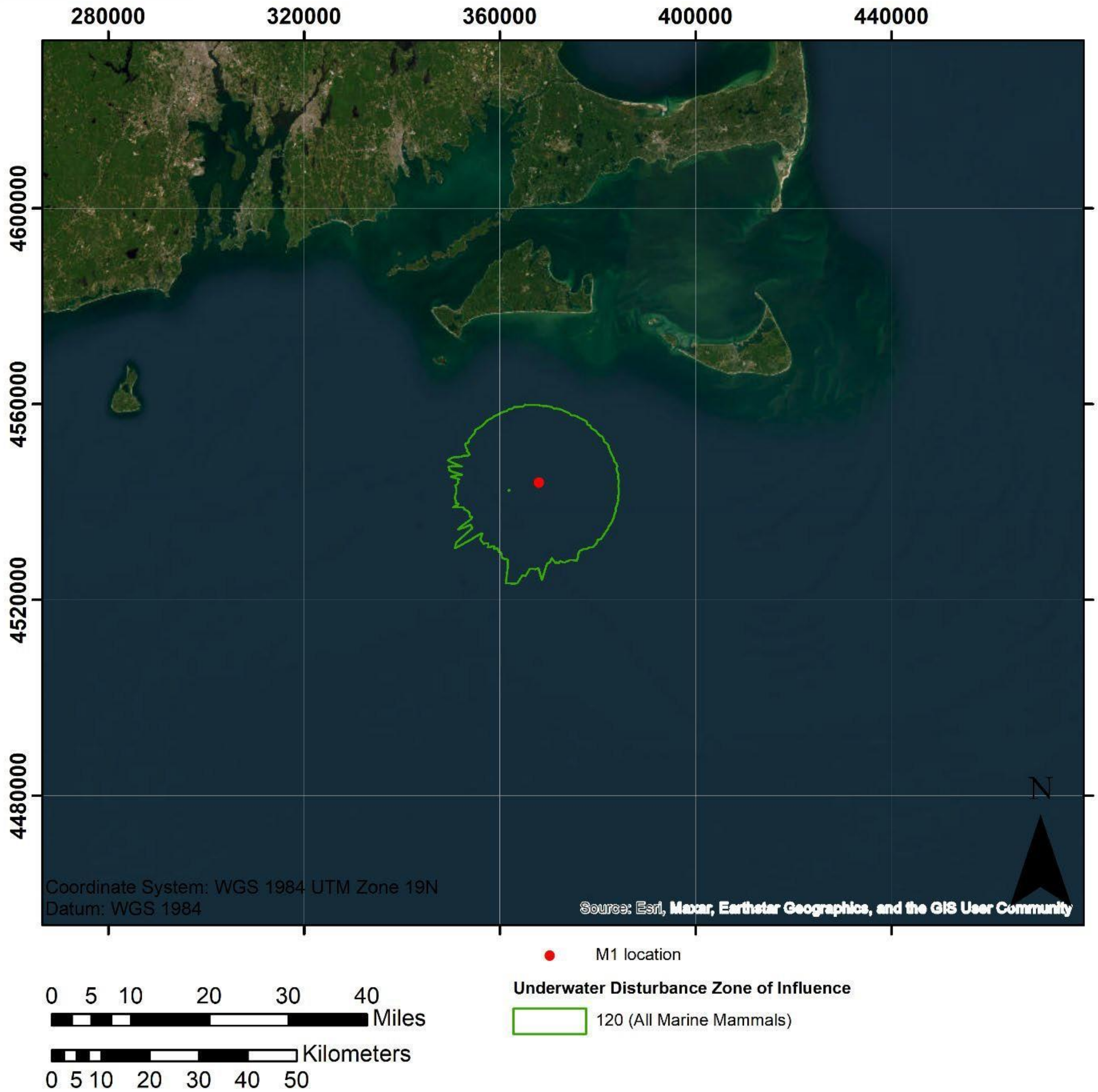

Figure 10. Location M2 – Underwater disturbance zone of influence for marine mammals for 24 hours of drilling.

K.3.2. Exposure Estimates

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 was obtained directly from the acoustic propagation modeling results, where the ensonified area was summed over the gridded maximum-over-depth sound fields corresponding to each of the acoustic thresholds for injury and behavioral response. Exposures were estimated at each location and for all species using:

$$\text{exposures} = \text{ZOI} \times \text{density}, \qquad \text{(I-2)}$$

where density is from Table 6.

Exposure estimates were calculated for the months of May through September (modeled using the summer sound speed profile) for drilling at sites M1, M2, and J1. The numbers of exposures of marine mammals to sound above injury and behavioral thresholds are provided in Sections K.3.3.1 and K.3.4.1 for site J1, Sections K.3.3.2 and K.3.4.2 for site M1, and Sections K.3.3.3 and K.3.4.3 for site M2. Sections K.3.3.4 and K.3.4.4 provide the maximum exposures from the three locations for each species at each attenuation.

Harbor porpoises had the highest number of injury exposures (0.17) at location M1 for Construction Schedule B and without sound attenuation. When broadband sound attenuation of 10 dB is applied to this case, the exposure estimate is reduced to <0.01.

In all cases, the exposure estimation showed no sea turtle exposures above any threshold at any location.

Table 26 and Table 27 show the number of days per month and year during which drilling may be required during pile installation for Schedules A and B, respectively. Pile installation is expected to occur during year 2 and year 3 of the five-year proposed Construction Schedule (2025-2029) under Schedule A or during years 2 through 4 under Schedule B.

Table 26. Construction Schedule A: Number of pile driving days during which drilling may be required, used in exposure estimation.

Month	Construction Schedule A		
	Year 2 (2026)	Year 3 (2027)	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 27. Construction Schedule B: Number of pile driving days during which drilling may be required, used in exposure estimation.

Month	Construction Schedule B			
	Year 2 (2026)	Year 3 (2027)	Year 4 (2028)	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**

K.3.3. Construction Schedule A Estimates

K.3.3.1 Site J1

Table 28. Construction Schedule A, All Years Summed, Site J1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	127.33	21.32	13.17
	Minke whale	0.11	<0.01	<0.01	332.39	55.64	34.38
	Humpback whale	0.03	<0.01	<0.01	89.47	14.98	9.25
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	23.30	3.90	2.41
	Sei whale[a]	<0.01	<0.01	<0.01	17.62	2.95	1.82
MF	Atlantic white sided dolphin	0	0	0	820.78	137.40	84.91
	Atlantic spotted dolphin	0	0	0	64.83	10.85	6.71
	Common dolphin	0	0	0	7495.29	1254.74	775.35
	Bottlenose dolphin, offshore	0	0	0	667.97	111.82	69.10
	Risso's dolphin	0	0	0	49.48	8.28	5.12
	Long-finned pilot whale	0	0	0	88.30	14.78	9.13
	Short-finned pilot whale	0	0	0	22.07	3.70	2.28
	Sperm whale[a]	0	0	0	27.58	4.62	2.85
HF	Harbor porpoise	0.13	<0.01	<0.01	633.55	106.06	65.54
PPW	Gray seal	<0.01	0	0	317.36	53.13	32.83
	Harbor seal	<0.01	0	0	476.04	79.69	49.24
	Harp seal	<0.01	0	0	340.03	56.92	35.17

[a] Listed as Endangered under the ESA.

Table 29. Construction Schedule A, Year 2, Site J1: The mean number of marine mammals predicted to receive sound levels above exposure criteriawith sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.03	<0.01	<0.01	90.40	15.13	9.35
	Minke whale	0.08	<0.01	<0.01	231.73	38.79	23.97
	Humpback whale	0.02	<0.01	<0.01	61.10	10.23	6.32
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	15.44	2.59	1.60
	Sei whale[a]	<0.01	<0.01	<0.01	11.45	1.92	1.18
MF	Atlantic white sided dolphin	0	0	0	560.31	93.80	57.96
	Atlantic spotted dolphin	0	0	0	44.32	7.42	4.58
	Common dolphin	0	0	0	5240.26	877.24	542.08
	Bottlenose dolphin, offshore	0	0	0	461.08	77.19	47.70
	Risso's dolphin	0	0	0	34.22	5.73	3.54
	Long-finned pilot whale	0	0	0	60.70	10.16	6.28
	Short-finned pilot whale	0	0	0	15.18	2.54	1.57
	Sperm whale[a]	0	0	0	18.93	3.17	1.96
HF	Harbor porpoise	0.09	<0.01	<0.01	427.68	71.60	44.24
PPW	Gray seal	<0.01	0	0	201.97	33.81	20.89
	Harbor seal	<0.01	0	0	302.96	50.72	31.34
	Harp seal	<0.01	0	0	216.40	36.23	22.39

[a] Listed as Endangered under the ESA.

Table 30. Construction Schedule A, Year 3, Site J1: The mean number of marine mammals predicted to receive sound levels above exposure criteriawith sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.01	<0.01	<0.01	36.93	6.18	3.82
	Minke whale	0.03	<0.01	<0.01	100.67	16.85	10.41
	Humpback whale	<0.01	<0.01	<0.01	28.37	4.75	2.93
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	7.86	1.32	0.81
	Sei whale[a]	<0.01	<0.01	<0.01	6.17	1.03	0.64
MF	Atlantic white sided dolphin	0	0	0	260.47	43.60	26.94
	Atlantic spotted dolphin	0	0	0	20.51	3.43	2.12
	Common dolphin	0	0	0	2255.03	377.50	233.27
	Bottlenose dolphin, offshore	0	0	0	206.89	34.63	21.40
	Risso's dolphin	0	0	0	15.26	2.55	1.58
	Long-finned pilot whale	0	0	0	27.59	4.62	2.85
	Short-finned pilot whale	0	0	0	6.90	1.15	0.71
	Sperm whale[a]	0	0	0	8.65	1.45	0.89
HF	Harbor porpoise	0.04	<0.01	<0.01	205.87	34.46	21.30
PPW	Gray seal	<0.01	0	0	115.39	19.32	11.94
	Harbor seal	<0.01	0	0	173.08	28.97	17.90
	Harp seal	<0.01	0	0	123.63	20.70	12.79

[a] Listed as Endangered under the ESA.

K.3.3.2 Site M1

Table 31. Construction Schedule A, All Years Summed, Site M1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	114.85	19.78	12.39
	Minke whale	0.11	<0.01	<0.01	299.82	51.65	32.34
	Humpback whale	0.03	<0.01	<0.01	80.70	13.90	8.70
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	21.02	3.62	2.27
	Sei whale[c]	<0.01	<0.01	<0.01	15.89	2.74	1.71
MF	Atlantic white sided dolphin	0	0	0	740.35	127.53	79.86
	Atlantic spotted dolphin	0	0	0	58.48	10.07	6.31
	Common dolphin	0	0	0	6760.79	1164.56	729.26
	Bottlenose dolphin, offshore	0	0	0	602.51	103.78	64.99
	Risso's dolphin	0	0	0	44.63	7.69	4.81
	Long-finned pilot whale	0	0	0	79.64	13.72	8.59
	Short-finned pilot whale	0	0	0	19.91	3.43	2.15
	Sperm whale[a]	0	0	0	24.88	4.29	2.68
HF	Harbor porpoise	0.16	<0.01	<0.01	571.47	98.44	61.64
PPW	Gray seal	<0.01	0	0	286.26	49.31	30.88
	Harbor seal	<0.01	0	0	429.39	73.96	46.32
	Harp seal	<0.01	0	0	306.70	52.83	33.08

[a] Listed as Endangered under the ESA.

Table 32. Construction Schedule A, Year 2, Site M1: The mean number of marine mammals predicted to receive sound levels above exposure criteriawith sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.03	<0.01	<0.01	81.54	14.05	8.80
	Minke whale	0.08	<0.01	<0.01	209.02	36.00	22.55
	Humpback whale	0.02	<0.01	<0.01	55.11	9.49	5.94
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	13.93	2.40	1.50
	Sei whale[a]	<0.01	<0.01	<0.01	10.33	1.78	1.11
MF	Atlantic white sided dolphin	0	0	0	505.41	87.06	54.52
	Atlantic spotted dolphin	0	0	0	39.98	6.89	4.31
	Common dolphin	0	0	0	4726.74	814.19	509.85
	Bottlenose dolphin, offshore	0	0	0	415.90	71.64	44.86
	Risso's dolphin	0	0	0	30.86	5.32	3.33
	Long-finned pilot whale	0	0	0	54.76	9.43	5.91
	Short-finned pilot whale	0	0	0	13.69	2.36	1.48
	Sperm whale[a]	0	0	0	17.08	2.94	1.84
HF	Harbor porpoise	0.11	<0.01	<0.01	385.77	66.45	41.61
PPW	Gray seal	<0.01	0	0	182.18	31.38	19.65
	Harbor seal	<0.01	0	0	273.27	47.07	29.48
	Harp seal	<0.01	0	0	195.19	33.62	21.05

[a] Listed as Endangered under the ESA.

Table 33. Construction Schedule A, Year 3, Site M1: The mean number of marine mammals predicted to receive sound levels above exposure criteriawith sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.01	<0.01	<0.01	33.31	5.74	3.59
	Minke whale	0.03	<0.01	<0.01	90.80	15.64	9.79
	Humpback whale	<0.01	<0.01	<0.01	25.59	4.41	2.76
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	7.09	1.22	0.76
	Sei whale[a]	<0.01	<0.01	<0.01	5.57	0.96	0.60
MF	Atlantic white sided dolphin	0	0	0	234.94	40.47	25.34
	Atlantic spotted dolphin	0	0	0	18.50	3.19	2.00
	Common dolphin	0	0	0	2034.04	350.37	219.40
	Bottlenose dolphin, offshore	0	0	0	186.62	32.15	20.13
	Risso's dolphin	0	0	0	13.76	2.37	1.48
	Long-finned pilot whale	0	0	0	24.89	4.29	2.68
	Short-finned pilot whale	0	0	0	6.22	1.07	0.67
	Sperm whale[a]	0	0	0	7.80	1.34	0.84
HF	Harbor porpoise	0.05	<0.01	<0.01	185.70	31.99	20.03
PPW	Gray seal	<0.01	0	0	104.08	17.93	11.23
	Harbor seal	<0.01	0	0	156.12	26.89	16.84
	Harp seal	<0.01	0	0	111.51	19.21	12.03

[a] Listed as Endangered under the ESA.

K.3.3.3 Site M2

Table 34. Construction Schedule A, All Years Summed, Site M2: The mean number of marine mammals predicted to receive sound levels above exposure criteriawith sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	143.37	19.91	12.54
	Minke whale	0.10	<0.01	<0.01	374.26	51.99	32.74
	Humpback whale	0.03	<0.01	<0.01	100.74	13.99	8.81
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	26.24	3.64	2.30
	Sei whale[a]	<0.01	<0.01	<0.01	19.84	2.76	1.74
MF	Atlantic white sided dolphin	0	0	0	924.17	128.37	80.85
	Atlantic spotted dolphin	0	0	0	73.00	10.14	6.39
	Common dolphin	0	0	0	8439.42	1172.27	738.28
	Bottlenose dolphin, offshore	0	0	0	752.11	104.47	65.79
	Risso's dolphin	0	0	0	55.71	7.74	4.87
	Long-finned pilot whale	0	0	0	99.42	13.81	8.70
	Short-finned pilot whale	0	0	0	24.85	3.45	2.17
	Sperm whale[a]	0	0	0	31.05	4.31	2.72
HF	Harbor porpoise	0.13	<0.01	<0.01	713.36	99.09	62.40
PPW	Gray seal	<0.01	0	0	357.33	49.63	31.26
	Harbor seal	<0.01	0	0	536.00	74.45	46.89
	Harp seal	<0.01	0	0	382.86	53.18	33.49

[a] Listed as Endangered under the ESA.

Table 35. Construction Schedule A, Year 2, Site M2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.03	<0.01	<0.01	101.78	14.14	8.90
	Minke whale	0.07	<0.01	<0.01	260.92	36.24	22.82
	Humpback whale	0.02	<0.01	<0.01	68.80	9.56	6.02
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	17.39	2.42	1.52
	Sei whale[a]	<0.01	<0.01	<0.01	12.89	1.79	1.13
MF	Atlantic white sided dolphin	0	0	0	630.89	87.63	55.19
	Atlantic spotted dolphin	0	0	0	49.91	6.93	4.37
	Common dolphin	0	0	0	5900.35	819.58	516.16
	Bottlenose dolphin, offshore	0	0	0	519.16	72.11	45.42
	Risso's dolphin	0	0	0	38.53	5.35	3.37
	Long-finned pilot whale	0	0	0	68.35	9.49	5.98
	Short-finned pilot whale	0	0	0	17.09	2.37	1.49
	Sperm whale[a]	0	0	0	21.32	2.96	1.86
HF	Harbor porpoise	0.09	<0.01	<0.01	481.56	66.89	42.13
PPW	Gray seal	<0.01	0	0	227.41	31.59	19.89
	Harbor seal	<0.01	0	0	341.12	47.38	29.84
	Harp seal	<0.01	0	0	243.66	33.84	21.31

[a] Listed as Endangered under the ESA.

Table 36. Construction Schedule A, Year 3, Site M2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.01	<0.01	<0.01	41.58	5.78	3.64
	Minke whale	0.03	<0.01	<0.01	113.35	15.74	9.92
	Humpback whale	<0.01	<0.01	<0.01	31.94	4.44	2.79
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	8.85	1.23	0.77
	Sei whale[a]	<0.01	<0.01	<0.01	6.95	0.97	0.61
MF	Atlantic white sided dolphin	0	0	0	293.28	40.74	25.66
	Atlantic spotted dolphin	0	0	0	23.09	3.21	2.02
	Common dolphin	0	0	0	2539.08	352.69	222.12
	Bottlenose dolphin, offshore	0	0	0	232.95	32.36	20.38
	Risso's dolphin	0	0	0	17.18	2.39	1.50
	Long-finned pilot whale	0	0	0	31.07	4.32	2.72
	Short-finned pilot whale	0	0	0	7.77	1.08	0.68
	Sperm whale[a]	0	0	0	9.74	1.35	0.85
HF	Harbor porpoise	0.04	<0.01	<0.01	231.80	32.20	20.28
PPW	Gray seal	<0.01	0	0	129.92	18.05	11.37
	Harbor seal	<0.01	0	0	194.88	27.07	17.05
	Harp seal	<0.01	0	0	139.20	19.34	12.18

[a] Listed as Endangered under the ESA.

K.3.3.4 Maximum

Table 37. Construction Schedule A, All Years Summed, Max: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

	Species	Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	143.37	21.32	13.17
	Minke whale	0.11	<0.01	<0.01	374.26	55.64	34.38
	Humpback whale	0.03	<0.01	<0.01	100.74	14.98	9.25
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	26.24	3.90	2.41
	Sei whale[a]	<0.01	<0.01	<0.01	19.84	2.95	1.82
MF	Atlantic white sided dolphin	0	0	0	924.17	137.40	84.91
	Atlantic spotted dolphin	0	0	0	73.00	10.85	6.71
	Common dolphin	0	0	0	8439.42	1254.74	775.35
	Bottlenose dolphin, offshore	0	0	0	752.11	111.82	69.10
	Risso's dolphin	0	0	0	55.71	8.28	5.12
	Long-finned pilot whale	0	0	0	99.42	14.78	9.13
	Short-finned pilot whale	0	0	0	24.85	3.70	2.28
	Sperm whale[a]	0	0	0	31.05	4.62	2.85
HF	Harbor porpoise	0.16	<0.01	<0.01	713.36	106.06	65.54
PPW	Gray seal	<0.01	0	0	357.33	53.13	32.83
	Harbor seal	<0.01	0	0	536.00	79.69	49.24
	Harp seal	<0.01	0	0	382.86	56.92	35.17

[a] Listed as Endangered under the ESA.

Table 38. Construction Schedule A, Year 2, Max: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.03	<0.01	<0.01	101.78	15.13	9.35
	Minke whale	0.08	<0.01	<0.01	260.92	38.79	23.97
	Humpback whale	0.02	<0.01	<0.01	68.80	10.23	6.32
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	17.39	2.59	1.60
	Sei whale[a]	<0.01	<0.01	<0.01	12.89	1.92	1.18
MF	Atlantic white sided dolphin	0	0	0	630.89	93.80	57.96
	Atlantic spotted dolphin	0	0	0	49.91	7.42	4.58
	Common dolphin	0	0	0	5900.35	877.24	542.08
	Bottlenose dolphin, offshore	0	0	0	519.16	77.19	47.70
	Risso's dolphin	0	0	0	38.53	5.73	3.54
	Long-finned pilot whale	0	0	0	68.35	10.16	6.28
	Short-finned pilot whale	0	0	0	17.09	2.54	1.57
	Sperm whale[a]	0	0	0	21.32	3.17	1.96
HF	Harbor porpoise	0.11	<0.01	<0.01	481.56	71.60	44.24
PPW	Gray seal	<0.01	0	0	227.41	33.81	20.89
	Harbor seal	<0.01	0	0	341.12	50.72	31.34
	Harp seal	<0.01	0	0	243.66	36.23	22.39

[a] Listed as Endangered under the ESA.

Table 39. Construction Schedule A, Year 3, Max: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.01	<0.01	<0.01	41.58	6.18	3.82
	Minke whale	0.03	<0.01	<0.01	113.35	16.85	10.41
	Humpback whale	<0.01	<0.01	<0.01	31.94	4.75	2.93
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	8.85	1.32	0.81
	Sei whale[a]	<0.01	<0.01	<0.01	6.95	1.03	0.64
MF	Atlantic white sided dolphin	0	0	0	293.28	43.60	26.94
	Atlantic spotted dolphin	0	0	0	23.09	3.43	2.12
	Common dolphin	0	0	0	2539.08	377.50	233.27
	Bottlenose dolphin, offshore	0	0	0	232.95	34.63	21.40
	Risso's dolphin	0	0	0	17.18	2.55	1.58
	Long-finned pilot whale	0	0	0	31.07	4.62	2.85
	Short-finned pilot whale	0	0	0	7.77	1.15	0.71
	Sperm whale[a]	0	0	0	9.74	1.45	0.89
HF	Harbor porpoise	0.05	<0.01	<0.01	231.80	34.46	21.30
PPW	Gray seal	<0.01	0	0	129.92	19.32	11.94
	Harbor seal	<0.01	0	0	194.88	28.97	17.90
	Harp seal	<0.01	0	0	139.20	20.70	12.79

[a] Listed as Endangered under the ESA.

K.3.4. Construction Schedule B Estimates

K.3.4.1 Site J1

Table 40. Construction Schedule B, All Years Summed, Site J1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	129.57	21.69	13.40
	Minke whale	0.13	<0.01	<0.01	393.68	65.90	40.72
	Humpback whale	0.03	<0.01	<0.01	96.19	16.10	9.95
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	26.30	4.40	2.72
	Sei whale[a]	<0.01	<0.01	<0.01	20.00	3.35	2.07
MF	Atlantic white sided dolphin	0	0	0	898.59	150.43	92.95
	Atlantic spotted dolphin	0	0	0	56.34	9.43	5.83
	Common dolphin	0	0	0	7237.58	1211.60	748.69
	Bottlenose dolphin, offshore	0	0	0	656.82	109.95	67.94
	Risso's dolphin	0	0	0	46.25	7.74	4.78
	Long-finned pilot whale	0	0	0	88.30	14.78	9.13
	Short-finned pilot whale	0	0	0	22.07	3.70	2.28
	Sperm whale[a]	0	0	0	25.19	4.22	2.61
HF	Harbor porpoise	0.15	0.01	<0.01	684.22	114.54	70.78
PPW	Gray seal	<0.01	0	0	368.51	61.69	38.12
	Harbor seal	<0.01	0	0	552.77	92.54	57.18
	Harp seal	<0.01	0	0	394.84	66.10	40.84

[a] Listed as Endangered under the ESA.

Table 41. Construction Schedule B, Year 2, Site J1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

	Species	Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	52.76	8.83	5.46
	Minke whale	0.05	<0.01	<0.01	165.66	27.73	17.14
	Humpback whale	0.01	<0.01	<0.01	40.27	6.74	4.17
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	11.79	1.97	1.22
	Sei whale[a]	<0.01	<0.01	<0.01	8.78	1.47	0.91
MF	Atlantic white sided dolphin	0	0	0	379.48	63.53	39.25
	Atlantic spotted dolphin	0	0	0	25.03	4.19	2.59
	Common dolphin	0	0	0	3080.69	515.72	318.68
	Bottlenose dolphin, offshore	0	0	0	272.25	45.58	28.16
	Risso's dolphin	0	0	0	19.69	3.30	2.04
	Long-finned pilot whale	0	0	0	36.79	6.16	3.81
	Short-finned pilot whale	0	0	0	9.20	1.54	0.95
	Sperm whale[a]	0	0	0	10.76	1.80	1.11
HF	Harbor porpoise	0.06	<0.01	<0.01	304.10	50.91	31.46
PPW	Gray seal	<0.01	0	0	164.99	27.62	17.07
	Harbor seal	<0.01	0	0	247.48	41.43	25.60
	Harp seal	<0.01	0	0	176.77	29.59	18.29

[a] Listed as Endangered under the ESA.

Table 42. Construction Schedule B, Year 3, Site J1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

	Species	Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	53.82	9.01	5.57
	Minke whale	0.05	<0.01	<0.01	151.13	25.30	15.63
	Humpback whale	0.01	<0.01	<0.01	36.80	6.16	3.81
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	8.63	1.44	0.89
	Sei whale[a]	<0.01	<0.01	<0.01	6.68	1.12	0.69
MF	Atlantic white sided dolphin	0	0	0	337.07	56.43	34.87
	Atlantic spotted dolphin	0	0	0	20.96	3.51	2.17
	Common dolphin	0	0	0	2901.79	485.77	300.17
	Bottlenose dolphin, offshore	0	0	0	265.71	44.48	27.49
	Risso's dolphin	0	0	0	18.57	3.11	1.92
	Long-finned pilot whale	0	0	0	34.95	5.85	3.62
	Short-finned pilot whale	0	0	0	8.74	1.46	0.90
	Sperm whale[a]	0	0	0	10.44	1.75	1.08
HF	Harbor porpoise	0.05	<0.01	<0.01	234.75	39.30	24.28
PPW	Gray seal	<0.01	0	0	115.12	19.27	11.91
	Harbor seal	<0.01	0	0	172.68	28.91	17.86
	Harp seal	<0.01	0	0	123.34	20.65	12.76

[a] Listed as Endangered under the ESA.

Table 43. Construction Schedule B, Year 4, Site J1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	<0.01	<0.01	<0.01	22.99	3.85	2.38
	Minke whale	0.03	<0.01	<0.01	76.89	12.87	7.95
	Humpback whale	<0.01	<0.01	<0.01	19.11	3.20	1.98
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	5.88	0.98	0.61
	Sei whale[a]	<0.01	<0.01	<0.01	4.55	0.76	0.47
MF	Atlantic white sided dolphin	0	0	0	182.04	30.47	18.83
	Atlantic spotted dolphin	0	0	0	10.36	1.73	1.07
	Common dolphin	0	0	0	1255.10	210.11	129.83
	Bottlenose dolphin, offshore	0	0	0	118.86	19.90	12.30
	Risso's dolphin	0	0	0	7.98	1.34	0.83
	Long-finned pilot whale	0	0	0	16.56	2.77	1.71
	Short-finned pilot whale	0	0	0	4.14	0.69	0.43
	Sperm whale[a]	0	0	0	3.99	0.67	0.41
HF	Harbor porpoise	0.03	<0.01	<0.01	145.37	24.34	15.04
PPW	Gray seal	<0.01	0	0	88.41	14.80	9.15
	Harbor seal	<0.01	0	0	132.61	22.20	13.72
	Harp seal	<0.01	0	0	94.72	15.86	9.80

[a] Listed as Endangered under the ESA.

K.3.4.2 Site M1

Table 44. Construction Schedule B, All Years Summed, Site M1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	116.87	20.13	12.61
	Minke whale	0.13	<0.01	<0.01	355.10	61.17	38.30
	Humpback whale	0.03	<0.01	<0.01	86.76	14.94	9.36
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	23.72	4.09	2.56
	Sei whale[a]	<0.01	<0.01	<0.01	18.04	3.11	1.95
MF	Atlantic white sided dolphin	0	0	0	810.53	139.62	87.43
	Atlantic spotted dolphin	0	0	0	50.82	8.75	5.48
	Common dolphin	0	0	0	6528.34	1124.52	704.19
	Bottlenose dolphin, offshore	0	0	0	592.46	102.05	63.91
	Risso's dolphin	0	0	0	41.71	7.19	4.50
	Long-finned pilot whale	0	0	0	79.64	13.72	8.59
	Short-finned pilot whale	0	0	0	19.91	3.43	2.15
	Sperm whale[a]	0	0	0	22.72	3.91	2.45
HF	Harbor porpoise	0.17	<0.01	<0.01	617.17	106.31	66.57
PPW	Gray seal	<0.01	0	0	332.40	57.26	35.85
	Harbor seal	<0.01	0	0	498.60	85.89	53.78
	Harp seal	<0.01	0	0	356.15	61.35	38.42

[a] Listed as Endangered under the ESA.

Table 45. Construction Schedule B, Year 2, Site M1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	47.59	8.20	5.13
	Minke whale	0.05	<0.01	<0.01	149.42	25.74	16.12
	Humpback whale	0.01	<0.01	<0.01	36.33	6.26	3.92
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	10.63	1.83	1.15
	Sei whale[a]	<0.01	<0.01	<0.01	7.92	1.36	0.85
MF	Atlantic white sided dolphin	0	0	0	342.29	58.96	36.92
	Atlantic spotted dolphin	0	0	0	22.57	3.89	2.44
	Common dolphin	0	0	0	2778.80	478.66	299.74
	Bottlenose dolphin, offshore	0	0	0	245.57	42.30	26.49
	Risso's dolphin	0	0	0	17.76	3.06	1.92
	Long-finned pilot whale	0	0	0	33.18	5.72	3.58
	Short-finned pilot whale	0	0	0	8.30	1.43	0.89
	Sperm whale[a]	0	0	0	9.71	1.67	1.05
HF	Harbor porpoise	0.08	<0.01	<0.01	274.30	47.25	29.59
PPW	Gray seal	<0.01	0	0	148.82	25.63	16.05
	Harbor seal	<0.01	0	0	223.23	38.45	24.08
	Harp seal	<0.01	0	0	159.45	27.47	17.20

[a] Listed as Endangered under the ESA.

Table 46. Construction Schedule B, Year 3, Site M1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	48.55	8.36	5.24
	Minke whale	0.05	<0.01	<0.01	136.32	23.48	14.70
	Humpback whale	0.01	<0.01	<0.01	33.19	5.72	3.58
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	7.78	1.34	0.84
	Sei whale[a]	<0.01	<0.01	<0.01	6.02	1.04	0.65
MF	Atlantic white sided dolphin	0	0	0	304.04	52.37	32.80
	Atlantic spotted dolphin	0	0	0	18.90	3.26	2.04
	Common dolphin	0	0	0	2617.43	450.86	282.33
	Bottlenose dolphin, offshore	0	0	0	239.67	41.28	25.85
	Risso's dolphin	0	0	0	16.75	2.89	1.81
	Long-finned pilot whale	0	0	0	31.53	5.43	3.40
	Short-finned pilot whale	0	0	0	7.88	1.36	0.85
	Sperm whale[a]	0	0	0	9.41	1.62	1.02
HF	Harbor porpoise	0.06	<0.01	<0.01	211.74	36.47	22.84
PPW	Gray seal	<0.01	0	0	103.84	17.89	11.20
	Harbor seal	<0.01	0	0	155.76	26.83	16.80
	Harp seal	<0.01	0	0	111.26	19.16	12.00

[a] Listed as Endangered under the ESA.

Table 47. Construction Schedule B, Year 4, Site M1: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	<0.01	<0.01	<0.01	20.73	3.57	2.24
	Minke whale	0.03	<0.01	<0.01	69.35	11.95	7.48
	Humpback whale	<0.01	<0.01	<0.01	17.24	2.97	1.86
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	5.30	0.91	0.57
	Sei whale[a]	<0.01	<0.01	<0.01	4.10	0.71	0.44
MF	Atlantic white sided dolphin	0	0	0	164.20	28.28	17.71
	Atlantic spotted dolphin	0	0	0	9.34	1.61	1.01
	Common dolphin	0	0	0	1132.11	195.01	122.12
	Bottlenose dolphin, offshore	0	0	0	107.21	18.47	11.56
	Risso's dolphin	0	0	0	7.20	1.24	0.78
	Long-finned pilot whale	0	0	0	14.93	2.57	1.61
	Short-finned pilot whale	0	0	0	3.73	0.64	0.40
	Sperm whale[a]	0	0	0	3.60	0.62	0.39
HF	Harbor porpoise	0.04	<0.01	<0.01	131.12	22.59	14.14
PPW	Gray seal	<0.01	0	0	79.75	13.74	8.60
	Harbor seal	<0.01	0	0	119.62	20.60	12.90
	Harp seal	<0.01	0	0	85.44	14.72	9.22

[a] Listed as Endangered under the ESA.

K.3.4.3 Site M2

Table 48. Construction Schedule B, All Years Summed, Site M2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	145.89	20.26	12.76
	Minke whale	0.12	<0.01	<0.01	443.27	61.57	38.78
	Humpback whale	0.03	<0.01	<0.01	108.30	15.04	9.47
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	29.61	4.11	2.59
	Sei whale[a]	<0.01	<0.01	<0.01	22.52	3.13	1.97
MF	Atlantic white sided dolphin	0	0	0	1011.78	140.54	88.51
	Atlantic spotted dolphin	0	0	0	63.44	8.81	5.55
	Common dolphin	0	0	0	8149.26	1131.97	712.89
	Bottlenose dolphin, offshore	0	0	0	739.56	102.73	64.70
	Risso's dolphin	0	0	0	52.07	7.23	4.56
	Long-finned pilot whale	0	0	0	99.42	13.81	8.70
	Short-finned pilot whale	0	0	0	24.85	3.45	2.17
	Sperm whale[a]	0	0	0	28.36	3.94	2.48
HF	Harbor porpoise	0.15	<0.01	<0.01	770.41	107.01	67.40
PPW	Gray seal	<0.01	0	0	414.93	57.64	36.30
	Harbor seal	<0.01	0	0	622.40	86.45	54.45
	Harp seal	<0.01	0	0	444.57	61.75	38.89

[a] Listed as Endangered under the ESA.

Table 49. Construction Schedule B, Year 2, Site M2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	59.40	8.25	5.20
	Minke whale	0.05	<0.01	<0.01	186.52	25.91	16.32
	Humpback whale	0.01	<0.01	<0.01	45.35	6.30	3.97
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	13.27	1.84	1.16
	Sei whale[a]	<0.01	<0.01	<0.01	9.88	1.37	0.86
MF	Atlantic white sided dolphin	0	0	0	427.28	59.35	37.38
	Atlantic spotted dolphin	0	0	0	28.18	3.91	2.47
	Common dolphin	0	0	0	3468.75	481.82	303.44
	Bottlenose dolphin, offshore	0	0	0	306.55	42.58	26.82
	Risso's dolphin	0	0	0	22.17	3.08	1.94
	Long-finned pilot whale	0	0	0	41.42	5.75	3.62
	Short-finned pilot whale	0	0	0	10.36	1.44	0.91
	Sperm whale[a]	0	0	0	12.12	1.68	1.06
HF	Harbor porpoise	0.06	<0.01	<0.01	342.41	47.56	29.95
PPW	Gray seal	<0.01	0	0	185.77	25.80	16.25
	Harbor seal	<0.01	0	0	278.65	38.71	24.38
	Harp seal	<0.01	0	0	199.04	27.65	17.41

[a] Listed as Endangered under the ESA.

Table 50. Construction Schedule B, Year 3, Site M2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	60.60	8.42	5.30
	Minke whale	0.04	<0.01	<0.01	170.17	23.64	14.89
	Humpback whale	0.01	<0.01	<0.01	41.44	5.76	3.62
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	9.71	1.35	0.85
	Sei whale[a]	<0.01	<0.01	<0.01	7.52	1.04	0.66
MF	Atlantic white sided dolphin	0	0	0	379.53	52.72	33.20
	Atlantic spotted dolphin	0	0	0	23.60	3.28	2.06
	Common dolphin	0	0	0	3267.31	453.84	285.82
	Bottlenose dolphin, offshore	0	0	0	299.18	41.56	26.17
	Risso's dolphin	0	0	0	20.91	2.91	1.83
	Long-finned pilot whale	0	0	0	39.35	5.47	3.44
	Short-finned pilot whale	0	0	0	9.84	1.37	0.86
	Sperm whale[a]	0	0	0	11.75	1.63	1.03
HF	Harbor porpoise	0.05	<0.01	<0.01	264.32	36.72	23.12
PPW	Gray seal	<0.01	0	0	129.62	18.00	11.34
	Harbor seal	<0.01	0	0	194.43	27.01	17.01
	Harp seal	<0.01	0	0	138.88	19.29	12.15

[a] Listed as Endangered under the ESA.

Table 51. Construction Schedule B, Year 4, Site M2: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	<0.01	<0.01	<0.01	25.88	3.60	2.26
	Minke whale	0.02	<0.01	<0.01	86.57	12.03	7.57
	Humpback whale	<0.01	<0.01	<0.01	21.52	2.99	1.88
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	6.62	0.92	0.58
	Sei whale[a]	<0.01	<0.01	<0.01	5.12	0.71	0.45
MF	Atlantic white sided dolphin	0	0	0	204.97	28.47	17.93
	Atlantic spotted dolphin	0	0	0	11.66	1.62	1.02
	Common dolphin	0	0	0	1413.20	196.30	123.63
	Bottlenose dolphin, offshore	0	0	0	133.83	18.59	11.71
	Risso's dolphin	0	0	0	8.99	1.25	0.79
	Long-finned pilot whale	0	0	0	18.64	2.59	1.63
	Short-finned pilot whale	0	0	0	4.66	0.65	0.41
	Sperm whale[a]	0	0	0	4.49	0.62	0.39
HF	Harbor porpoise	0.03	<0.01	<0.01	163.68	22.74	14.32
PPW	Gray seal	<0.01	0	0	99.55	13.83	8.71
	Harbor seal	<0.01	0	0	149.32	20.74	13.06
	Harp seal	<0.01	0	0	106.66	14.81	9.33

[a] Listed as Endangered under the ESA.

K.3.4.4 Maximum

Table 52. Construction Schedule B, All Years Summed, Max: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.04	<0.01	<0.01	145.89	21.69	13.40
	Minke whale	0.13	<0.01	<0.01	443.27	65.90	40.72
	Humpback whale	0.03	<0.01	<0.01	108.30	16.10	9.95
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	29.61	4.40	2.72
	Sei whale[a]	<0.01	<0.01	<0.01	22.52	3.35	2.07
MF	Atlantic white sided dolphin	0	0	0	1011.78	150.43	92.95
	Atlantic spotted dolphin	0	0	0	63.44	9.43	5.83
	Common dolphin	0	0	0	8149.26	1211.60	748.69
	Bottlenose dolphin, offshore	0	0	0	739.56	109.95	67.94
	Risso's dolphin	0	0	0	52.07	7.74	4.78
	Long-finned pilot whale	0	0	0	99.42	14.78	9.13
	Short-finned pilot whale	0	0	0	24.85	3.70	2.28
	Sperm whale[a]	0	0	0	28.36	4.22	2.61
HF	Harbor porpoise	0.17	0.01	<0.01	770.41	114.54	70.78
PPW	Gray seal	<0.01	0	0	414.93	61.69	38.12
	Harbor seal	<0.01	0	0	622.40	92.54	57.18
	Harp seal	<0.01	0	0	444.57	66.10	40.84

[a] Listed as Endangered under the ESA.

Table 53. Construction Schedule B, Year 2, Max: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	59.40	8.83	5.46
	Minke whale	0.05	<0.01	<0.01	186.52	27.73	17.14
	Humpback whale	0.01	<0.01	<0.01	45.35	6.74	4.17
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	13.27	1.97	1.22
	Sei whale[a]	<0.01	<0.01	<0.01	9.88	1.47	0.91
MF	Atlantic white sided dolphin	0	0	0	427.28	63.53	39.25
	Atlantic spotted dolphin	0	0	0	28.18	4.19	2.59
	Common dolphin	0	0	0	3468.75	515.72	318.68
	Bottlenose dolphin, offshore	0	0	0	306.55	45.58	28.16
	Risso's dolphin	0	0	0	22.17	3.30	2.04
	Long-finned pilot whale	0	0	0	41.42	6.16	3.81
	Short-finned pilot whale	0	0	0	10.36	1.54	0.95
	Sperm whale[a]	0	0	0	12.12	1.80	1.11
HF	Harbor porpoise	0.08	<0.01	<0.01	342.41	50.91	31.46
PPW	Gray seal	<0.01	0	0	185.77	27.62	17.07
	Harbor seal	<0.01	0	0	278.65	41.43	25.60
	Harp seal	<0.01	0	0	199.04	29.59	18.29

[a] Listed as Endangered under the ESA.

Table 54. Construction Schedule B, Year 3, Max: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	0.02	<0.01	<0.01	60.60	9.01	5.57
	Minke whale	0.05	<0.01	<0.01	170.17	25.30	15.63
	Humpback whale	0.01	<0.01	<0.01	41.44	6.16	3.81
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	9.71	1.44	0.89
	Sei whale[a]	<0.01	<0.01	<0.01	7.52	1.12	0.69
MF	Atlantic white sided dolphin	0	0	0	379.53	56.43	34.87
	Atlantic spotted dolphin	0	0	0	23.60	3.51	2.17
	Common dolphin	0	0	0	3267.31	485.77	300.17
	Bottlenose dolphin, offshore	0	0	0	299.18	44.48	27.49
	Risso's dolphin	0	0	0	20.91	3.11	1.92
	Long-finned pilot whale	0	0	0	39.35	5.85	3.62
	Short-finned pilot whale	0	0	0	9.84	1.46	0.90
	Sperm whale[a]	0	0	0	11.75	1.75	1.08
HF	Harbor porpoise	0.06	<0.01	<0.01	264.32	39.30	24.28
PPW	Gray seal	<0.01	0	0	129.62	19.27	11.91
	Harbor seal	<0.01	0	0	194.43	28.91	17.86
	Harp seal	<0.01	0	0	138.88	20.65	12.76

[a] Listed as Endangered under the ESA.

Table 55. Construction Schedule B, Year 4, Max: The mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation.

Species		Injury			Behavior		
		Attenuation (dB)			Attenuation (dB)		
		0	10	12	0	10	12
LF	Fin whale[a]	<0.01	<0.01	<0.01	25.88	3.85	2.38
	Minke whale	0.03	<0.01	<0.01	86.57	12.87	7.95
	Humpback whale	<0.01	<0.01	<0.01	21.52	3.20	1.98
	North Atlantic right whale[a]	<0.01	<0.01	<0.01	6.62	0.98	0.61
	Sei whale[a]	<0.01	<0.01	<0.01	5.12	0.76	0.47
MF	Atlantic white sided dolphin	0	0	0	204.97	30.47	18.83
	Atlantic spotted dolphin	0	0	0	11.66	1.73	1.07
	Common dolphin	0	0	0	1413.20	210.11	129.83
	Bottlenose dolphin, offshore	0	0	0	133.83	19.90	12.30
	Risso's dolphin	0	0	0	8.99	1.34	0.83
	Long-finned pilot whale	0	0	0	18.64	2.77	1.71
	Short-finned pilot whale	0	0	0	4.66	0.69	0.43
	Sperm whale[a]	0	0	0	4.49	0.67	0.41
HF	Harbor porpoise	0.04	<0.01	<0.01	163.68	24.34	15.04
PPW	Gray seal	<0.01	0	0	99.55	14.80	9.15
	Harbor seal	<0.01	0	0	149.32	22.20	13.72
	Harp seal	<0.01	0	0	106.66	15.86	9.80

[a] Listed as Endangered under the ESA.

K.4.Summary

Marine mammal PTS injury is unlikely to occur from the proposed drilling construction because the ranges are <100 m at both sites for all hearing groups, except for low-frequency and high-frequency animals animals (FHWG 2008) whose predicted maximum acoustic ranges are ~300 m, with the furthest acoustic ranges predicted at the M2 site. Injury is not expected to occur for sea turtles as the ranges to threshold are detected at all the modeled locations. These distances may be considered conservative, because animals will be moving through the area during the potential 24-hour drilling activity per day.

The acoustic ranges to the behavioral thresholds for marine mammal hearing groups sounds SPL 120 dB re 1 µPa threshold (NMFS 2018) and sea turtles SPL 175 dB re 1 µPa threshold, without frequency weighting, are shown in Table 18-22 for locations J1, M1, and M2. The tables capture the ranges at attenuations, 0 dB, 10 dB, and 12 dB. The maximum unweighted behavioral acoustic ranges were found to extend to 20.73 km at J1, 21.65 km at M1, and 25.37 km at M2 location. Excluding 5% of the farthest points ($R_{95\%}$), the behavioral threshold ranges were 17.76 km at J1, 16.62 km at M1 and 19.67 at M2 location.

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