VINEYARD MID-ATLANTIC

CONSTRUCTION AND OPERATIONS PLAN

VOLUME II APPENDIX

JANUARY 2025

PREPARED BY:

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SUBMITTED BY:

VINEYARD MID-ATLANTIC LLC

VINEYARD MID-ATLANTIC

VINEYARD OFFSHORE

PUBLIC VERSION

Vineyard Mid-Atlantic COP

Appendix II-E Vineyard Mid-Atlantic Acoustic and Exposure Modeling

Prepared by:
JASCO

Prepared for:
Vineyard Mid-Atlantic LLC

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Hydroacoustic Analysis Report–
Animal Exposure Estimates, Ranges, and Zones

Vineyard Mid-Atlantic
Lease Area OCS-A 0544

JASCO Applied Sciences (USA) Inc.

5 November 2024

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Executive Summary

Vineyard Mid-Atlantic LLC (the "Proponent") proposes to develop, construct, and operate offshore renewable wind energy facilities in Offshore Wind Lease Area OCS-A 0544 (the "Lease Area") along with associated offshore and onshore transmission systems. This proposed development is referred to as "Vineyard Mid-Atlantic." Vineyard Mid-Atlantic includes 118 total wind turbine generator (WTG) and electrical service platform (ESP) positions within the Lease Area. One or two of those positions will be occupied by ESPs and the remaining positions will be occupied by WTGs. The WTGs will be supported by monopiles and ESP(s) will be supported by monopiles or piled jacket foundations.

Vineyard Mid-Atlantic has submitted a Construction and Operations Plan (COP) for review by the Bureau of Ocean Energy Management (BOEM) and has commissioned JASCO Applied Sciences (USA) Inc. (JASCO) to prepare this Hydroacoustic Report to support a COP and Letter of Authorization (LOA) application.

The primary sound sources associated with Vineyard Mid-Atlantic are impact pile driving and vibratory pile driving during construction. To assess potential impacts to marine mammals, sea turtles, and fish from sound exposure associated with anthropogenic activities, JASCO performed acoustic modeling of impact and vibratory pile driving during pile installation (see Sections 1–5 and Supplements F–H) on behalf of the Proponent. Multiple construction schedules were evaluated to provide for flexibility in the project implementation that will likely be needed due to logistical constraints.

As the final construction schedule for Vineyard Mid-Atlantic is unknown at this early stage in the construction planning process, a conservative approach was taken in this assessment. The piling construction schedules were established based on various pile characteristics, including piling scenarios for 12.5 m monopile foundations and 4.25 m jacket foundations. For some scenarios, the construction schedules used to calculate exposures are conservative and may overestimate potential environmental impacts. The conservative modeling scenarios and hammering schedules are based on preliminary information and will continue to be refined.

The goal of this underwater acoustic modeling study was to predict monitoring distances (acoustic and exposure ranges) to regulatory-defined acoustic thresholds associated with injury and behavioral disturbance for various marine fauna, including marine mammals, sea turtles, and fish. Sound generated during impact and vibratory pile driving, the primary sound sources associated with Vineyard Mid-Atlantic, was modeled by characterizing the sound produced at the pile and then calculating how the sound propagates within the surrounding water column. For impulsive sounds from impact pile driving and non-impulsive sounds from vibratory pile driving, time-domain representations of the pressure waves generated in the water are required for calculating sound pressure level (SPL) and zero-to-peak pressure level (PK), which are then used to evaluate potential impacts. JASCO's animal movement modeling software, JASMINE, was used to integrate the computed sound fields with species-typical movement (e.g., dive patterns) to estimate received sound levels for the modeled (animat) marine mammals and sea turtles that may occur near the construction area.

The numbers of potential acoustic exposures (to regulatory thresholds) for marine mammals and sea turtles were estimated by calculating the accumulated sound energy (SEL) and maximum SPL and PK pressure level for each animat received over the course of the simulation. Exposure criteria are based on relevant regulatory-defined thresholds for sea turtles (Finneran et al. 2017) and marine mammals (Wood et al. 2012, NMFS 2023). The projected number of animals exposed to sound levels above threshold values was determined by scaling the number of animats exposed to a criterion in the model to reflect local populations. The Duke University Habitat-based Cetacean Density Models were used to estimate densities for marine mammal species (Roberts et al. 2016, 2023, 2024). Sea turtle densities were estimated using the US Naval Undersea Warfare Center models (NUWC; DiMatteo et al. 2024).

Exposure ranges accounting for 95% of exposures ($ER_{95\%}$) above regulatory-defined injury and behavioral disruption thresholds (McCauley et al. 2000b, NMFS 2005, Finneran et al. 2017, NMFS 2018) were calculated using the exposure history of the animat model output. Section 4.3 provides the number of animals predicted to experience levels exceeding injury or behavioral thresholds. The species-specific $ER_{95\%}$ (see tables in Section 4.4) were determined with different broadband attenuation levels (0, 6, 10, and 12 dB) to account for the use of noise reduction systems, such as bubble curtains. $ER_{95\%}$ can be used for mitigation purposes, such as establishing monitoring or exclusion areas. Fish were considered static receivers, so only the acoustic distance $R_{95\%}$ to their regulatory thresholds (Stadler and Woodbury 2009, Popper et al. 2014) were calculated (see tables in Section 4.2).

Acronyms and Abbreviations

ANSI	American National Standards Institute
BOEM	Bureau of Ocean Energy Management
C	degrees centigrade
COP	Construction and Operations Plan
CPA	closest point of approach
CRM	Coastal Relief Model
dB	decibel
DPS	Distinct Population Segment
DTD	Difficult to Drive
$ER_{95\%}$	95% exposure range
ESA	Endangered Species Act
ESP	electrical service platforms
FD	finite difference
FHWG	Fisheries Hydroacoustic Working Group
ft	foot
FWRAM	Full Wave Range Dependent Acoustic Model
GDEM	Generalized Digital Environmental Model
h	hour
HFC	high frequency cetacean (hearing group)
Hz	hertz
in	inch
JASCO	JASCO Applied Sciences
JASMINE	JASCO Animal Simulation Model Including Noise Exposure
kg	kilogram
kHz	kilohertz
kJ	kilojoule
km	kilometer
kN	kilonewton
LFC	low frequency cetacean (hearing group)
LOA	Letter of Authorization
m	meter
m/s	meter per second
MFC	mid-frequency cetacean (hearing group)
MGEL	Marine Geospatial Ecology Laboratory (Duke University)
min	minute
mm	millimeter
MMPA	Marine Mammal Protection Act
ms	millisecond
NARW	North Atlantic right whale
NAS	noise abatement system
NavES	Experience Report Pile-Driving Noise
NCEI	National Centers for Environmental Information
NMFS	National Marine Fisheries Service (also known as NOAA Fisheries)
NMS	Noise Mitigation System
NOAA	National Oceanic and Atmospheric Administration
NUWC	Naval Undersea Warfare Center
OBIS	Ocean Biodiversity Information System
OCS	Outer Continental Shelf
OECC	offshore export cable corridor
PDE	Project Design Envelope
PDSM	Pile Driving Source Model
PE	parabolic equation
PK	zero-to-peak sound pressure level
PSO	protected species observer
PTS	permanent (hearing) threshold shift
PW	phocid (seal) in water (hearing group)
rms	root mean square
s	second
SEL	sound exposure level
SELcum	cumulative sound exposure level
SL	source level
SPL	root-mean-square sound pressure level
SSP	sound speed profile
TTS	temporary (hearing) threshold shift
TU	sea turtles in water (hearing group)
US	United States (of America)
UXO	unexploded ordnance
WTG	wind turbine generator
μPa	micropascal

1. Introduction

1.1. Project Background and Overview of Assessed Activity

JASCO Applied Sciences (USA) Inc. (JASCO) has been commissioned by Vineyard Mid-Atlantic LLC. to perform underwater acoustic modeling associated with installation of Vineyard Mid-Atlantic in Lease Area OCS-A 0544. Vineyard Mid-Atlantic includes 118 total wind turbine generator (WTG) and electrical service platform (ESP) positions within the Lease Area.[1] One or two of those positions will be occupied by ESPs and the remaining positions will be occupied by WTGs. The WTGs will be supported by monopiles and ESP(s) will be supported by monopiles or piled jacket foundations. The modeling results will be used to support a Construction and Operations Plan (COP) and Letter of Authorization (LOA) application. Figure 1 provides an overview of the Vineyard Mid-Atlantic Lease Area OCS-A 0544. The offshore wind facility, located in water approximately 39.5-47.1 m deep, will be connected to land via offshore export cable corridors (OECCs).

Underwater sound may be generated by construction at the Vineyard Mid-Atlantic Lease Area. The effects of noise on marine fauna are regulated in the United States by agencies such as the US National Oceanic and Atmospheric Administration (NOAA) and the Bureau of Ocean Energy and Management (BOEM). The sound sources that could have stronger effects on marine fauna are impact (impulsive sound) and vibratory (non-impulsive continuous sound) pile driving during foundation installation for the WTGs and ESP(s). A quantitative assessment of the sound generated by these pile driving activities is undertaken here to inform the construction permitting process.

Acoustic modeling was conducted to quantify the potential underwater acoustic impacts resulting from the installation of the monopile foundations and jacket foundations. The monopiles have a diameter of 12.5 meters (m)[2] and the jacket foundations use 4.25 m diameter pin piles. This underwater acoustic assessment considers the currently available information about the project, marine fauna, and environmental conditions. The precise locations, sound sources, schedule of the construction, and operation scenarios are subject to change as the engineering design progresses. This initial assessment uses conservative modeling scenarios based on preliminary information and will continue to be refined.

The methodology for modeling the acoustic field and estimating marine fauna exposures is presented in Section 2. The marine fauna included in the assessment are described in Section 3, and results are presented in Section 4 and Supplements F to H.

[1] Six WTG/ESP positions along the northwestern boundary of Lease Area OCS-A 0544 are contingent upon the final layout of the neighboring Empire Wind 2 project. Vineyard Mid-Atlantic will not develop these contingent WTG/ESP positions if the final Empire Wind 2 layout includes WTGs at immediately adjacent positions within Lease Area OCS-A 0512.

[2] While the Project Design Envelope (PDE) in the COP currently includes a maximum monopile diameter of 13 m (43 ft), this report focuses on a 12.5 m (41 ft) diameter monopile as the likely largest monopile to be used.

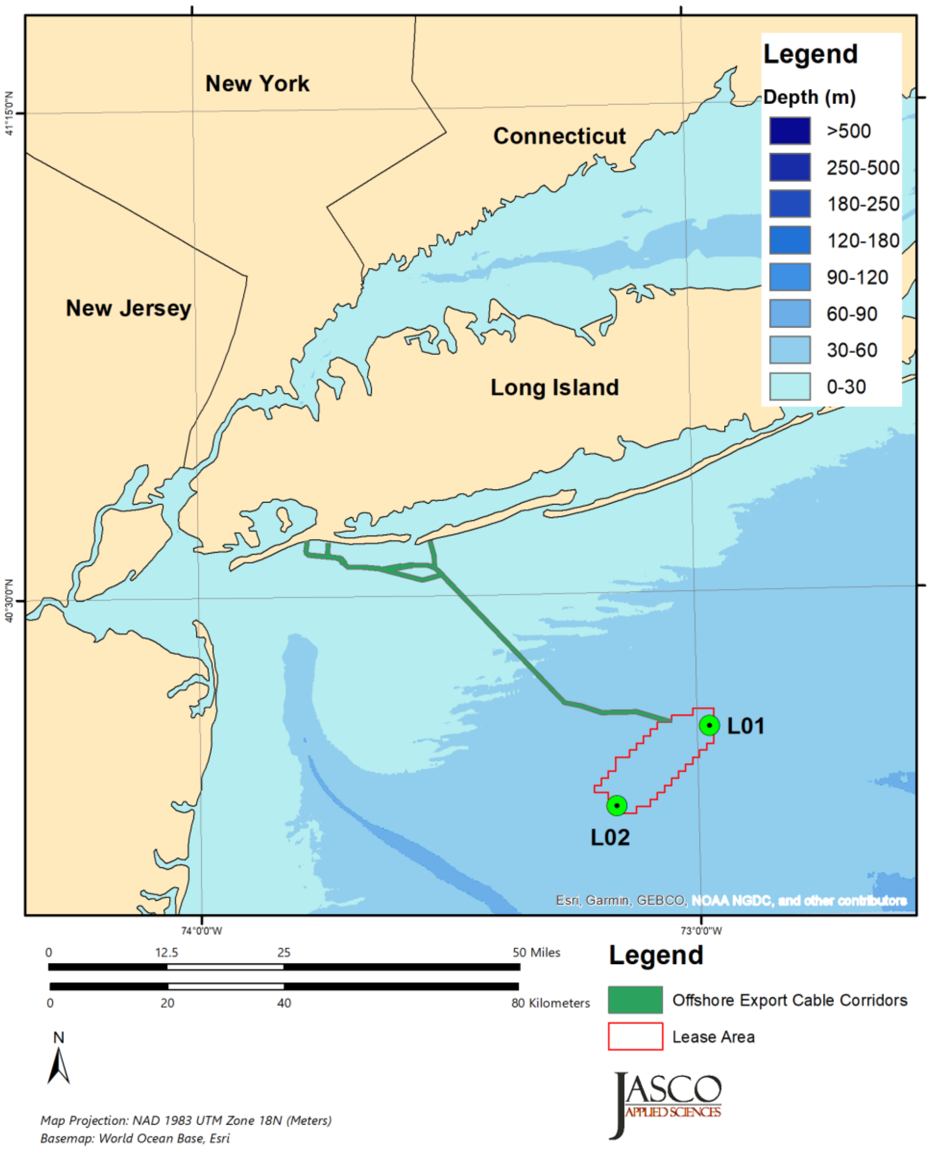

Figure 1. Location of the Vineyard Mid-Atlantic Lease Area OCS-A 0544.

1.2. Effects of Noise on Marine Fauna

Many terrestrial animals rely most heavily on vision because light travels well in air. However, for marine life, the dominant sensory modality underwater is sound because sound travels much better in water than does light. Pressure and particle motion are different but complimentary ways of quantifying a sound field, and the anatomy of acoustically sensitive species in the ocean varies such that species may be sensitive to particle motion, pressure, or both.

Fish and invertebrates have acoustic sensors that respond to particle motion in a manner similar to accelerometers. Fish ears contain sensory hair cells in contact with a dense otolith. When a sound wave encounters a fish, the fish's body moves with the passing wave (particle motion) while the dense otolith moves less and lags behind the motion of the fish's body. This relative motion triggers the hair cells, and sound is transduced into a nerve-signal sent to the brain. This is the basic ear structure of all fish. Some fish species have evolved auxiliary mechanisms, such as swim bladders, that respond to pressure waves, which are converted into vibration that their ears can sense. Invertebrates have acoustical sensitivity that is a similar system to the basic fish ear, but their sensing structure is known as a statocyst.

Sea turtles and marine mammals have evolved an ear with a basilar membrane lined with hair cells within their cochlea. Acoustic pressure waves that impinge upon the ear are transmitted to the basilar membrane, which vibrates, and that motion triggers the hair cells to send a signal. The frequency of the sound determines where on the membrane the vibration occurs. This is how mammalian ears sense frequency and is why different species have different ranges of frequency sensitivity (Yost 2001).

The potential effects of noise on marine life are similar across species, and, in very general terms, those effects scale with noise amplitude. Low level noise may be detected, while higher level noise may produce behavioral changes that have a negative impact on the animal (e.g., leaving a feeding area). Even higher noise levels may affect an individual's hearing by temporarily increasing their hearing threshold, called a temporary threshold shift (TTS). Prolonged exposure or even higher amplitudes can produce a permanent threshold shift (PTS) where the deficit in hearing does not recover. There is also the potential for tissue injury or mortality from sound. This acoustic assessment is performed in part to understand risk to potential impacts on marine life from noise.

1.3. Assessing Noise Effects on Marine Fauna

This study applies the current US regulatory acoustic criteria metrics, which are summarized as follows:

1. For marine mammals:
    a. Peak sound pressure levels (PK; L_{pk}) and frequency-weighted, accumulated, sound exposure levels (SEL; $L_{E,24h}$) are from the NOAA's National Marine Fisheries Service (NMFS) Technical Guidance for injury thresholds (NMFS 2018). Henceforth referred to as NMFS.
    b. Sound pressure levels (SPL; L_p) for behavioral thresholds are based on the unweighted NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria.
2. For sea turtles:
    a. Peak sound 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).
    b. A flat behavioral response threshold of 175 dB was used (McCauley et al. 2000a, Finneran et al. 2017).

3. For fish:
   a. Injury thresholds (PK and SEL) are from the Fisheries Hydroacoustic Working Group (FHWG 2008) and Stadler and Woodbury (2009) for fish that are equal to, greater than, or less than 2 g.
   b. Injury thresholds (PK and SEL) 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.
   c. NMFS typically use a conservative unweighted behavioral threshold of 150 dB SPL for ESA-listed fish species (NMFS 2023).

Sections 1.3.1, 1.3.2, and 1.3.3 provide further details on these criteria.

1.3.1. Marine Mammals

The Marine Mammal Protection Act (MMPA) prohibits the take of marine mammals (Marine Mammal Protection Act of 1972 as amended through 2018 (16 U.S.C. 1362). The MMPA defines the term ‘take’ as: “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.” The MMPA regulations define harassment in two categories relevant to the construction and operation of Vineyard Mid-Atlantic. The two levels are defined as any act of pursuit, torment, or annoyance, which has the potential to:

- Level A: Injure a marine mammal or marine mammal stock in the wild, and
- Level B: Disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.

To assess the potential impacts of the underwater sound in the Lease Area, it is necessary to first establish the acoustic exposure criteria used by United States regulators to estimate marine mammal takes. In 2016, NMFS issued a Technical Guidance document that provides acoustic thresholds for the onset of PTS in marine mammals exposed to noise from several sound source types, and this has since been updated (NMFS 2016, 2018). The NMFS Technical Guidance also recognizes two main types of sound sources: impulsive and non-impulsive. Non-impulsive sources are further separated into continuous or intermittent categories.

The NMFS Technical Guidance (NMFS 2018, 2023) recommends using dual criteria for assessing Level A exposures. The acoustic metrics are an unweighted/flat PK and a weighted SEL. The Technical Guidance further defines the frequency weighting functions to be applied when assessing SEL criteria. Both PK and SEL metrics are specific to the hearing groups: low-, mid-, and high-frequency cetaceans, and phocid pinnipeds. All marine mammal species are assigned to a group based on the species’ respective hearing sensitivities.

Sound levels thought to elicit disruptive behavioral responses are described using an SPL metric. For marine mammals, NMFS currently uses behavioral response thresholds of SPL 160 dB re 1 μPa^2 for intermittent non-impulsive sounds and impulsive sounds (such as impact pile driving). A threshold of SPL 120 dB re 1 μPa^2 is applied for continuous sounds (such as vibratory pile driving) (NMFS 2023). 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).

ISO 18405 Underwater Acoustics–Terminology (ISO 18405:2017) provides a dictionary of underwater bioacoustics terminology (the previous standard was ANSI and ASA S1.1-2013). In the remainder of this report, we follow the definitions and conventions of ISO (18405:2017), except where stated otherwise (see Table 1).

Table 1. Summary of relevant acoustic terminology used by US regulators and in this report.

Metric	NMFS (2018)	Main text [a]	Equations and Tables [a]	unit	Reference
Sound pressure level	n/a	SPL	$L_{p,w}$ [c]	dB	1 μPa^2
Peak pressure level	PK	PK	L_{pk}	dB	1 μPa
Cumulative sound exposure level	SELcum [b]	SEL	$L_{E,w,T}$ [d]	dB	1 μPa^2 s

[a] This report follows ISO (18405:2017), except for the following modifications:

- [b] w in $L_{p,w}$ and $L_{E,w,T}$ describes a frequency-weighting function, if used.
- [c] T in $L_{E,w,T}$ describes the time window used to calculate SEL.

[d] The SELcum metric used by NMFS describes the sound energy a receptor receives over a 24 h period. Following the ISO standard, this is denoted as SEL in this report, except for in tables and equations where $L_{E,w,T}$ may be used.

1.3.1.1. Hearing Groups

Marine mammal species have differing hearing capabilities, both in absolute hearing acuity and in frequency-dependent sensitivity (Richardson et al. 1995, Wartzok and Ketten 1999, Southall et al. 2007, Au and Hastings 2008). Southall et al. (2007) originally proposed that marine mammals be divided into hearing groups. This division was updated in 2016 and 2018 by NMFS using more-recent best-available science (see Table 2). Hearing measurements are available for only a small number of species. As a result, 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, Frankel et al. 1995, see review in Reichmuth et al. 2007, Frankel and Stein 2020). Hearing measurements have recently been made with minke whales, but those results have not yet been published.

Southall et al. (2019) published an updated set of Level A sound exposure criteria, including the onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) in marine mammals. While the authors proposed a new nomenclature and classification for the marine mammal hearing groups, the proposed thresholds and weighting functions do not differ in effect from those proposed by NMFS (2018). The new hearing group definitions proposed by Southall et al. (2019) have not yet been adopted by NOAA. Table 2 presents the NOAA Fisheries (NMFS 2018) hearing groups used in this analysis.

Table 2. Marine mammal hearing groups.

Hearing group	Abbreviation	Generalized hearing range [a]
Low-frequency cetaceans (mysticetes or baleen whales)	LF	7 Hz to 35 kHz
Mid-frequency cetaceans (odontocetes: delphinids, beaked whales, sperm whale)	MF	150 Hz to 160 kHz
High-frequency cetaceans (other odontocetes including porpoises)	HF	275 Hz to 160 kHz
Phocid pinnipeds in water	PW	50 Hz to 86 kHz

[a] The generalized hearing frequency range is for all species within a group. Individual hearing will vary.

1.3.1.2. Auditory Weighting Functions

Marine fauna responses to anthropogenic sound at moderate to high levels largely depend on whether an animal can hear a sound. Auditory (frequency) weighting functions reflect hearing sensitivity across a range of frequencies (Houser et al. 2017). Very high amplitude sounds have the potential to cause tissue damage regardless of their frequency.

Auditory weighting functions for marine mammals associated with PTS thresholds reflect what is known about marine mammal hearing (e.g., SEL; Southall et al. 2007, Erbe et al. 2016, Finneran 2016). These weighting functions are included in NMFS (2018) Technical Guidance for use in conjunction with corresponding PTS onset (Level A) criteria (see Table 3 and Supplement C for details on the weighting functions).

1.3.1.3. Auditory Injury Criteria

Injury to the hearing apparatus of a marine mammal may result from a fatiguing stimulus. The SEL metric considers both a sound's level and duration. Because intense sounds may damage hearing independent of the duration of the sound signal, the peak pressure (PK) metric is also used to assess risk of injury. The received sound levels at which TTS starts to occur (onset) have been measured for several species. Those TTS onset levels are used to extrapolate the onset of PTS through an assumed growth function (Southall et al. 2007). The NMFS (2018) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy accumulated over 24 h (SEL; L_E), or very loud, instantaneous PK. These dual threshold criteria of SEL and PK are used to calculate marine mammal exposures (Table 3). Impulsive sounds are known to be more damaging than non-impulsive sounds. For this reason, there are lower SEL thresholds for injury exposure to impulsive sounds than non-impulsive sounds (Table 3).

Table 3. Summary of applicable permanent threshold shift (PTS) onset acoustic thresholds for marine mammal hearing groups (NMFS 2018).

Hearing group	Impulsive signals [a] L_{pk} (dB re 1 µPa)	Impulsive signals [a] $L_{E,W,24h}$ (dB re 1 µPa²·s)	Non-impulsive signals $L_{E,W,24h}$ (dB re 1 µPa²·s)
Low-frequency (LF) cetaceans	219	183	199
Mid-frequency (MF) cetaceans	230	185	198
High-frequency (HF) cetaceans	202	155	173
Phocid seals in water (PW)	218	185	201

[a] Dual-metric acoustic thresholds for impulsive sounds: PK and SEL thresholds are defined for PTS. The longer of the two corresponding exposure distances is used to assess PTS onset zones. The PK threshold was also applied to non-impulsive sounds that had the potential for high PK levels.

1.3.1.4. Behavioral Response Criteria

Numerous studies on marine mammal behavioral responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioral reactions. It is recognized that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison et al. 2012). Due to the complexity and variability of marine mammal behavioral responses to acoustic exposure, NOAA has not yet released technical guidance for determining potential behavioral responses of marine mammals exposed to sounds (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^2 as the behavioral disruption threshold for impulsive sources. An SPL of 120 dB re 1 μPa^2 was set as the behavioral disruption threshold for continuous sound sources (NOAA 2005).

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^2, but lack of convergence in the data prevented them from suggesting explicit step functions. In 2012, Wood et al. (2012) proposed a graded probability of response for impulsive sounds using a frequency M-weighted SPL metric defined in Southall et al. (2007). 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 SPL from NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria are used to estimate behavioral exposures (Table 4).

Table 4. 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 ($L_{p,w}$ > 120 dB re 1 μPa^2)	Frequency-weighted probabilistic response ($L_{p,w}$ > 140 dB re 1 μPa^2)	Frequency-weighted probabilistic response ($L_{p,w}$ > 160 dB re 1 μPa^2)	Frequency-weighted probabilistic response ($L_{p,w}$ > 180 dB re 1 μPa^2)	Unweighted probabilistic response, impulsive (L_p = 160 dB re 1 μPa^2)	Unweighted probabilistic response, continuous (L_p = 120 dB re 1 μPa^2)
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%

1.3.2. Sea Turtles

As with marine mammals, auditory injury, impairment, and behavioral thresholds are potential acoustic effects on sea turtles. Acoustic criteria 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 using PK and SEL metrics have been suggested by NMFS for assessing PTS and TTS, with auditory weighting functions published by Finneran et al. (2017) and applied to received signals for the SEL calculation. The recommended behavioral threshold is an SPL of 175 dB re 1 µPa^2 (McCauley et al. 2000b, Finneran et al. 2017). Table 5 lists the criteria.

In this report the results of sea turtles are presented alongside marine mammals, while fish are presented separately. This grouping is because the evaluation criteria of sea turtles and marine mammals are similar (Section 1.3.1), while fish differ (Section 1.3.3).

Table 5. Acoustic metrics and thresholds for sea turtles currently used by National Marine Fisheries Service (NMFS) for impact pile driving (impulsive). For vibratory (non-impulsive) pile setting, only the $L_{E,24h}$ and behavioral thresholds apply.

Hearing group	Injury, Impulsive signals (L_{pk})	Injury, Impulsive signals ($L_{E,24h}$)	Injury, Non-impulsive signals ($L_{E,24h}$)	Behavior (L_p)
Sea turtles [b, c]	232	204	220	175

L_{pk} – peak sound pressure level (dB re 1 µPa), $L_{E,24h}$ – sound exposure level (dB re 1 µPa^2·s), L_p – root mean square sound pressure level (dB re 1 µPa^2). A dash indicates that there are no thresholds for the category.

[b] Popper et al. (2014).

[c] Finneran et al. (2017).

1.3.3. Fish

A cooperative effort between Federal and State transportation and resource agencies produced interim criteria to assess the potential for injury to fish exposed to pile driving sounds (FHWG 2008, Stadler and Woodbury 2009). The injury and behavioral response levels for assessing the potential effects to ESA-listed fish exposed to pile driving were compiled and listed in NMFS (2023). Impulsive criteria are used in this study for both impulsive and non-impulsive sounds because there is limited research available for fish injury thresholds from non-impulsive sound types.

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). Table 6 provides a list of the criteria.

Table 6. Acoustic metrics and thresholds for fish currently used by NMFS for impact pile driving (impulsive). For vibratory (non-impulsive) pile driving, only the $L_{E,24h}$ and behavioral thresholds apply. Best available science recommendations are below the NMFS criteria. Pile driving and vibratory driving used injury thresholds for impulsive signals.

Hearing group	Injury, Impulsive signals (L_{pk})	Injury, Impulsive signals ($L_{E,24h}$)	Injury, Non-impulsive signals ($L_{E,24h}$)	Behavior (L_p)
Fish greater than or equal 2 g [a]	206	187	-	150
Fish less than 2 g [a]	206	183	-	150
Fish without swim bladder [b]	213	216	-	-
Fish with swim bladder [b]	207	203	-	-

L_{pk} – peak sound pressure level (dB re 1 µPa), $L_{E,24h}$ – sound exposure level (dB re 1 µPa^2·s), L_p – root mean square sound pressure level (dB re 1 µPa^2). A dash indicates that there are no thresholds for the category.

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).

[b] Popper et al. (2014).

1.4. 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 in and around the Lease Area during pile driving in the construction stage of Vineyard Mid-Atlantic. JASCO also used the results of animal movement and exposure modeling to estimate potential exposure ranges ($ER_{95\%}$) and exposure numbers for marine mammals and sea turtles.

There are several potential anthropogenic sound sources associated with Vineyard Mid-Atlantic; however, the primary sound sources will be impact (impulsive) and vibratory (non-impulsive continuous) pile driving during foundation installation of monopile and jacket foundations in the construction stage.

A monopile foundation is a single hollow cylinder fabricated from steel that is installed by driving (hammering) it into the seabed. The monopiles used for Vineyard Mid-Atlantic modeling are 12.5 m in diameter. Up to two monopiles are expected to be installed per day. Jacket foundations that may be used for electrical service platforms (ESPs) consist of a large lattice structure supported/secured by pin piles. Up to four pin piles are expected to be installed per day. The pin piles to secure the jacket structure for Vineyard Mid-Atlantic are 4.25 m diameter straight piles.

Sound fields from 12.5 m monopiles and 4.25 m pin piles were modeled at two representative locations in the Lease Area (locations L01 and L02; see Table 7) shown in Figure 1. The modeling locations were selected as they represent the range of water depths and slightly different soil conditions (5.3.E.1.2) in the Lease Area. The 12.5 m monopiles were assumed to be vertical and driven to a maximum expected penetration depth of 45 m (147.6 ft) and the pin piles were assumed to be vertical and driven to a maximum expected depth of 50 m (164.04 ft) and 80 m (262.5 ft).

Table 7. Acoustic modeling locations and water depth for the monopile and jacket foundations.

Modeling location	Latitude	Longitude	Depth (m)
L01	672168	4462222	45.27
L02	656298	4448451	43.97

The amount of sound generated during pile driving varies with the energy required to drive piles to a desired depth and the sediment resistance encountered. For example, hard sediments with more resistance to the pile penetration require hammers that deliver higher energy strikes and/or an increased number of strikes, relative to installations in softer sediment. Maximum sound levels usually occur during the last stage of impact pile driving where the most resistance is encountered (Betke 2008). The difficulty to drive a pile is determined based on drivability analyses, which suggest that some piles would be installed at locations requiring a larger number of strikes. This acoustic modeling study includes 'normal' and 'difficult to drive' piling scenarios, as described below.

Foundations may be entirely installed using only impact pile driving. Alternatively, a vibratory hammer could be used to install the pile through surficial sediments in a controlled way to avoid the potential for a 'pile run,' where the pile could drop quickly through the looser surficial sediments and destabilize the installation vessel. Once the pile has penetrated the surficial sediments with the vibratory hammer, an impact hammer would be used for the remainder of the installation. The extent to which a vibratory hammer may be used has been assumed for this modeling exercise and will continue to be evaluated based on site-specific data and the selected contractor's installation methodologies.

Table 8 provides details of the impact-only piling scenarios for monopiles (scenarios B1–B4) and for jacket piles (scenarios B5–B6). Note that each of those scenarios was modeled at both locations L01 and L02, and they represent difficult and normal conditions for pile drivability. Two seasons were considered in this study: summer (Apr-Nov) and winter (Dec-Mar). The corresponding scenarios for the vibratory-impact installation approach (scenarios BV1–BV6) are described in Table 9. Vineyard Mid-Atlantic is not proposing concurrent piling and therefore it was not modeled.

Each of these scenarios was modeled using a conservative piling schedule that defines the strike count (impact piling) or drive time (vibratory) required to achieve a certain pile penetration. Tables 10–15 list the piling schedules for scenarios B1 to B6. Tables 16–21 list those for scenarios BV1 to BV6.

The make and model of the modeled impact hammers (MHU 3500S and MHU 5500), vibratory hammers (TR-CV640 and TR-CV320), and the conservative piling schedules (see Tables 10–21) in the modeling were provided by the client in coordination with potential hammer suppliers. For the MHU 5500 hammer used to drive the monopiles, the maximum modeled energies of 6600 and 8000 kJ were simulated by artificially increasing the stroke length. The scaled MHU 5500 hammer is herein labeled with MHU 6600 and MHU 8000 to represent the MHU 5500 hammer scaled to 6600 and 8000 kJ, respectively. The MHU 3500S hammer, which did not require modifications to its stroke length, was used to model driving of the jacket pin piles.

Table 8. Key piling assumptions used in underwater acoustic modeling during impact only pile driving. Each scenario was modeled at both locations (L01 and L02) for summer and winter.

Scenario	Drivability	Foundation type	Modeled impact hammer energies (kJ)	Pile length (m)	Pile diameter (m)	Pile wall thickness (mm)	Seabed pile penetration (m)	Number of piles/day	Piling schedule
B1	Difficult	Monopile	2200–8000	126	12.5	200	45	1, 2	Table 10
B2	Normal	Monopile	2200–8000	126	12.5	200	45	1, 2	Table 11
B3	Difficult	Monopile	2200–6600	126	12.5	200	45	1, 2	Table 12
B4	Normal	Monopile	2200–6600	126	12.5	200	45	1, 2	Table 13
B5	Difficult	Jacket	500–3500	60	4.25	100	50	4, 8	Table 14
B6	Difficult	Jacket	200–3500	90	4.25	100	80	4, 8	Table 15

Table 9. Key piling assumptions used in underwater acoustic modeling during pile driving involving vibratory settling and impact pile driving. Each scenario was modeled at both locations (L01 and L02) for summer and winter.

Scenario	Drivability	Foundation type	Modeled impact hammer energy (kJ)	Pile length (m)	Pile diameter (m)	Pile wall thickness (mm)	Seabed Pile penetration (m)	Number of piles/day	Piling schedule
BV1	Difficult	Monopile	3500–8000	126	12.5	200	45	1	Table 16
BV2	Normal	Monopile	3500–8000	126	12.5	200	45	1	Table 17
BV3	Difficult	Monopile	3500–6600	126	12.5	200	45	1	Table 18
BV4	Normal	Monopile	3500–6600	126	12.5	200	45	1	Table 19
BV5	Difficult	Jacket	500–3500	60	4.25	100	50	4	Table 20
BV6	Normal	Jacket	500–3500	90	4.25	100	80	4	Table 21

1.4.1. Piling Schedules for Impact-only Installation

Table 10. Scenario B1 (Difficult to Drive): Piling schedule for a 12.5 m monopile with an MHU 8000 hammer.

Energy level (kJ)	Strike rate (strikes/min)	Strike count	Pile penetration depth (m)
500	30	0	6
2200	30	615	8
3500	30	574	4
8000	30	4860	27
Total	**NA**	**6049**	**45**

Table 11. Scenario B2 (Normal Driving): Piling schedule for a 12.5 m monopile with an MHU 8000 hammer.

Energy level (kJ)	Strike rate (strikes/min)	Strike count	Pile penetration depth (m)
500	30	0	6
2200	30	1170	8
3500	30	505	4
8000	30	3888	27
Total	**NA**	**5563**	**45**

Table 12. Scenario B3 (Difficult to Drive): Piling schedule for a 12.5 m monopile with an MHU 6600 hammer.

Energy level (kJ)	Strike rate (strikes/min)	Strike count	Pile penetration depth (m)
500	30	0	6
2200	30	615	8
3500	30	574	4
6600	30	4860	27
Total	**NA**	**6049**	**45**

Table 13. Scenario B4 (Normal Driving): Piling schedule for a 12.5 m monopile with an MHU 6600 hammer.

Energy level (kJ)	Strike rate (strikes/min)	Strike count	Pile penetration depth (m)
500	30	0	6
2200	30	1170	8
3500	30	505	4
6600	30	3888	27
Total	**NA**	**5563**	**45**

Table 14. Scenarios B5 (50 m Difficult to Drive): Piling schedule for a 4.25 m foundation with an MHU 3500S hammer.

Energy level (kJ)	4 pin piles/day Strike rate (strikes/min)	Strike count	Pile penetration depth (m)
500	28	700	5
1000	28	1000	5
1500	28	1000	5
2000	28	1000	5
3000	28	1000	5
3500	28	5000	25
Total	**NA**	**9700**	**50**

Table 15. Scenarios B6 (80 m Difficult to Drive): Piling schedule for a 4.25 m foundation with an MHU 3500S hammer.

Energy level (kJ)	4 pin piles/day Strike rate (strikes/min)	Strike count	Pile penetration depth (m)
200	44	1400	10
500	44	2000	10
1000	44	2000	10
1500	44	2000	10
2000	44	2000	10
2500	44	2000	10
3500	44	2000	10
3500	44	2000	10
Total	**NA**	**15400**	**80**

1.4.2. Piling Schedules for Vibratory and Impact Installation

Table 16. Scenario BV1 (Difficult to Drive): Piling schedule for a 12.5 m monopile using vibratory pile setting (TR-CV640) followed by impact hammering (MHU 8000).

Hammer type	Pile penetration depth (m)	Time vibratory piling (min)	Hammer energy (kJ)	Strike count
Self-penetration	6	-	-	-
Vibratory	10	60	-	-
Impact	2	-	3500	198
Impact	27	-	8000	4860
Total	**45**	**60**	**-**	**5058**

Table 17. Scenario BV2 (Normal Driving): Piling schedule for a 12.5 m monopile using vibratory pile setting (TR-CV640) followed by impact hammering (MHU 8000).

Hammer type	Pile penetration depth (m)	Time vibratory piling (min)	Hammer energy (kJ)	Strike count
Self-penetration	6	-	-	-
Vibratory	10	30	-	-
Impact	2	-	3500	202
Impact	27	-	8000	3888
Total	**45**	**30**	**-**	**4090**

Table 18. Scenario BV3 (Difficult to Drive): Piling schedule for a 12.5 m monopile using vibratory pile setting (TR-CV640) followed by impact hammering (MHU 6600).

Hammer type	Pile penetration depth (m)	Time vibratory piling (min)	Hammer energy (kJ)	Strike count
Self-penetration	6	-	-	-
Vibratory	10	60	-	-
Impact	2	-	3500	198
Impact	27	-	6600	4860
Total	**45**	**60**	**-**	**5058**

Table 19. Scenario BV4 (Normal Driving): Piling schedule for a 12.5 m monopile using vibratory pile setting (TR-CV640) followed by impact hammering (MHU 6600).

Hammer type	Pile penetration depth (m)	Time vibratory piling (min)	Hammer energy (kJ)	Strike count
Self-penetration	6	-	-	-
Vibratory	10	30	-	-
Impact	2	-	3500	202
Impact	27	-	6600	3888
Total	**45**	**30**	**-**	**4090**

Table 20. Scenarios BV5 (50 m Difficult to Drive): Piling schedule for a 4.25 m jacket pile using vibratory pile setting (TR-CV320) followed by impact hammering (3500 kJ hammer).

Hammer type	Pile penetration depth (m)	Duration vibratory piling (min)	Hammer energy (kJ)	Strike count
Vibratory	10	60	-	-
Impact	5	-	500	500
Impact	5	-	1000	1000
Impact	5	-	1500	1000
Impact	5	-	2000	1000
Impact	5	-	2500	1000
Impact	15	-	3500	3000
Total	**50**	**60**	**-**	**7500**

Table 21. Scenarios BV6 (80 m Difficult to Drive): Installation schedule for a 4.25 m jacket pile using vibratory pile setting (TR-CV320) followed by impact hammering (3500 kJ hammer).

Hammer type	Pile penetration depth (m)	Duration vibratory piling (min)	Hammer energy (kJ)	Strike count
Vibratory	10	60	-	-
Impact	10	-	500	2000
Impact	10	-	1000	2000
Impact	10	-	1500	2000
Impact	10	-	2000	2000
Impact	10	-	2500	2000
Impact	10	-	3500	2000
Impact	10		3500	2000
Total	**80**	**60**	**-**	**14000**

1.4.3. Modeling Pile Construction Schedules

Construction schedules are difficult to predict because of factors such as weather and installation variations related to drivability. To allow flexibility in the final design and during foundation installation, multiple construction schedules (see Tables 22–26) were used to calculate potential impacts to marine mammals and sea turtles during pile installation. Each construction schedule includes normal and difficult to drive (DTD) piling scenarios, and all schedules (except schedule A.1) include a combination of foundations installed with impact pile driving alone and foundations installed with vibratory setting of the pile followed by impact pile driving. As noted in Section 1.4, the modeled duration of vibratory hammering was 30 and 60 minutes (min) for all foundation types that included vibratory setting of the pile. Each construction schedule includes 116 WTGs installed on monopile foundations and two ESPs installed on post-piled jacket foundations, with twelve pin piles each. Sections 1.4.1 and 1.4.2 describe acoustic modeling assumptions for each foundation type and installation scenario.

Schedule A.1 shows a one-year buildout of pile installation. In this schedule, all monopiles and jacket foundations are installed using vibratory setting of the pile followed by impact pile driving. Schedules A.2 and A.3 show two-year installation schedules. Schedule A.2 uses a combination of impact pile driving alone and foundations installed with vibratory setting of the pile followed by impact pile driving. Monopiles and jacket foundations are equally distributed between the years, with 58 monopiles and 12 pin piles, or one jacket foundation, installed each year. Schedule A.3 predicts the installation of 70% of the monopiles to be installed in the first year and 30% in the second. Year 1 shows the installation of 82 monopiles and

12 pin piles, or one jacket foundation. Year 2 shows the installation of the remaining 30% of the monopiles and the remaining ESP (34 monopiles and 12 pin piles will be installed). Schedules A.2 and A.3 both assume fewer monopiles are installed in May compared to June. This is to account for a learning curve in construction operations.

To estimate exposures, it is necessary to predict not only the number of piles installed per day but also the number of days of piling in each year. Modeling included the installation of monopiles at a rate of one or two monopiles per day depending on the scenario, and the installation of four pin piles per day for jacket foundations. Tables 22–26 outline the number of days of piling under the different modeled construction schedules that were carried forward to calculate potential exposures of marine mammals and sea turtles for this project.

Table 22. Construction Schedule A.1 (Year 1): Number of potential days of pile installation per month for each case [a], used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation month	WTG foundations 60 min Vibratory + impact 12.5 m MP 8000 kJ DTD 1 pile/day (BV1)	WTG foundations 30 min Vibratory + impact 12.5 m MP 8000 kJ Normal 1 pile/day (BV2)	WTG foundations 60 min Vibratory + impact 12.5 m MP 6600 kJ DTD 1 pile/day (BV3)	WTG foundations 30 min Vibratory + impact 12.5 m MP 6600 kJ Normal 1 pile/day (BV4)	ESP foundations 60 min Vibratory + impact 4.25 m post-piled jacket pile 3500 kJ 4 piles/day (BV6)
May	2	2	2	2	-
June	5	5	5	5	-
July	5	5	5	5	-
August	4	4	4	4	3
September	4	4	4	4	3
October	4	4	4	4	-
November	4	4	4	4	-
December	1	1	1	1	-
Total # days	**29**	**29**	**29**	**29**	**6**
Total # piles	**29**	**29**	**29**	**29**	**24**
Total # foundations [b]	**29**	**29**	**29**	**29**	**2**

[a] WTGs are installed on 12.5 m monopile foundations. ESPs are installed on jacket foundations with twelve 4.25 m post-piled pin piles. This schedule includes only foundations installed with vibratory setting of the pile followed by impact pile driving. Tables A-1 and A-2 list the modeled parameters for all foundations.

[b] The total number of foundations in the final row equal 116 WTG MPs and 2 ESP jackets, for a grand total of 118 foundations.

Table 23. Construction Schedule A.2 (Year 1): Number of potential days of pile installation per month for each case [a], used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation month	WTG Impact only 12.5m MP 8000 kJ DTD 1 pile/ day (B1)	WTG Impact only 12.5m MP 8000 kJ DTD 2 piles/ day (B1)	WTG Impact only 12.5m MP 8000 kJ Normal 1 pile/ day (B2)	WTG Impact only 12.5m MP 6600 kJ DTD 1 pile/ day (B3)	WTG Impact only 12.5m MP 6600 kJ DTD 2 piles/ day (B3)	WTG Impact only 12.5m MP 6600 kJ Normal 1 pile/ day (B4)	ESP Impact only 4.25m post-piled jacket pile 3500 kJ 4 piles/ day (B6)	WTG 60 min Vibratory + impact 8000 kJ DTD 1 pile/ day (BV1)	WTG 30 min Vibratory + impact 8000 kJ Normal 1 pile/ day (BV2)	WTG 60 min Vibratory + impact 6600 kJ DTD 1 pile/ day (BV3)	WTG 30 min Vibratory + impact 6600 kJ Normal 1 pile/ day (BV4)
May	1	-	1	1	-	1	-	1	1	1	-
June	-	1	-	-	1	-	-	1	1	1	-
July	-	1	-	1	1	1	-	1	1	1	-
August	1	-	1	1	-	1	-	1	1	1	-
September	1	-	1	1	-	1	3	1	1	1	1
October	1	-	1	1	-	1	-	1	1	1	1
November	1	-	1	1	-	1	-	1	1	1	1
December	-	-	-	1	-	1	-	-	-	1	1
Total # days	**5**	**2**	**5**	**7**	**2**	**7**	**3**	**7**	**7**	**8**	**4**
Total # piles	**5**	**4**	**5**	**7**	**4**	**7**	**12**	**7**	**7**	**8**	**4**
Total # foundations [b]	**5**	**4**	**5**	**7**	**4**	**7**	**1**	**7**	**7**	**8**	**4**

[a] WTGs are installed on 12.5 m monopile foundations. ESPs installed on jacket foundations with twelve 4.25 m post-piled 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. Tables A-1 and A-2 list the modeled parameters for all foundations.

[b] The total number of foundations in the final row equal 58 WTG MPs and 1 ESP jacket, for a grand total of 59 foundations.

Table 24. Construction Schedule A.2 (Year 2): Number of potential days of pile installation per month for each case [a], used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation month	WTG Impact only 12.5m MP 8000 kJ DTD 1 pile/ day (B1)	WTG Impact only 12.5m MP 8000 kJ DTD 2 piles/ day (B1)	WTG Impact only 12.5m MP 8000 kJ Normal 1 pile/ day (B2)	WTG Impact only 12.5m MP 6600 kJ DTD 1 pile/ day (B3)	WTG Impact only 12.5m MP 6600 kJ DTD 2 piles/ day (B3)	WTG Impact only 12.5m MP 6600 kJ Normal 1 pile/ day (B4)	ESP Impact only 4.25m post-piled jacket pile 3500 kJ 4 piles/ day (B6)	WTG 60 min Vibratory + impact 8000 kJ DTD 1 pile/ day (BV1)	WTG 30 min Vibratory + impact 8000 kJ Normal 1 pile/ day (BV2)	WTG 60 min Vibratory + impact 6600 kJ DTD 1 pile/ day (BV3)	WTG 30 min Vibratory + impact 6600 kJ Normal 1 pile/ day (BV4)
May	1	-	1	1	-	1	-	1	1	1	-
June	-	1	-	-	1	-	-	1	1	1	-
July	-	1	-	1	1	1	-	1	1	1	-
August	1	-	1	1	-	1	-	1	1	1	-
September	1	-	1	1	-	1	3	1	1	1	1
October	1	-	1	1	-	1	-	1	1	1	1
November	1	-	1	1	-	1	-	1	1	1	1
December	-	-	-	1	-	1	-	-	-	1	1
Total # days	**5**	**2**	**5**	**7**	**2**	**7**	**3**	**7**	**7**	**8**	**4**
Total # piles	**5**	**4**	**5**	**7**	**4**	**7**	**12**	**7**	**7**	**8**	**4**
Total # foundations [b]	**5**	**4**	**5**	**7**	**4**	**7**	**1**	**7**	**7**	**8**	**4**

[a] WTGs are installed on 12.5 m monopile foundations. ESPs installed on jacket foundations with twelve 4.25 m post-piled 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. Tables A-1 and A-2 list the modeled parameters for all foundations.

[b] The total number of foundations in the final row equal 58 WTG MPs and 1 ESP jacket, for a grand total of 59 foundations.

Table 25. Construction Schedule A.3 (Year 1): Number of potential days of pile installation per month for each case [a], used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation month	WTG Impact only 12.5m MP 8000 kJ DTD 1 pile/ day (B1)	WTG Impact only 12.5m MP 8000 kJ DTD 2 piles/ day (B1)	WTG Impact only 12.5m MP 8000 kJ Normal 1 pile/ day (B2)	WTG Impact only 12.5m MP 6600 kJ DTD 1 pile/ day (B3)	WTG Impact only 12.5m MP 6600 kJ DTD 2 piles/ day (B3)	WTG Impact only 12.5m MP 6600 kJ Normal 1 pile/ day (B4)	ESP Impact only 4.25m post-piled jacket pile 3500 kJ 4 piles/ day (B6)	WTG 60 min Vibratory + impact 8000 kJ DTD 1 pile/ day (BV1)	WTG 30 min Vibratory + impact 8000 kJ Normal 1 pile/ day (BV2)	WTG 60 min Vibratory + impact 6600 kJ DTD 1 pile/ day (BV3)	WTG 30 min Vibratory + impact 6600 kJ Normal 1 pile/ day (BV4)
May	1	-	1	1	-	-	-	1	1	1	1
June	1	1	1	1	1	-	-	1	1	1	1
July	1	1	1	1	1	1	-	2	1	2	1
August	1	1	1	1	1	1	-	2	1	2	1
September	1	1	1	1	1	1	3	2	1	2	1
October	1	-	1	1	-	1	-	1	1	1	1
November	1	-	1	1	-	1	-	1	1	1	1
December	-	-	-	1	-	1	-	1	1	1	1
Total # days	**7**	**4**	**7**	**8**	**4**	**6**	**3**	**11**	**8**	**11**	**8**
Total # piles	**7**	**8**	**7**	**8**	**8**	**6**	**12**	**11**	**8**	**11**	**8**
Total # foundations [b]	**7**	**8**	**7**	**8**	**8**	**6**	**1**	**11**	**8**	**11**	**8**

[a] WTGs are installed on jacket foundations with four 4.25 m pre-piled pin piles. ESPs installed on jacket foundations with twelve 4.25 m post-piled 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. Tables A-1 and A-2 list the modeled parameters for all foundations.

[b] The total number of foundations in the final row equal 82 WTG MPs and 1 ESP jacket, for a grand total of 83 foundations.

Table 26. Construction Schedule A.3 (Year 2): Number of potential days of pile installation per month for each case [a], used to estimate the total number of marine mammal and sea turtle acoustic exposures above threshold criteria.

Installation month	WTG Impact only 12.5m MP 8000 kJ DTD 1 pile/ day (B1)	WTG Impact only 12.5m MP 8000 kJ DTD 2 piles/ day (B1)	ESP Impact only 4.25m post-piled jacket pile 3500 kJ 4 piles/ day (B6)	WTG 60 min Vibratory + impact 8000 kJ DTD 1 pile/ day (BV1)	WTG 30 min Vibratory + impact 8000 kJ Normal 1 pile/ day (BV2)
May	1	-	-	1	1
June	1	1	-	1	1
July	1	1	-	1	1
August	1	1	-	3	1
September	1	1	3	2	1
October	1	-	-	1	1
November	1	-	-	1	1
December	1	-	-	1	-
Total # days	**8**	**4**	**3**	**11**	**7**
Total # piles	**8**	**8**	**12**	**11**	**7**
Total # foundations [b]	**8**	**8**	**1**	**11**	**7**

[a] WTGs are installed on jacket foundations with four 4.25 m pre-piled pin piles. ESPs installed on jacket foundations with twelve 4.25 m post-piled 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. Tables A-1 and A-2 list the modeled parameters for all foundations.

[b] The total number of foundations in the final row equal 34 WTG MPs and 1 ESP jacket, for a grand total of 35 foundations.

2. Methods

The basic modeling approach is to characterize the sounds produced by the source, determine how the sounds propagate within the surrounding water column, and then estimate species-specific exposure probability by considering the range- and depth-dependent sound fields in relation to animal movement in simulated representative scenarios.

For impact and vibratory pile driving sounds, time-domain representations of the pressure waves generated in the water are required for calculating sound pressure level (SPL) and peak pressure level (PK), which are then used to evaluate potential impacts. The source signatures associated with installing each of the modeled normal and difficult-to-drive monopiles and jacket piles were predicted using a finite-difference model of the physical vibration of the pile caused by pile driving equipment. The pile as a sound source radiating into the environment was simulated as an array of point sources.

For this study, synthetic pressure waveforms were computed using the Full Waveform Range-dependent Acoustic Model (FWRAM), which is JASCO's acoustic propagation model capable of producing time-domain waveforms. The sound propagation modeling incorporates site-specific environmental data including bathymetry, sound speed in the water column, and seabed geoacoustics in the modeled area.

JASCO's Animal Simulation Model Including Noise Exposure (JASMINE) integrates sound fields with species-normal behavioral parameters (e.g., dive patterns). Animats (Wilson 1985) are built into JASMINE as simulated animals that move through space and time. These animats are programmed with parameters that produce representative species-specific movement patterns that allow for different sampling of the predicted sound fields. This process estimates received levels for marine mammals and sea turtles in the construction area that are exposed to sounds associated with installing the monopiles and jacket piles. Animats that are exposed to noise levels that exceed acoustic thresholds/criteria are identified, and the range for the exceedances is determined. The potential acoustic exposure for marine species was estimated by calculating the accumulated sound exposure level (SEL) and maximum SPL and PK each animat received over the course of the simulation. The number of animals expected to exceed the regulatory thresholds is determined by scaling the number of modeled animat exposures by the species-specific density of animals in the area.

This section provides an overview of the modeling and analysis undertaken for this study, and additional details can be found in the supplement sections. Supplement A summarizes the assumptions made about each acoustic source. Supplement B defines the acoustic metrics and decidecade frequency band analysis used in this study. Supplement C describes the frequency weighting functions used in calculating some acoustic metrics associated with acoustic criteria. Supplements D and E provide details of the acoustic modeling. Supplement F provides reference spectra and distances to acoustic criteria per scenario for impact-only scenarios, while Supplement G provides those results for scenarios that include vibratory piling. Detailed exposure results obtained via animat modeling are presented in Supplement H.

2.1. Acoustic Environment

Vineyard Mid-Atlantic is located in a continental shelf environment predominantly characterized by very fine-to-coarse grained sandy-seabed sediments, with some Glauconitic content. The client provided borehole measurement of the geoacoustic layering across the project area. Water depths in the Lease Area vary between approximately 39.5–47.1 m, while the surrounding area of impact varies between 10–500 m.

From May to October, the average temperature of the upper (0–50 m) water column is warmer, which can lead to a surface layer of increased sound speeds (see Supplement E). This may create 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 winter, from December through April, results in a cooler surface layer. The cooler surface layer combined with a layer of warmer subsurface water may create sound ducts that enable sound to travel farther during these months. Average sound speed profiles for summer (June through September) and winter (December) were used in the acoustic propagation modeling. See Supplement E for more details on the environmental parameters used in acoustic propagation and exposure modeling.

2.2. Modeling Acoustic Sources

2.2.1. 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 2). 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.

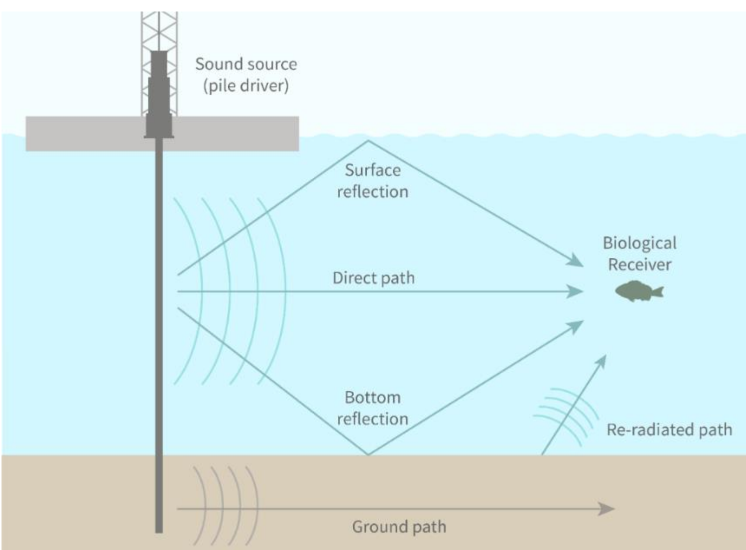

Figure 2. Sound propagation paths associated with pile driving (adapted from Buehler et al. 2015).

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 2010) 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 Supplement D for a more detailed description.

Forcing functions were computed for the normal and difficult to drive monopiles and jacket foundation piles using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010). 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 Supplement D.

JASCO's FWRAM (see Supplement E) 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 create 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). Section 4.1 provides examples of decidecade band levels for each pile type, hammer energy, and modeled location, using the average summer and winter sound speed profiles 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 (Bellmann et al. 2020), a quantitative comparison between installations of monopiles and main-piles by the post-piling procedure showed an up to 2 dB increase in noise levels due to post-piling. 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.

2.2.2. Vibratory Pile Driving

During vibratory pile driving, a vibratory hammer creates a rapid set of deformations that propagate down the pile and cause the surrounding soil to liquefy, thereby reducing skin friction that supports the pile and placing more pressure on the bottom end of the pile (referred to as the toe). The vibrations also lead to small penetrations of the toe, so that the entire pile sinks into the seabed.

One-and-a-half second long vibratory forcing functions were computed for the 12.5 m monopile and the 4.25 m jacket foundations, using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010). The vibratory functions were then truncated to a 1-s duration plus a 50-millisecond (ms) tapered section at the start and end of the signal to avoid numerical edge effects. Clamps are used to connect the vibratory hammer to the pile. The model assumed the use of 16 clamps with a total weight of 1051.2 kilonewtons (kN) for the 12.5 m monopile and 6 clamps with total weight of 394.2 kN for the 4.25 m jacket piles. No cushion between the hammer and pile was used in the modeling. 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), which is used to estimate an equivalent acoustic source represented by a linear array of monopoles evenly distributed along the pile, as detailed in Supplement D. Sound propagation of the vibratory pile driving source signature is performed using FWRAM (Supplement E).

Section 4.1.2 provides decidecade band levels at 10 m from the source for each pile type, hammer energy, and modeled location, using average summer and winter sound speed profiles.

2.3. Noise Mitigation

Noise abatement systems (NASs) are often used to decrease the sound levels in the water near a source by inserting a local impedance change and absorbing layer into the water column that acts as a barrier to sound transmission. Various technologies can achieve attenuation by changing impedance. These technologies include bubble curtains, evacuated sleeve systems (e.g., IHC-Noise Mitigation System [NMS]), encapsulated bubble systems (e.g., HydroSound Dampers), or Helmholtz resonators (AdBm NMS). The effectiveness of each system is frequency-dependent and may be influenced by local environmental conditions such as water current and depth. For example, the size of the bubbles determines the effective frequency band of absorption. Effective air bubble curtains use a range of bubble diameters to optimize their performance over a wide range of sound frequencies.

Small bubble curtains (bubble curtains positioned within in a short radius around the pile) have been measured to reduce sound levels from impact pile driving by approximately 10 dB to more than 20 dB, but their effectiveness is highly dependent on water current and depth and how the curtain is configured and operated (Koschinski and Lüdemann 2013, Bellmann 2014, Austin and Li 2016). Larger diameter bubble curtains tend to perform better and more reliably, particularly when deployed with two rings, known as double bubble curtains (Koschinski and Lüdemann 2013, Bellmann 2014, Nehls et al. 2016). Buehler et al. (2015) concluded that attenuation higher than 10 dB could not be reliably predicted for 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 (10 m [32 ft]) the pile.

A recent analysis by Bellmann et al. (2020) of NAS performance, measured during impact driving for wind farm foundation installation, provides expected performance for common NAS configurations. Measurements with a single bubble curtain and an air supply of 0.3 m^3/min resulted in 7–11 dB of broadband attenuation for optimized systems in up to 40 m water depth. Increased air flow (0.5 m^3/min) may improve the attenuation levels to up to 11–13 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 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 HydroSound Dampers were measured at 10 to 12 dB attenuation and are independent of depth (Bellmann et al. 2020). Systems may be deployed in series to achieve higher levels of attenuation.

The NAS must be chosen, tailored, and optimized for site-specific conditions. NAS performance of 10 dB broadband (across all frequencies) attenuation was chosen for this study as a conservative and achievable reduction of sound levels 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-based radial distance estimation, several levels of broadband attenuation were included for comparison purposes.

The studies and measurements referenced above are representative of impact pile driving. For vibratory pile driving, Austin et al. (2016) found that sound levels at 10 m from the pile were reduced by using NAS, with a median reduction of 8 dB for a passive resonator and 9 dB for a single confined bubble curtain. The same study showed reductions due to the bubble curtain varied from 3.4 to 13.1 dB across sites. These results are in line with reductions observed for damping systems and single bubble curtains for impact pile driving. Because primary sound production of both vibratory and impact pile driving is in similar frequency bands, NAS performance for vibratory pile driving is expected to be comparable to impact pile driving. The same levels of attenuation were therefore also used for vibratory pile driving.

2.4. 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 Vineyard Mid-Atlantic. Sound exposure models such as JASMINE use simulated animals (animats) to sample the predicted 3-D sound fields with movement rules derived from animal observations. Figure 3 gives an overview of the exposure modeling process using JASMINE.

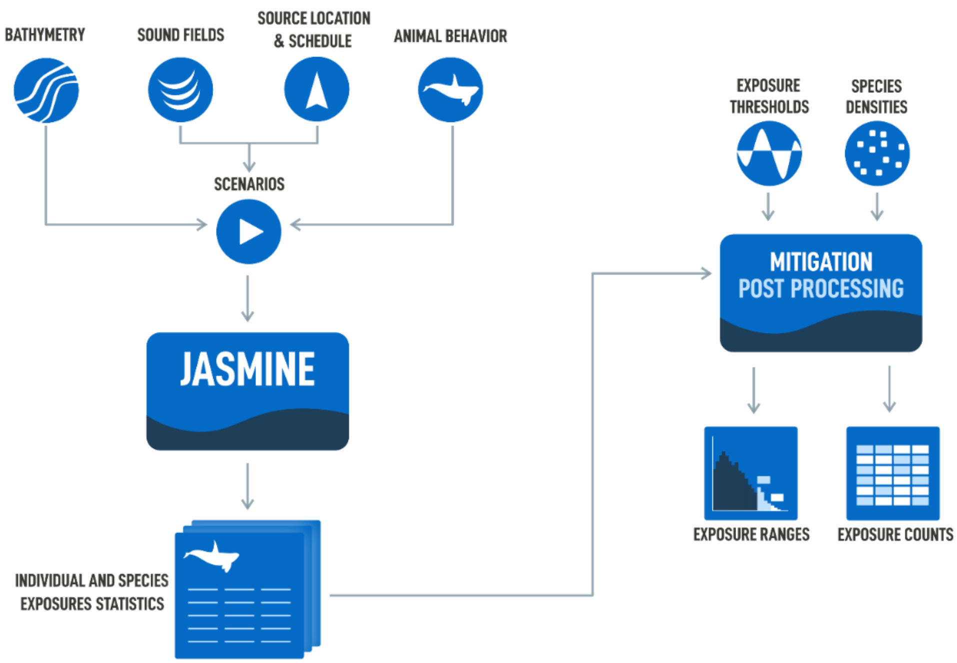

Figure 3. Exposure modeling process overview.

The parameters used for simulating realistic animal behavior (e.g., diving, foraging, and surface times) were determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species (see Supplement H and Figure 4). The predicted sound fields were sampled by the animats programmed to behave like marine species found in the study area. The output of the simulation is the exposure history for each animat. An individual animat's received sound levels are integrated over a specified duration, i.e., 24 h (Supplement H), to determine its total received acoustic energy (SEL) and maximum received PK and SPL. Exposure metrics are then compared to the threshold criteria described in Section 1.3 within each analysis period. Supplement H provides a fuller description of animal movement modeling and the parameters used in the JASMINE simulations. 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 4.3.1.1). Finally, the number of animals predicted to be impacted by the pile driving operations varies over time due to changes in local animal density and seasonal sound propagation effects.

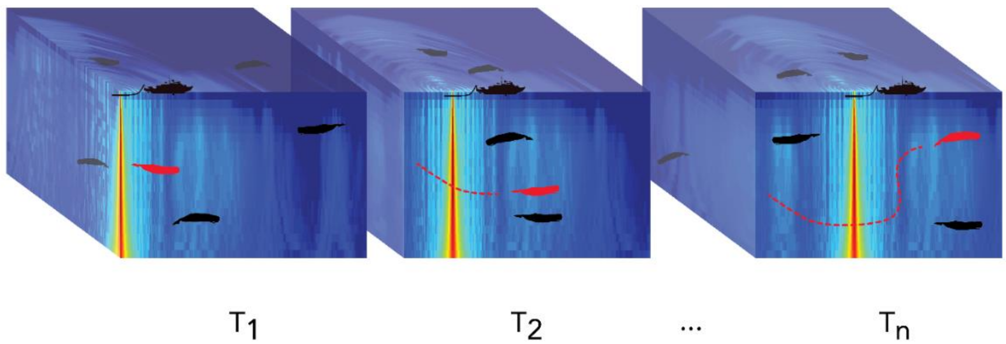

Figure 4. Depiction of animats in an environment with a moving sound field. Example animat (red) shown moving with each time step. The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

2.5. Summing Different Source Types

The SEL metric, which is used to assess TTS and PTS, represents an accumulated exposure to sound energy received over a specified time interval. The presently accepted interval is one day (24 h). Consequently, when multiple noise generating activities occur less than 24 h apart, it is necessary to assess the combined SEL produced by all those activities; even when the different activities occur at different locations or different times during the day, including the animals' movement relative to the activities.

Vibratory setting of piles followed by impact pile driving is being considered for Vineyard Mid-Atlantic for the installation of monopile foundations. Although the potential to induce hearing loss is low during vibratory driving, it does introduce sound into the water and must be considered in the SEL total. For this reason, the sound energy from vibratory is included as the starting SEL for impact pile driving (see Supplement H). The accumulated SEL (total from vibratory and impact driving) is compared to the thresholds for impulsive sounds (see Section 1.3.1.3), noting that the thresholds for impulsive sounds are lower than the thresholds for non-impulsive sounds and are therefore conservative.

Exposure to sound above a behavioral response threshold is a simple one-time exposure. Exceedance of thresholds for animats is tracked during vibratory and impact pile driving separately because these two sound sources use different thresholds. After the completion of piling, animats that exceeded the non-impulsive threshold during vibratory driving are counted as exposed and animats that exceeded the impulsive threshold during impact driving are considered exposed. Animats that exceeded both thresholds are only counted once toward the total number of animats exposed during the installation of a pile (in practice, an animat that was exposed above threshold during vibratory driving would not be counted again if it also exceeds the impulsive threshold during impact driving).

2.5.1. Implementing Pile Installation Schedules in JASMINE

JASMINE is an agent-based exposure model that calculates accumulated and instantaneous sound exposures to virtual animals ("animats") that move realistically relative to multiple noise generating activities. Exposure modeling locations were chosen to represent expected construction activities in the Lease Area over a seven-day period. Section 1.4.1 describes the pile installation schedules.

Exposure modeling locations were chosen to represent expected construction activity in the Lease Area over a seven-day period. Section 1.4.1 describes the pile installation schedules.

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 5 displays the pile installation schedule for vibratory followed by impact pile driving operations.

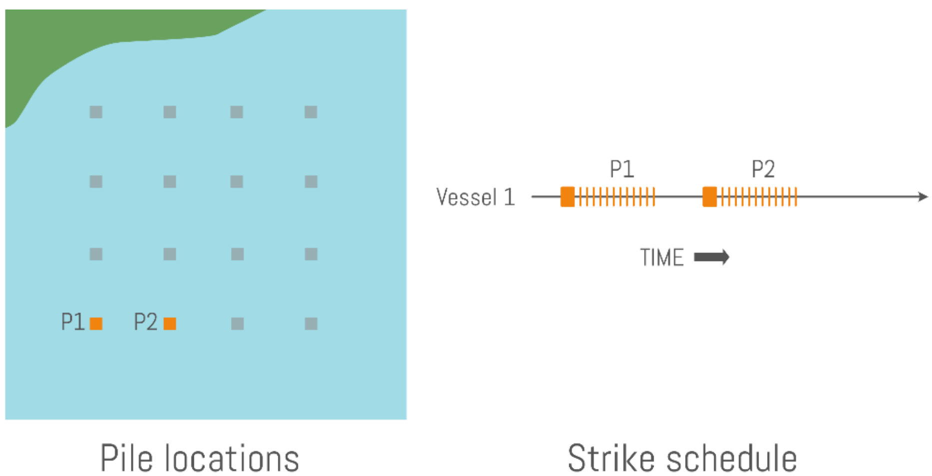

Figure 5. Pile installation schedule for vibratory pile driving followed by impact pile driving. Vertical orange tick marks show conceptual representations of each hammer strike. Solid orange bars preceding the tick marks indicate periods of vibratory pile driving.

The animal movement modeling assumed 30 or 60 min of vibratory setting for some monopiles in each construction schedule. Following vibratory piling, 5 min was assumed to switch from vibratory to impact piling equipment (i.e., 5 min with no sound source). A strike rate of 30 strikes per minute was used for monopile installation with the MHU 5500 hammer, with 10 min 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 Client 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 hour (h) period to capture 24-h 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-h period, a maximum strike rate of 44 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 10 min and the time for swapping equipment was 5 min.

2.6. Estimating Monitoring Zones for Mitigation

Monitoring zones for mitigation purposes have traditionally been estimated by determining the acoustic distance to injury and behavioral thresholds (see Supplement E.4). The traditional method 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 as it evolves over time determines the received level for each animal, considering animals to be stationary may not produce realistic estimates for the monitoring zones.

Animal movement and exposure modeling can be used to account for the movement of receivers when estimating distances for monitoring zones. The distance to the closest point of approach (CPA) for each of the species-specific animats 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. The $ER_{95\%}$ (95% exposure radial distance) is the horizontal distance that includes 95% of the CPAs of animats exceeding a given impact threshold (see Figure 6). $ER_{95\%}$ 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%.

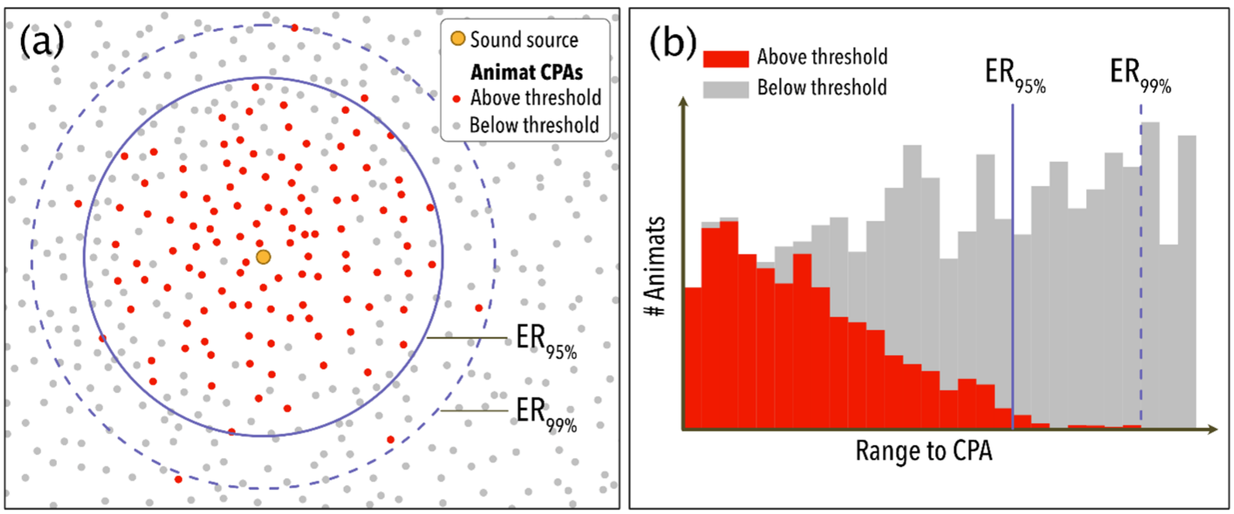

Figure 6. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animat CPAs near a sound source. Panel (b) shows the distribution of ranges to animat CPAs. The 95 and 99% Exposure Ranges ($ER_{95\%}$ and $ER_{99\%}$) are indicated in both panels.

For fish, only acoustic ranges to impact criteria thresholds were calculated. Fish acoustic ranges are determined by the isopleth at which thresholds could be exceeded (see Supplement E.4). Because fish were considered static (not moving) receivers, exposure ranges were not calculated.

3. Marine Fauna Included in the Acoustic Assessment

Marine fauna included in the acoustic assessment are marine mammals (cetaceans and pinnipeds), sea turtles, and fish.

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 the following are true:

- 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.

The MMPA defines a depleted species or population stock as any case in which the following are true:

- The Secretary, after consultation with the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals established under the 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 Endangered Species Act (2002), and 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" (ESE 2002). Five marine mammal species known to occur in the Northwest Atlantic OCS region are ESA listed (Table 27). All four species of sea turtles (Table 30) as well as four fish species (Section 3.2) known to occur in the Northwest Atlantic OCS region are also ESA listed.

3.1. Marine Mammals and Density Estimates

Thirty-nine marine mammal species (whales, dolphins, porpoise, seals) have been documented as present (either year–round, seasonally, or as occasional visitors) in the Northwest Atlantic Outer Continental Shelf OCS region (CeTAP 1982, USFWS 2014, Roberts et al. 2016, Hayes et al. 2022). All 39 marine mammal species identified in Tables 27 and 28 are protected under 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 the Offshore Development Area are sperm whale (*Physeter macrocephalus*), North Atlantic right whale (NARW; *Eubalaena glacialis*), fin whale (*Balaenoptera physalus*), blue whale (*B. musculus*), and sei whale (*B. borealis*).

Southern New England waters (including the Lease Area, see Figure 1**)** are primarily used as opportunistic feeding areas or habitat during seasonal migratory movements that occur between the feeding areas located further north and the breeding areas located further south that are typically used by some of these large whale species. The modeling used in this assessment considered minke and sei whales to be migratory in the region.

The four species of phocids (true seals) that have ranges overlapping the Lease Area are harbor seals (*Phoca vitulina*), gray seals (*Halichoerus grypus*), harp seals (*Pagophilus groenlandicus*), and hooded seals (*Cystophora cristata*) (Hayes et al. 2022). None of these phocids are ESA-listed, but all are protected under the MMPA.

Table 28 lists the expected occurrence of each marine mammal species in the Lease Area. Many of these marine mammal species do not commonly occur in this region of the Atlantic Ocean. For this assessment, species presence was categorized as the following:

- Common - Occurring consistently in moderate to large numbers.
- Uncommon - Occurring in low numbers or on an irregular basis.
- Rare - There are limited species records for some years. The range includes the proposed Offshore Development Area but, due to habitat preferences and distribution information, species are not expected to occur in the Lease Area. Rare sightings are still a possibility. Records may exist for adjacent waters.

Marine mammal species considered *common* and *uncommon* were selected for quantitative assessment by acoustic impact analysis and exposure modeling. Quantitative assessment of *rare* species was not conducted because impacts to those species approach zero due to their low densities. Tables 27 and 28 identify the modeled species. Section 4.3 describes the numbers of exposures for each species based on its presence, density, and overlap of proposed activities.

Table 27. Marine cetaceans that may occur in the Project Area.

Species	Scientific name	Stock	Regulatory status [a]	Relative occurrence	Abundance [b]
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
Common minke whale [c]	*Balaenoptera acutorostrata*	Canadian Eastern Coastal	MMPA	Common	21,968
North Atlantic right whale [c]	*Eubalaena glacialis*	Western North Atlantic	ESA-Endangered	Common	340
Sei whale [c]	*Balaenoptera borealis*	Nova Scotia	ESA-Endangered	Common	6,292
Sperm whale [c]	*Physeter macrocephalus*	North Atlantic	ESA-Endangered	Uncommon	5,895
Dwarf sperm whale	*Kogia sima*	Western North Atlantic	MMPA	Rare	9,474 [d]
Pygmy sperm whale	*Kogia breviceps*	Western North Atlantic	MMPA	Rare	9,474 [d]
Atlantic spotted dolphin [c]	*Stenella frontalis*	Western North Atlantic	MMPA	Uncommon	31,506
Atlantic white-sided dolphin [c]	*Lagenorhynchus acutus*	Western North Atlantic	MMPA	Common	93,233
Common bottlenose dolphin [c]	*Tursiops truncatus*	Western North Atlantic, offshore [e]	MMPA	Common	64,587
Tamanend's bottlenose dolphin	*Tursiops erebenndus*	Western North Atlantic, Northern Migratory Coastal	MMPA-Strategic	Rare	6,639
Clymene dolphin	*Stenella clymene*	Western North Atlantic	MMPA	Rare	21,778
Common dolphin [c]	*Delphinus delphis*	Western North Atlantic	MMPA	Common	93,100
False killer whale	*Pseudorca crassidens*	Western North Atlantic	MMPA	Rare	1,298
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	2,757
Long-finned pilot whale [c]	*Globicephala melas*	Western North Atlantic	MMPA	Uncommon	39,215
Short-finned pilot whale [c]	*Globicephala macrorhynchus*	Western North Atlantic	MMPA	Uncommon	18,726
Pygmy killer whale	*Feresa attenuata*	Western North Atlantic	MMPA	Rare	Unknown
Risso's dolphin [c]	*Grampus griseus*	Western North Atlantic	MMPA	Uncommon	44,067
Rough-toothed dolphin	*Steno bredanensis*	Western North Atlantic	MMPA	Rare	Unknown
Spinner dolphin	*Stenella longirostris*	Western North Atlantic	MMPA	Rare	3,181
Striped dolphin	*Stenella coeruleoalba*	Western North Atlantic	MMPA	Rare	48,274
White-beaked dolphin	*Lagenorhynchus albirostris*	Western North Atlantic	MMPA	Rare	536,016
Goose-beaked whale [e]	*Ziphius cavirostris*	Western North Atlantic	MMPA	Rare	2,936
Blainville's beaked whale	*Mesoplodon densirostris*	Western North Atlantic	MMPA	Rare	2,936
Gervais' beaked whale	*Mesoplodon europaeus*	Western North Atlantic	MMPA	Rare	8,595
Sowerby's beaked whale	*Mesoplodon bidens*	Western North Atlantic	MMPA	Rare	492
True's beaked whale	*Mesoplodon mirus*	Western North Atlantic	MMPA	Rare	4,480
Northern bottlenose whale	*Hyperoodon ampullatus*	Western North Atlantic	MMPA	Rare	Unknown
Harbor porpoise [c]	*Phocoena phocoena*	Gulf of Maine/Bay of Fundy	MMPA	Common	85,765

[a] Highest federal regulatory classification. A 'strategic stock' is 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. Source: NOAA Fisheries (2024).

[b] Best available abundance estimate is from NOAA Fisheries Stock Assessment Reports. Source: NOAA Fisheries (2024).

[c] Modeled species.

[d] This estimate includes dwarf and pygmy sperm whales. Source: NOAA Fisheries (2024).

[e] Goose-beaked whales were formerly referred to as Cuvier's beaked whales.

Table 28. Earless seals (Phocidae) that may occur in the Project Area.

Species	Scientific name	Stock	Regulatory status [a]	Relative occurrence	Abundance [b]
Gray seal [c]	*Halichoerus grypus*	Western North Atlantic	MMPA	Common	27,911 [d]
Harbor seal [c]	*Phoca vitulina*	Western North Atlantic	MMPA	Common	61,336 [e]
Harp seal [c]	*Pagophilus groenlandicus*	Western North Atlantic	MMPA	Uncommon	Unknown
Hooded seal	*Cystophora cristata*	Western North Atlantic	MMPA	Rare	Unknown

[a] Highest federal regulatory classification. A ‘strategic stock’ is 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. Source: NOAA Fisheries (2024).

[b] Best available abundance estimate is from NOAA Fisheries Stock Assessment Reports. Source: NOAA Fisheries (2024).

[c] Modeled species.

[d] Estimate of gray seal population in US waters. Data are derived from pup production estimates; (NOAA Fisheries 2024) 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.

[e] NOAA Fisheries (2024) reports insufficient data to estimate the population size of harp seals in US waters. The best estimate for the whole population is 7.6 million.

Mean monthly marine mammal density estimates (animals per 100 square kilometers [animals/100 km^2]) were obtained using the 2022 Duke University Marine Geospatial Ecology Laboratory (MGEL) model results (Roberts et al. 2016, 2023, 2024).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. (2024). 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. (2022).

For cases with impact pile driving and vibratory setting of piles followed by impact pile driving, densities were calculated within buffered polygons of various ranges around the Lease Area perimeter (see Supplement H). The following ranges were pre-selected: 1, 5, 10, 15, 20, 30, 40, 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. For example, if the $ER_{95\%}$ was 8.5 km, the 10 km perimeter would be 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 demonstrate received levels, distance from the source, and behavioral context are known to influence the probability of behavioral response (Dunlop et al. 2017). Table 29 provides the marine mammal densities using the 10 km perimeter as an example. Supplement H provides the other density perimeters that were included in density calculations (1, 5, 15, 20, 30, 40, and 50 km).

The mean species density for each month was determined by calculating the unweighted mean of all 5 × 5 km grid cells partially or fully within the analysis perimeter (Figure 7). Densities were computed for an entire year to coincide with proposed pile driving activities. In cases where monthly densities were unavailable, annual mean densities were used instead.

The MGEL/Duke models report densities for two species guilds considered in this study: pilot whales and seals. When calculating exposures for individual pilot whale and seal species, the guild densities provided by Roberts et al. (2016, 2023, 2024) 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 were downloaded from the Ocean Biodiversity Information System (OBIS) data repository (available at https://obis.org/). The best data available for pilot whales came from the Mystic Aquarium data set of marine mammal strandings in the region, due to their overlap with the project area. The proportions of 0.93 for long-finned and 0.07 for short-finned pilot whales were used (Smith 2014). For the two seal species, 2022–2023 protected species observer (PSO) sighting data from the 0544 Lease Area was insufficient, so proportions of seals were determined from OBIS data as cited in the Final Rule for the adjacent Empire Wind project: 0.34 for gray seals and 0.66 for harbor seals (DoC and NOAA 2024).

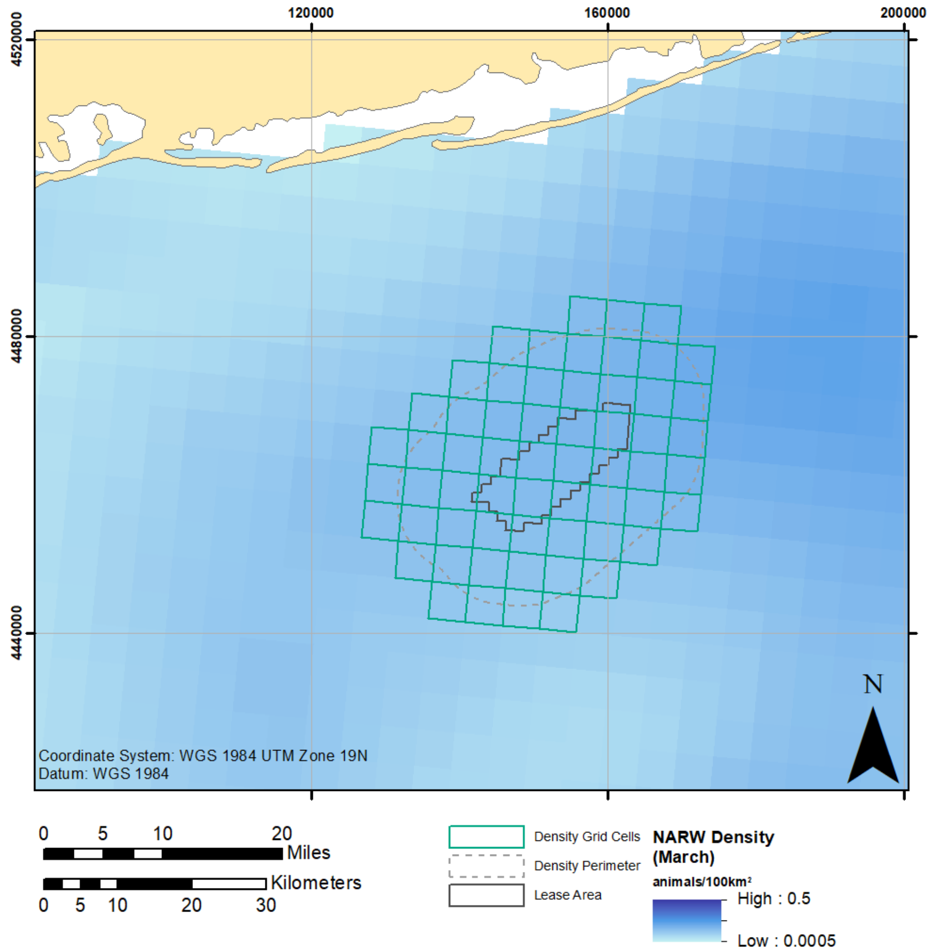

Figure 7. Marine mammal (e.g., North Atlantic right whale [NARW]) density map demonstrating how grid cells are selected for an example 10 km perimeter. This subset of grid cells are used to extract mean monthly species density estimates around Lease Area OCS-A 0544 (Roberts et al. 2016, 2023, 2024). The other density perimeters that were included but are not shown here are: 1, 5, 15, 20, 30, 40, and 50 km.

Table 29. Mean monthly marine mammal density estimates for all common and uncommon species (see Table 27) in an example 10 km perimeter around the Lease Area. Supplement H provides density calculations using other density perimeters (1, 5, 15, 20, 30, 40, and 50 km).

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.187	0.200	0.176	0.140	0.261	0.324	0.296	0.222	0.111	0.038	0.055	0.117	0.177	0.178
Humpback whale	0.078	0.058	0.070	0.107	0.189	0.191	0.046	0.033	0.075	0.115	0.108	0.075	0.095	0.104
Common minke whale (migrating)	0.084	0.074	0.080	0.934	1.793	1.267	0.336	0.194	0.147	0.168	0.032	0.066	0.431	0.500
North Atlantic right whale [b]	0.118	0.147	0.149	0.115	0.036	0.008	0.004	0.003	0.006	0.011	0.019	0.054	0.056	0.017
Sei whale [b] (migrating)	0.023	0.014	0.032	0.083	0.084	0.015	0.003	0.002	0.007	0.018	0.039	0.031	0.029	0.025
Sperm whale [b]	0.013	0.003	0.003	0.003	0.004	0.008	0.013	0.027	0.015	<0.001	0.007	0.007	0.009	0.010
Atlantic spotted dolphin	0.003	<0.001	0.002	0.008	0.034	0.056	0.055	0.120	0.407	0.653	0.278	0.025	0.137	0.204
Atlantic white sided dolphin	1.126	0.704	0.524	1.005	2.064	2.141	0.204	0.082	0.451	1.311	1.112	1.452	1.015	1.102
Common bottlenose dolphin	0.922	0.289	0.182	0.426	1.438	2.355	2.190	1.550	1.505	1.801	2.030	2.120	1.401	1.874
Long-finned pilot whale	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Short-finned pilot whale	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Risso's dolphin	0.097	0.014	0.007	0.042	0.078	0.032	0.028	0.015	0.017	0.022	0.098	0.290	0.062	0.073
Common dolphin	10.206	3.695	2.112	3.265	5.290	5.302	3.062	4.247	4.650	8.054	9.837	14.324	6.170	6.846
Harbor porpoise (sensitive)	6.965	7.376	7.415	8.716	3.215	0.585	0.847	0.445	0.338	0.357	0.707	3.877	3.404	1.296
Gray seal	5.099	5.418	4.406	3.939	6.477	0.528	0.035	0.023	0.065	0.344	1.221	4.399	2.663	1.636
Harbor seal	9.899	10.517	8.553	7.647	12.574	1.025	0.068	0.045	0.125	0.668	2.369	8.539	5.169	3.177

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).

[b] Listed as Endangered under the ESA.

[c] Density adjusted by relative abundance.

3.2. Sea Turtles and Density Estimates

Four species of sea turtles may occur in the Vineyard Mid-Atlantic Lease Area (Table 30): loggerhead sea turtle (*Caretta caretta*), Kemp's ridley sea turtle (*Lepidochelys kempii*), green sea turtle (*Chelonia mydas*), and leatherback sea turtle (*Dermochelys coriacea*). All four are listed as threatened or endangered. Many sea turtle species prefer coastal waters; however, leatherback and loggerhead sea turtles are known to occupy deep-water habitats and are considered common in summer and fall in Southern New England waters. Kemp's ridley sea turtles are thought to be regular visitors, and green sea turtles may be present in seasons when water temperatures are the highest, although they are considered uncommon.

Table 30. 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 on https://www.fisheries.noaa.gov/species-directory/. Accessed 3 April 2024.
[b] Modeled species.

Sea turtle densities within the Lease Area were estimated using the East Coast sea turtle density models developed by the U.S. Naval Undersea Warfare Center (NUWC; DiMatteo et al. 2024). The data are long-term monthly average estimates of density and are expressed as the number of individuals per square kilometer.

Densities were calculated within buffered polygons of various ranges around the Lease Area perimeter (see Supplement H). The following ranges were pre-selected: 1, 5, 10, 15, 20, 30, 40, 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 31 provides the sea turtle densities using the 10 km perimeter as an example. Supplement H provides the other density perimeters that were included in density calculations (1, 5, 15, 20, 30, 40, and 50 km).

Table 31. Sea turtle density estimates (animals/100 km^2)[a] for all modeled species in a 10 km perimeter around the Lease Area. Supplement H provides density calculations using other density perimeters (1, 5, 15, 20, 30, 40, and 50 km).

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.011	0.012	0.013	0.008	0.008	0.001	0	0.004	0.007
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.008	0.042	0.083	0.162	0.231	0.227	0.040	0.003	0.066	0.100
Loggerhead sea turtle	0.009	0.006	0.004	0.005	0.029	0.093	0.084	0.074	0.084	0.102	0.061	0.019	0.047	0.068
Green sea turtle	0	0	0	0	0	0.207	0.233	0.215	0.335	0.151	0.012	0	0.096	0.144

[a] Density estimates are from DiMatteo et al. (2024).

3.3. Fish

There are six ESA listed Threatened or Endangered fish species that may occur off the northeast Atlantic coast – the shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), Atlantic salmon (*Salmo salar)*, giant manta ray (*Manta birostris*), oceanic whitetip shark (*Carcharhinus logimanus*), and scalloped hammerhead (*Sphyrna lewini*). However, only the Atlantic sturgeon is anticipated to potentially occur within the Offshore Development Area and surrounding waters.

Atlantic sturgeon distribution varies by season, but are primarily found in shallow coastal waters (less than 20 m) during May to September and move to deeper waters (20-50 m) during 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 Lease Area.

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 is federally listed as Endangered. They spawn within eight coastal watersheds of Maine. In 2009, the DPS was expanded to include all areas of the Gulf of Maine between the Androscoggin River and the Dennys River (NOAA Fisheries 2022). It is possible that adult Atlantic salmon may occur off the Massachusetts coast while migrating to rivers to spawn. However, only certain Gulf of Maine populations are listed as Endangered, and Gulf of Maine salmon are unlikely to be encountered south of Cape Cod (BOEM 2014).

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 2021).

The oceanic whitetip shark is a global pelagic and highly migratory species listed as threatened throughout its range under the ESA in 2018 (NOAA Fisheries 2018). They are typically a surface-dwelling species, preferring water of 20°C (68°F) or above; however, these species are capable of deep dives up to 1,082 m (3,549 ft) deep. Oceanic whitetip shark adults primarily occur on the outer edge of the shelf and prefer deep waters (Young 2020). It is thought that juvenile oceanic white tip sharks utilize shallow reef habitats that do not occur in the Offshore Development Area (Passerotti 2020).

The scalloped hammerhead shark is a global pelagic and highly migratory species listed as threatened in the central Atlantic under the ESA in 2014 (NOAA Fisheries 2014). Most commonly found in the central Atlantic, this species migrates north to waters off North Carolina and as far north as New York and New England in the summer months, following the jet stream. From the aerial digital surveys conducted on behalf of NYSERDA from summer 2016 through spring 2019, scalloped hammerhead sharks were only very sparsely observed in the vicinity of the Offshore Development Area during the summer showing a slight preference for shelf slope waters, and not observed within the New York Bight during spring, fall, or winter ([NYSERDA] 2021). Therefore, this species is not expected to be affected by Vineyard Mid-Atlantic activities.

4. Results

Sound fields were modeled at two modeling locations (L01 and L02) for monopile foundations and jacket foundation pin piles, representing the range of water depths within the Lease Area. This section summarizes the source modeling results (see Section 4.1), the acoustic propagation modeling results (see Section 4.2), and animal movement modeling results for marine mammals and sea turtles (see Sections 4.2, 4.3.2, 4.4, and 4.4.2).

4.1. Source Modeling

4.1.1. Impact Pile Driving

Forcing functions were computed for the monopiles and pin piles using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010). Figure 8 shows these functions for monopiles and Figure 11 for jacket piles. Supplement D details how the forcing functions serve as the inputs to JASCO's pile driving source models used to estimate equivalent acoustic source characteristics. Decidecade band levels at 10 m for the modeled piles are shown in Figures 9–10 for monopiles and Figures 12–13 for jacket piles.

4.1.1.1. 12.5 m Monopile

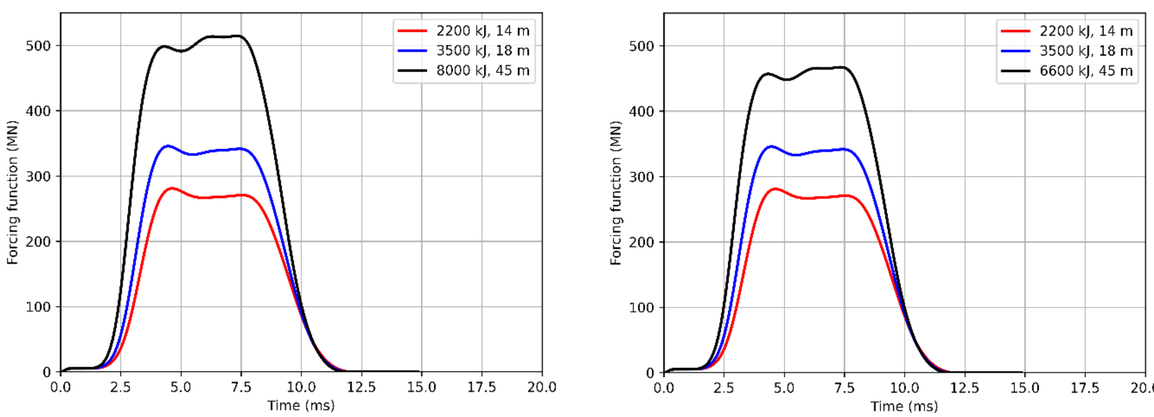

Figure 8. Scenarios B1–B4, modeled forcing functions versus time as a function of hammer energy for a 12.5 m monopile: (left) Scenarios B1 and B2 (MHU 5500 scaled to 8000 kJ) and (right) Scenarios B3 and B4 (MHU 5500 scaled to 6600 kJ)

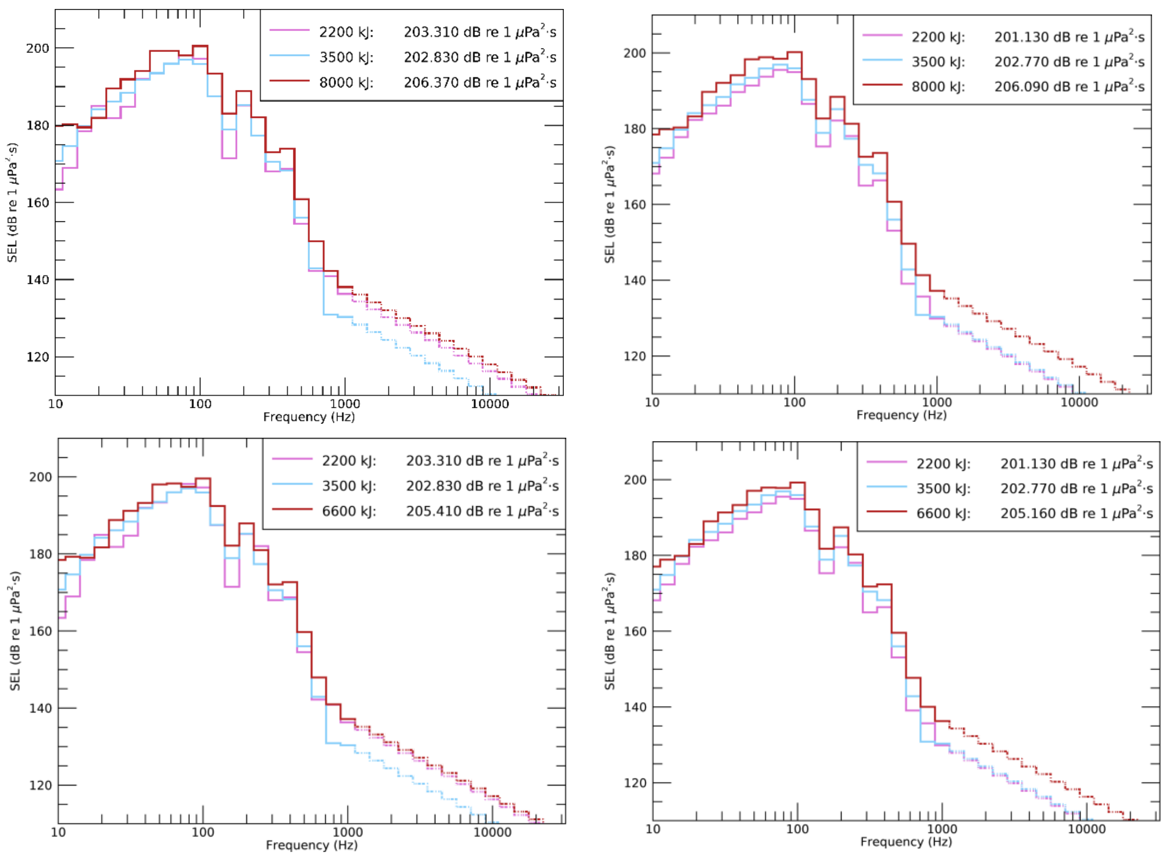

Figure 9. Scenarios B1–B4, decidecade band levels at 10 m from location L01 in winter for a 12.5 m monopile for: (left, top) Scenario B1 (MHU 5500 scaled to 8000 kJ, difficult-to-drive); (right, top) Scenario B2 (MHU 5500 scaled to 8000 kJ, normal); (left, bottom) Scenario B3 (MHU 5500 scaled to 6600 kJ, difficult-to-drive); (right, bottom) Scenario B4 (MHU 5500 scaled to 6600 kJ, normal). Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate. Due to the short propagation range of 10 m, summer and winter profiles are within 0.05 dB.

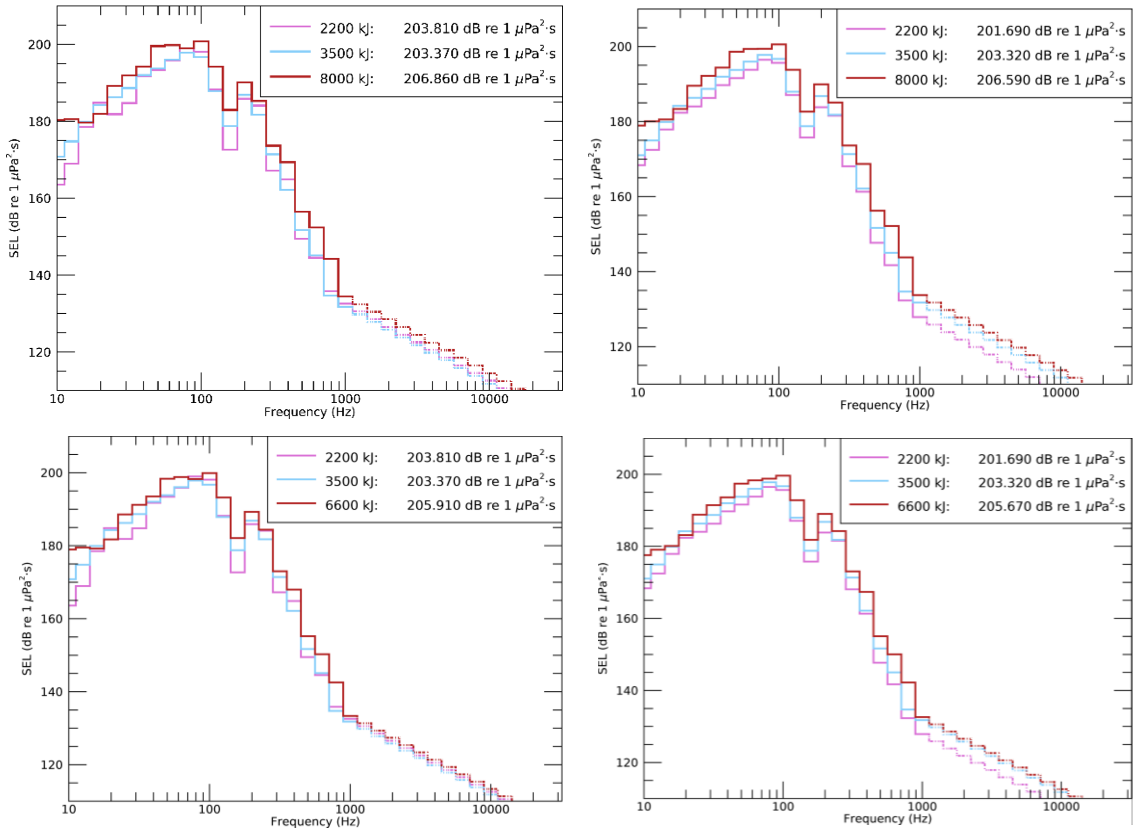

Figure 10. Scenarios B1–B4, decidecade band levels at 10 m from location L02 in winter for a 12.5 m monopile for: (left, top) Scenario B1 (MHU 5500 scaled to 8000 kJ, difficult-to-drive); (left, bottom) Scenario B2 (MHU 5500 scaled to 8000 kJ, normal); (left, bottom) Scenario B3 (MHU 5500 scaled to 6600 kJ, difficult-to-drive); (right, bottom) Scenario B4 (MHU 5500 scaled to 6600 kJ, normal). Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate. Due to the short propagation range of 10 m, summer and winter profiles are within 0.05 dB.

4.1.1.2. 4.25 m Jacket

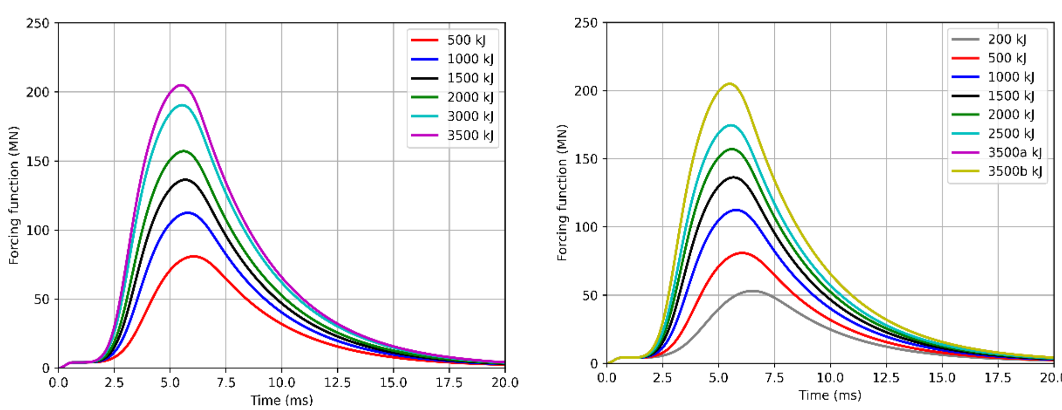

Figure 11. Scenarios B5–B6, modeled forcing functions versus time for a 4.25 m jacket foundation pin pile as a function of hammer energy (MHU 3500S): (left) Scenario B5 (50 m Scenario) and (right) Scenario B6 (80 m Scenario).

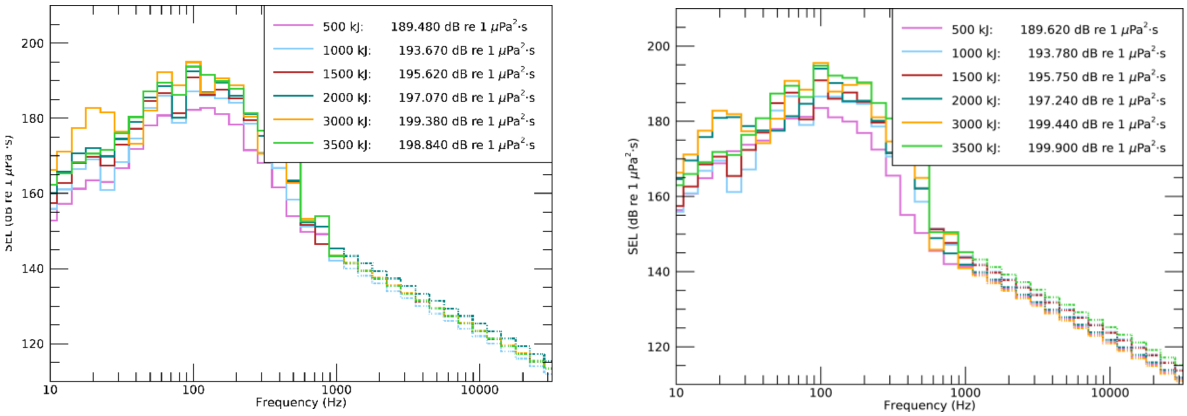

Figure 12. Scenario B5, decidecade band levels at 10 m from (left) location L01 and (right) location L02 in winter for a 4.25 m diameter pin pile assuming an expected installation scenario using an MHU 3500S hammer. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate. Due to the short propagation range of 10 m, summer and winter profiles are within 0.05 dB.

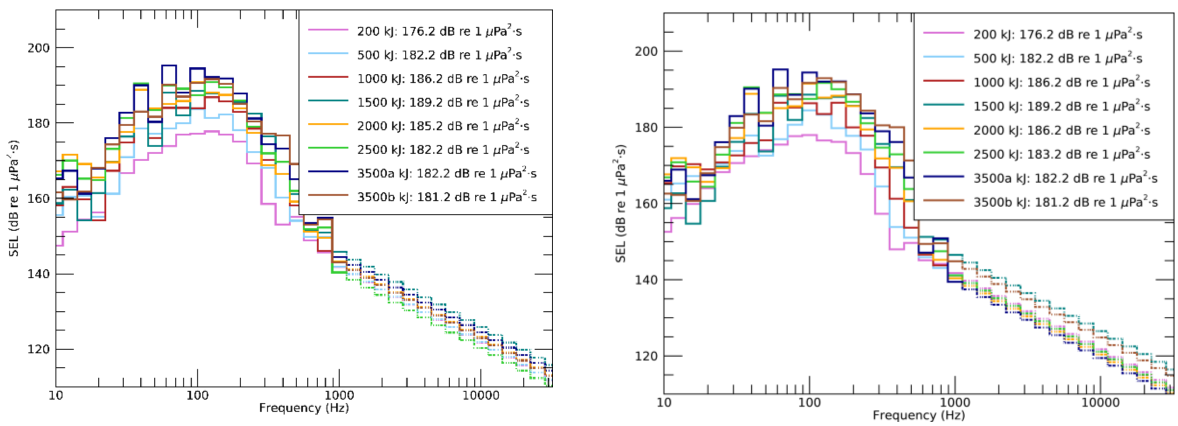

Figure 13. Scenario B6, decidecade band levels at 10 m from (left) location L01 and (right) location L02 in winter for a 4.25 m diameter pin pile assuming an expected installation scenario using an MHU 3500S hammer. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate. Due to the short propagation range of 10 m, summer and winter profiles are within 0.05 dB. 3500a and 3500b indicate piling at 3500 kJ with different pile penetration depths.

4.1.2. Vibratory Pile Driving

Figures 14 and 16 show 1.5-s long forcing functions for the jacket and monopile under vibratory hammers calculated using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010) with the addition of non-linearities (see Section 2.2.2). Figures 15, 17, and 18 show decidecade band levels at 10 m for the modeled piles. Observed peaks correspond to the frequency of hammer vibration and subsequent harmonics.

4.1.2.1. 12.5 m Monopile

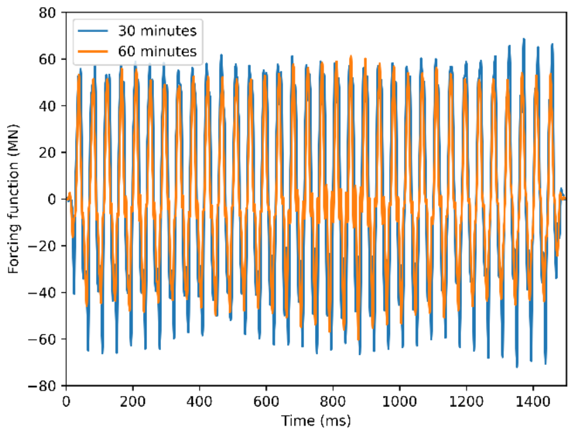

Figure 14. Scenarios BV1–BV4, modeled 1.5 second (s) vibratory forcing function for a 12.5 m diameter monopile (TR-CV640) produced from a 30-minute (min) hammering duration and a 60-min hammering duration. The forcing function was clipped and tapered (see Section 2.2.2) and then used with Pile Driving Source Model (PDSM) to compute a representative 1-s signal.

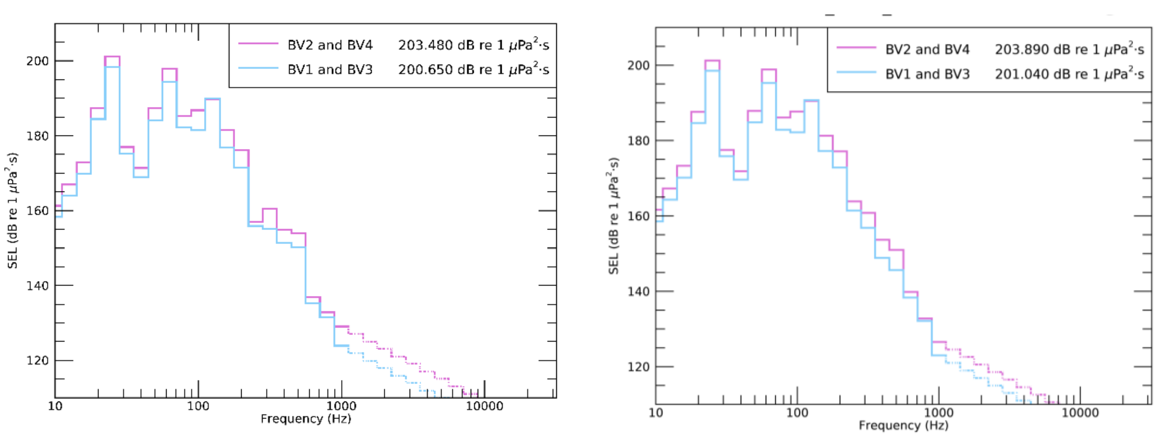

Figure 15. Scenarios BV1–BV4, decidecade band levels at 10 m from (left) location L01 and (right) location L02 for a 12.5 m monopile assuming an installation scenario with the TR-CV640 hammer with durations of 30 min (Scenarios BV2 and BV4) and 60 min (Scenarios BV1 and BV3) of vibratory piling, with average winter sound speed profiles. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate. Due to the short propagation range of 10 m, summer and winter profiles are within 0.05 dB.

4.1.2.2. 4.25 m Jacket

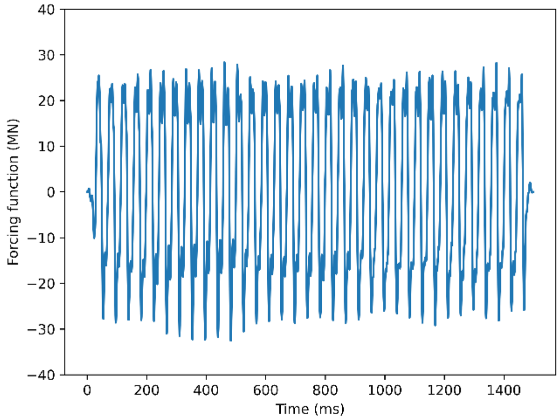

Figure 16. Scenarios BV5 and BV6, modeled 1.5-second (s) vibratory forcing function for a 4.25 m diameter jacket (TR-CV320). The forcing function was clipped and tapered (see Section 2.2.2) and then used with Pile Driving Source Model (PDSM) to compute a representative 1-s signal.

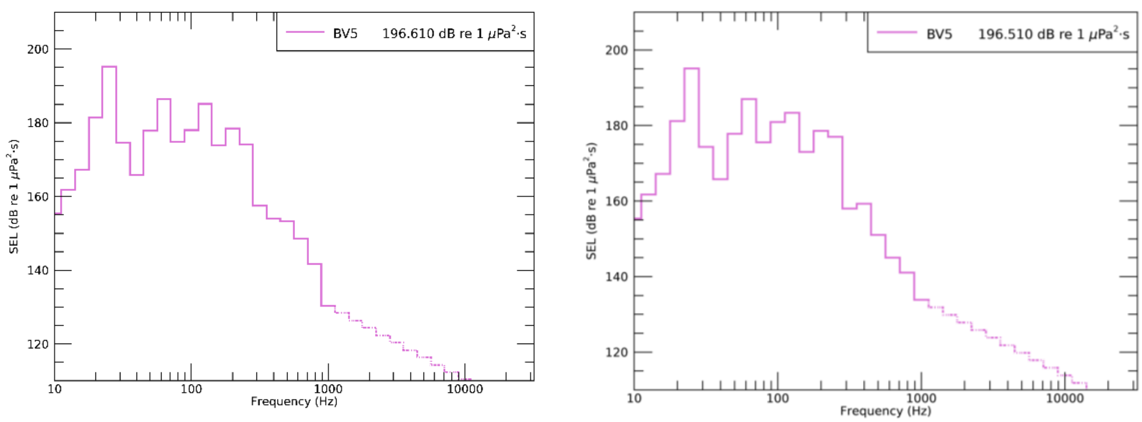

Figure 17. Scenario BV5, decidecade band levels at 10 m from (left) location L01 and (right) location L02 for a 4.25 m jacket assuming an installation scenario with the TR-CV320 hammer with 60 min of vibratory piling, with an average winter sound speed profiles. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate. Due to the short propagation range of 10 m, summer and winter profiles are within 0.05 dB.

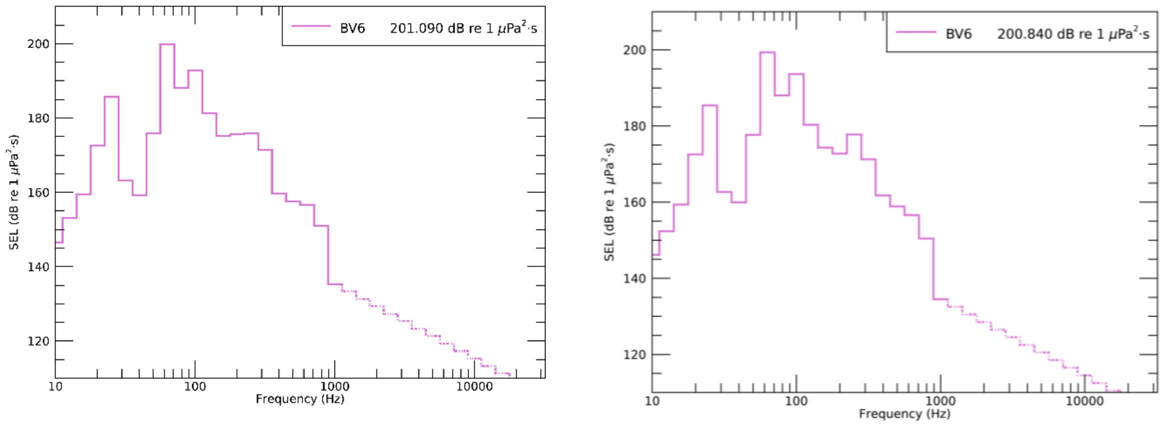

Figure 18. Scenario BV6, decidecade band levels at 10 m from (left) location L01 and (right) location L02 for a 4.25 m jacket assuming an installation scenario with the TR-CV320 hammer with 60 min of vibratory piling, with an average winter sound speed profiles. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate. Due to the short propagation range of 10 m, summer and winter profiles are within 0.05 dB.

4.2. Sound Field Propagation and Acoustic Ranges

This section presents a high-level summary of the underwater acoustic modeling performed for all impact and vibratory piling scenarios considered. The longest $R_{95\%}$ acoustic ranges to threshold, or the ranges required to reach the 95th percentile sound level (see Supplement E.4), are shown across all modeling locations and seasons for each pile scenario to demonstrate the maximum acoustic impact from the PDE. Installation is assumed with impact pile driving or with vibratory pile setting followed by impact pile driving (see Tables 10–20 to for drivability details). Acoustic ranges are shown for scenarios with 10 dB of attenuation from NAS. More detailed results are presented in Supplement F for impact pile driving only and Supplement G for vibratory pile setting followed by impact pile driving.

4.2.1. 12.5 m Monopile

4.2.1.1. Marine Mammals and Sea Turtles - Injury

Table 32. Scenarios B1 and BV1, maximum acoustic ranges ($R_{95\%}$ in km) for marine mammal and sea turtle PTS from a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 8000 kJ, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact -only piling	Vibratory + impact piling
LF	183	3.22	2.50
MF	185	0.00	0.00
HF	155	0.09	0.02
PW	185	0.61	0.41
TU	204	0.92	0.67

Table 33. Scenarios B2 and BV2, maximum acoustic ranges ($R_{95\%}$ in km) for marine mammal and sea turtle PTS from a monopile foundation (12.5 m diameter TR-CV640 and MHU 5500 scaled to 8000 kJ, 30 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact-only piling	Vibratory + impact piling
LF	183	2.89	2.23
MF	185	0.00	0.00
HF	155	0.09	0.01
PW	185	0.52	0.32
TU	204	0.86	0.58

Table 34. Scenarios B3 and BV3, maximum acoustic ranges ($R_{95\%}$ in km) for marine mammal and sea turtle PTS from a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 6600 kJ, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact-only piling	Vibratory + impact piling
LF	183	2.96	2.49
MF	185	0.00	0.00
HF	155	0.09	0.02
PW	185	0.55	0.40
TU	204	0.87	0.67

Table 35. Scenarios B4 and BV4, maximum acoustic ranges ($R_{95\%}$ in km) for marine mammal and sea turtle PTS from a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 6600 kJ, 30 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact-only piling	Vibratory + impact piling
LF	183	2.74	2.22
MF	185	0.00	0.00
HF	155	0.07	0.01
PW	185	0.46	0.31
TU	204	0.77	0.57

4.2.1.2. Fish - Injury

Table 36. Scenarios B1 and BV1, maximum acoustic ranges ($R_{95\%}$ in km) to fish injury thresholds for a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 8000 kJ, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact-only piling	Vibratory + impact piling
Fish ≥ 2 g [a]	187	4.45	3.62
Fish < 2 g [a]	183	5.64	4.67
Fish without swim bladder [b]	216	0.27	0.17
Fish with swim bladder [b]	203	1.31	0.97

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014).

Table 37. Scenarios B2 and BV2, maximum acoustic ranges ($R_{95\%}$ in km) to fish injury thresholds for a monopile foundation (12.5 m diameter difficult-to-drive, TR-CV640 and MHU 5500 scaled to 8000 kJ, 30 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact-only piling	Vibratory + impact piling
Fish ≥ 2 g [a]	187	4.13	3.28
Fish < 2 g [a]	183	5.28	4.27
Fish without swim bladder [b]	216	0.24	0.15
Fish with swim bladder [b]	203	1.17	0.92

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014).

Table 38. Scenarios B3 and BV3, maximum acoustic ranges ($R_{95\%}$ in km) to fish injury thresholds for a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 6600 kJ, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact-only piling	Vibratory + impact piling
Fish ≥ 2 g [a]	187	4.20	3.60
Fish < 2 g [a]	183	5.36	4.65
Fish without swim bladder [b]	216	0.25	0.17
Fish with swim bladder [b]	203	1.20	0.96

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014).

Table 39. Scenarios B4 and BV4, maximum acoustic ranges ($R_{95\%}$ in km) to fish injury thresholds for a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 6600 kJ, 30 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact piling	Vibratory + impact piling
Fish ≥ 2 g [a]	187	3.92	3.26
Fish < 2 g [a]	183	5.03	4.25
Fish without swim bladder [b]	216	0.22	0.15
Fish with swim bladder [b]	203	1.07	0.92

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014).

4.2.1.3. Marine Mammals, Sea Turtles, and Fish - Behavior

Table 40. Scenarios B1 and BV1, maximum acoustic ranges ($R_{95\%}$ in km) to behavioral thresholds for a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 8000 kJ, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Taxonomic group	L_p threshold (dB re 1 µPa²)	Impact piling: Acoustic range (km)	L_p threshold (dB re 1 µPa²)	Vibratory piling: Acoustic range (km)
Marine mammals	160	4.08	120	14.34
Fish	150	7.32	150	2.69
Sea turtles	175	1.26	175	0.17

Table 41. Scenarios B2 and BV2, maximum acoustic ranges ($R_{95\%}$ in km) to behavioral thresholds for a monopile foundation (12.5 m diameter difficult-to-drive, TR-CV640 and MHU 5500 scaled to 8000 kJ, 30 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Taxonomic group	L_p threshold (dB re 1 µPa^2)	Impact piling: Acoustic range (km)	L_p threshold (dB re 1 µPa^2)	Vibratory piling: Acoustic range (km)
Marine mammals	160	3.99	120	14.93
Fish	150	7.23	150	2.90
Sea turtles	175	1.21	175	0.24

Table 42. Scenarios B3 and BV3, maximum acoustic ranges ($R_{95\%}$ in km) to behavioral thresholds for a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 6600 kJ, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Taxonomic group	L_p threshold (dB re 1 µPa^2)	Impact piling: Acoustic range (km)	L_p threshold (dB re 1 µPa^2)	Vibratory piling: Acoustic range (km)
Marine mammals	160	3.82	120	14.34
Fish	150	6.93	150	2.69
Sea turtles	175	1.12	175	0.17

Table 43. Scenarios B4 and BV4, maximum acoustic ranges ($R_{95\%}$ in km) to behavioral thresholds for a monopile foundation (12.5 m diameter, TR-CV640 and MHU 5500 scaled to 6600 kJ, 30 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Taxonomic group	L_p threshold (dB re 1 µPa^2)	Impact piling: Acoustic range (km)	L_p threshold (dB re 1 µPa^2)	Vibratory piling: Acoustic range (km)
Marine mammals	160	3.74	120	14.93
Fish	150	6.85	150	2.90
Sea turtles	175	1.09	175	0.24

4.2.2. 4.25 m Jacket

4.2.2.1. Marine Mammals and Sea Turtles - Injury

Table 44. Scenarios B5 and BV5, maximum acoustic ranges ($R_{95\%}$ in km) for marine mammal and sea turtle PTS from a jacket foundation (4 post-piled pin piles, 4.25 m diameter, MHU 3500S hammer) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa^2·s)	Impact piling	Vibratory + impact piling
LF	183	4.61	4.20
MF	185	0.00	0.00
HF	155	0.22	0.20
PW	185	0.86	0.72
TU	204	1.14	0.93

Table 45. Scenarios B6 and BV6, maximum acoustic ranges ($R_{95\%}$ in km) for marine mammal and sea turtle PTS from a jacket foundation (4 post-piled pin piles, 4.25 m diameter, MHU 3500S hammer) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact piling	Vibratory + impact piling
LF	183	5.37	5.69
MF	185	0.00	0.00
HF	155	0.26	0.27
PW	185	1.00	1.09
TU	204	1.30	1.46

4.2.2.2. Fish - Injury

Table 46. Scenario B5 and BV5, maximum acoustic ranges ($R_{95\%}$ in km) to fish injury thresholds for a jacket foundation (4 post-piled pin piles, 4.25 m diameter, MHU 3500S hammer) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact piling	Vibratory + impact piling
Fish ≥ 2 g [a]	187	5.29	5.08
Fish < 2 g [a]	183	7.04	6.66
Fish without swim bladder [b]	216	0.32	0.26
Fish with swim bladder [b]	203	1.43	1.38

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014).

Table 47. Scenario B6 and BV6, maximum acoustic ranges ($R_{95\%}$ in km) to fish injury thresholds for a jacket foundation (4 post-piled pin piles, 4.25 m diameter, MHU 3500S hammer) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Hearing group	$L_{E,w,24h}$ threshold (dB re 1 µPa²·s)	Impact piling	Vibratory + impact piling
Fish ≥ 2 g [a]	187	6.10	6.58
Fish < 2 g [a]	183	8.21	8.64
Fish without swim bladder [b]	216	0.39	0.46
Fish with swim bladder [b]	203	1.66	1.87

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014).

4.2.2.3. Marine Mammals, Sea Turtles, and Fish - Behavior

Table 48. Scenarios B5 and BV5, maximum acoustic ranges ($R_{95\%}$ in km) to behavioral thresholds for a jacket foundation post-piled pin piles, 4.25 m diameter, MHU 3500S hammer, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Taxonomic group	L_p threshold (dB re 1 µPa²)	Impact piling: Acoustic range (km)	L_p threshold (dB re 1 µPa²)	Vibratory piling: Acoustic range (km)
Marine mammals	160	3.37	120	12.48
Fish	150	6.59	150	2.48
Sea turtles	175	0.81	175	0.15

Table 49. Scenarios B6 and BV6, maximum acoustic ranges ($R_{95\%}$ in km) to behavioral thresholds for a jacket foundation (post-piled pin piles, 4.25 m diameter, MHU 3500S hammer, 60 min vibratory pile-setting followed by impact) in summer and winter at locations L01 and L02 with 10 dB attenuation.

Taxonomic group	L_p threshold (dB re 1 µPa²)	Impact piling: Acoustic range (km)	L_p threshold (dB re 1 µPa²)	Vibratory piling: Acoustic range (km)
Marine mammals	160	3.43	120	16.61
Fish	150	7.84	150	3.91
Sea turtles	175	0.65	175	0.29

4.3. Exposure Estimates

This section contains tables summarizing the exposure estimates for marine mammals and sea turtles, with 10 dB attenuation. Results presented in this section are based on the construction schedules (see Modeling Pile Construction Schedules.).

4.3.1. Marine Mammals

Table 50Table 54 present the exposure estimates calculated for marine mammals using each of the proposed construction schedules, as seen in Modeling Pile Construction Schedules.

Table 50. Construction Schedule A.1 (Year 1). Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Table 22 summarizes the construction schedule assumptions.

Hearing group	Species	PTS ($L_{E,w,24h}$)	PTS (L_{pk})	Behavior (L_p) [a]	Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	4.59	0.02	87.09	12.19
LF	Humpback whale	3.16	0	44.72	7.47
LF	Common minke whale (migrating)	21.56	0	205.10	155.40
LF	North Atlantic right whale [c]	0.34	<0.01	4.49	0.82
LF	Sei whale [c] (migrating)	0	0	0	<0.01
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	149.67	16.57
MF	Atlantic white sided dolphin	0	0	493.23	50.46
MF	Common bottlenose dolphin	0	0	831.09	96.27
MF	Long-finned pilot whale	0	0	50.86	5.26
MF	Short-finned pilot whale	0	0	3.80	0.36
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	22.76	1.63
MF	Common dolphin	0	0	4100.01	446.28
HF	Harbor porpoise (sensitive)	0	2.46	329.44	283.82
PW	Gray seal	0.30	0	410.37	29.30
PW	Harbor seal	0.29	0.42	553.53	58.66

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²).

Table 51. Construction Schedule A.2 (Year 1). Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Table 23 summarizes the construction schedule assumptions.

Hearing group	Species	PTS ($L_{E,w,24h}$)	PTS (L_{pk})	Behavior (L_p) [a]	Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	2.39	<0.01	19.98	5.83
LF	Humpback whale	1.86	<0.01	12.61	4.15
LF	Common minke whale (migrating)	11.57	<0.01	62.77	90.22
LF	North Atlantic right whale [c]	0.23	<0.01	1.75	0.57
LF	Sei whale [c] (migrating)	0	0	0	0.19
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	50.61	11.87
MF	Atlantic white sided dolphin	0	0	170.06	30.34
MF	Common bottlenose dolphin	0	0	254.07	56.74
MF	Long-finned pilot whale	0	0	15.61	3.09
MF	Short-finned pilot whale	0	0	1.13	0.21
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	8.89	1.11
MF	Common dolphin	0	0	1413.00	276.41
HF	Harbor porpoise (sensitive)	0	1.44	129.09	226.68
PW	Gray seal	0.24	<0.01	166.51	22.50
PW	Harbor seal	0.15	0.17	241.41	45.71

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²).

Table 52. Construction Schedule A.2 (Year 2). Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Table 24 summarizes the construction schedule assumptions.

Hearing group	Species	PTS ($L_{E,w,24h}$)	PTS (L_{pk})	Behavior (L_p) [a]	Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	2.39	<0.01	19.98	5.83
LF	Humpback whale	1.86	<0.01	12.61	4.15
LF	Common minke whale (migrating)	11.57	<0.01	62.77	90.22
LF	North Atlantic right whale [c]	0.23	<0.01	1.75	0.57
LF	Sei whale [c] (migrating)	0	0	0	0.19
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	50.61	11.87
MF	Atlantic white sided dolphin	0	0	170.06	30.34
MF	Common bottlenose dolphin	0	0	254.07	56.74
MF	Long-finned pilot whale	0	0	15.61	3.09
MF	Short-finned pilot whale	0	0	1.13	0.21
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	8.89	1.11
MF	Common dolphin	0	0	1413.00	276.41
HF	Harbor porpoise (sensitive)	0	1.44	129.09	226.68
PW	Gray seal	0.24	<0.01	166.51	22.50
PW	Harbor seal	0.15	0.17	241.41	45.71

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²).

Table 53. Construction Schedule A.3 (Year 1). Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Table 25 summarizes the construction schedule assumptions.

Hearing group	Species	PTS ($L_{E,w,24h}$)	PTS (L_{pk})	Behavior (L_p) [a]	Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	3.40	<0.01	31.37	8.48
LF	Humpback whale	2.30	<0.01	16.91	5.26
LF	Common minke whale (migrating)	14.80	0.01	85.06	114.80
LF	North Atlantic right whale [c]	0.28	<0.01	2.54	0.72
LF	Sei whale [c] (migrating)	0	0	0	0.19
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	61.95	14.06
MF	Atlantic white sided dolphin	0	0	222.28	37.30
MF	Common bottlenose dolphin	0	0	358.33	74.88
MF	Long-finned pilot whale	0	0	22.09	4.05
MF	Short-finned pilot whale	0	0	1.61	0.28
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	13.69	1.45
MF	Common dolphin	0	0	1951.76	351.94
HF	Harbor porpoise (sensitive)	0	2.00	196.66	295.01
PW	Gray seal	0.27	<0.01	247.22	26.77
PW	Harbor seal	0.18	0.22	346.98	53.73

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2).

Table 54. Construction Schedule A.3 (Year 2). Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation. Table 26 summarizes the construction schedule assumptions.

Hearing group	Species	PTS ($L_{E,w,24h}$)	PTS (L_{pk})	Behavior (L_p) [a]	Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	1.72	<0.01	14.36	4.01
LF	Humpback whale	1.26	<0.01	7.83	2.60
LF	Common minke whale (migrating)	7.36	<0.01	40.50	57.49
LF	North Atlantic right whale [c]	0.14	<0.01	0.98	0.32
LF	Sei whale [c] (migrating)	0	0	0	0.19
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	34.27	8.85
MF	Atlantic white sided dolphin	0	0	99.37	18.22
MF	Common bottlenose dolphin	0	0	171.30	39.36
MF	Long-finned pilot whale	0	0	10.57	2.18
MF	Short-finned pilot whale	0	0	0.76	0.15
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	4.88	0.63
MF	Common dolphin	0	0	877.75	180.01
HF	Harbor porpoise (sensitive)	0	1.14	74.17	141.27
PW	Gray seal	0.13	<0.01	92.26	10.98
PW	Harbor seal	0.11	0.14	130.87	22.60

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2).

4.3.1.1. Effect of Aversion

The mean exposure estimates reported in Section 4.3.1 do not consider animals avoiding loud sounds (aversion) or implement 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), and it is assumed that most species will avert from noise. The Wood et al. (2012) criteria include 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 with and without aversion are shown for one sample year of one construction schedule (see Section 1.4.3). Aversion was not applied to the exposure estimates and is only presented here for comparison. The Proponent will implement mitigation and monitoring, including soft start for impact pile driving, to further reduce exposures.

Table 55. Construction schedule A (Year 1): Mean number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation and with and without aversion for aversive species Section 1.4.1 summarizes the construction schedule assumptions.

Species	PTS ($L_{E,w,24h}$) Without aversion	PTS (L_{pk}) Without aversion	Behavior (L_p) [a] Without aversion	Behavior ($L_{p,w}$) [b] Without aversion	PTS ($L_{E,w,24h}$) With aversion	PTS (L_{pk}) With aversion	Behavior (L_p) [a] With aversion	Behavior ($L_{p,w}$) [b] With aversion
North Atlantic right whale [c]	0.34	<0.01	4.49	0.82	0.15	0	4.09	0.66
Harbor porpoise	0	2.46	329.44	283.82	0	0	302.39	239.44

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²).

4.3.2. Sea Turtles

As was done for marine mammals (see Marine Mammals), the numbers of individual sea turtle animats predicted to receive sound levels above threshold criteria were determined using animal movement modeling. The construction schedules described in Section 1.4.3 were used to calculate the total number of individual turtles predicted to receive sound levels above injury and behavior thresholds (Finneran et al. 2017) in the Lease Area. Tables 56 to 58 include results assuming broadband attenuation of 10 dB, calculated in the same way as the marine mammal exposures.

Table 56. Construction schedule A.1: Mean number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB attenuation. Section 1.4.1 summarizes the construction schedule assumptions.

Species	Year 1 Injury $L_{E,w,24h}$ (dB re 1 µPa²·s)	Year 1 Injury L_{pk} (dB re 1 µPa)	Year 1 Behavior L_p (dB re 1 µPa²)
Kemp's ridley turtle [a]	0.02	0	0.06
Leatherback turtle [a]	0.16	0	0.74
Loggerhead turtle	0.09	0	1.00
Green turtle	0.50	0	2.07

[a] Listed as Endangered under the ESA.

Table 57. Construction schedule A.2: Mean number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB attenuation. Section 1.4.1 summarizes the construction schedule assumptions.

Species	Year 1 Injury $L_{E,w,24h}$ (dB re 1 µPa²·s)	Year 1 Injury L_{pk} (dB re 1 µPa)	Year 1 Behavior L_p (dB re 1 µPa²)	Year 2 Injury $L_{E,w,24h}$ (dB re 1 µPa²·s)	Year 2 Injury L_{pk} (dB re 1 µPa)	Year 2 Behavior L_p (dB re 1 µPa²)
Kemp's ridley turtle [a]	<0.01	0	0.03	<0.01	0	0.03
Leatherback turtle [a]	0.12	0	0.38	0.12	0	0.38
Loggerhead turtle	0.08	0	0.51	0.08	0	0.51
Green turtle	0.37	0	1.24	0.37	0	1.24

[a] Listed as Endangered under the ESA.

Table 58. Construction schedule A.3: Mean number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB at attenuation. Section 1.4.1 summarizes the construction schedule assumptions.

Species	Year 1 Injury $L_{E,w,24h}$ (dB re 1 µPa²·s)	Year 1 Injury L_{pk} (dB re 1 µPa)	Year 1 Behavior L_p (dB re 1 µPa²)	Year 2 Injury $L_{E,w,24h}$ (dB re 1 µPa²·s)	Year 2 Injury L_{pk} (dB re 1 µPa)	Year 2 Behavior L_p (dB re 1 µPa²)
Kemp's ridley turtle [a]	0.01	0	0.04	<0.01	0	0.02
Leatherback turtle [a]	0.15	0	0.54	0.12	0	0.26
Loggerhead turtle	0.10	0	0.70	0.09	0	0.35
Green turtle	0.47	0	1.79	0.33	0	1.05

[a] Listed as Endangered under the ESA.

4.4. Exposure Ranges

This section contains tables summarizing the exposure ranges, $ER_{95\%}$, to injury and behavior thresholds for marine mammals and sea turtles, with 10 dB attenuation. Only results from scenarios relevant to the construction schedules (see Modeling Pile Construction Schedules.) are presented in this section. For example, in order to be conservative, the construction schedules included Scenarios B6 and BV6 (jacket installation assuming 80 m penetration) but did not include Scenarios B5 and BV5 (jacket installation assuming 50 m). Therefore, results for Scenarios B5 and BV5 are not included below. Additional results for exposure ranges with different attenuation levels are presented in Supplement H.

4.4.1. Marine Mammals

Sections 4.4.1.1 and 4.4.1.2 summarize the exposure ranges, $ER_{95\%}$, to injury and behavior thresholds for marine mammals.

4.4.1.1. Impact Piling Only

Table 59. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	1 pile/ day PTS ($L_{E,w,24h}$)	1 pile/ day PTS (L_{pk})	1 pile/ day Behavior (L_p) [a]	1 pile/ day Behavior ($L_{p,w}$) [b]	2 piles/ day PTS ($L_{E,w,24h}$)	2 piles/ day PTS (L_{pk})	2 piles/ day Behavior (L_p) [a]	2 piles/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	1.91	0	3.38	3.42	1.96	0	3.42	3.45
LF	Humpback whale	1.72	0	3.40	3.41	1.83	0	3.41	3.42
LF	Common minke whale (migrating)	1.18	0	3.41	8.19	1.29	<0.01	3.32	8.27
LF	North Atlantic right whale [c]	1.47	<0.01	3.29	3.29	1.56	<0.01	3.27	3.28
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.24	1.44	0	0	3.28	1.48
MF	Atlantic white sided dolphin	0	0	3.29	1.45	0	0	3.28	1.50
MF	Common bottlenose dolphin	0	0	3.02	1.33	0	0	2.93	1.31
MF	Long-finned pilot whale	0	0	3.23	1.44	0	0	3.22	1.48
MF	Short-finned pilot whale	0	0	3.26	1.52	0	0	3.25	1.50
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	3.24	1.51	0	0	3.29	1.49
MF	Common dolphin	0	0	3.36	1.52	0	0	3.29	1.51
HF	Harbor porpoise (sensitive)	0	0.13	2.94	9.05	0	0.16	2.91	9.11
PW	Gray seal	0.23	0	3.48	2.47	0.40	0	3.47	2.39
PW	Harbor seal	0	0	3.16	2.19	0.19	<0.01	3.11	2.08

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

Table 60. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, winter): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	1 pile/ day PTS ($L_{E,w,24h}$)	1 pile/ day PTS (L_{pk})	1 pile/ day Behavior (L_p) [a]	1 pile/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	2.28	0	3.97	3.98
LF	Humpback whale	1.85	0	3.94	3.98
LF	Common minke whale (migrating)	1.30	0	3.91	11.87
LF	North Atlantic right whale [c]	1.63	<0.01	3.75	3.75
LF	Sei whale [c] (migrating)	0	0	0	0
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.83	1.51
MF	Atlantic white sided dolphin	0	0	3.81	1.52
MF	Common bottlenose dolphin	0	0	3.58	1.38
MF	Long-finned pilot whale	0	0	3.75	1.45
MF	Short-finned pilot whale	0	0	3.78	1.55
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	3.87	1.53
MF	Common dolphin	0	0	3.85	1.57
HF	Harbor porpoise (sensitive)	0	0.13	3.52	17.04
PW	Gray seal	0.44	0	4.04	2.61
PW	Harbor seal	0	0	3.43	2.48

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

Table 61. Scenario B2, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 8000 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	1 pile/ day PTS ($L_{E,w,24h}$)	1 pile/ day PTS (L_{pk})	1 pile/ day Behavior (L_p) [a]	1 pile/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	1.81	0	3.31	3.28
LF	Humpback whale	1.65	0	3.40	3.35
LF	Common minke whale (migrating)	1.17	0	3.21	8.19
LF	North Atlantic right whale [c]	1.48	0	3.16	3.14
LF	Sei whale [c] (migrating)	0	0	0	0
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.13	1.39
MF	Atlantic white sided dolphin	0	0	3.25	1.32
MF	Common bottlenose dolphin	0	0	2.96	1.31
MF	Long-finned pilot whale	0	0	3.09	1.44
MF	Short-finned pilot whale	0	0	3.20	1.49
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	3.17	1.43
MF	Common dolphin	0	0	3.28	1.46
HF	Harbor porpoise (sensitive)	0	0.13	2.93	9.05
PW	Gray seal	0.23	0	3.47	2.39
PW	Harbor seal	0	0	3.02	2.12

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

Table 62. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	1 pile/ day PTS ($L_{E,w,24h}$)	1 pile/ day PTS (L_{pk})	1 pile/ day Behavior (L_p) [a]	1 pile/ day Behavior ($L_{p,w}$) [b]	2 piles/ day PTS ($L_{E,w,24h}$)	2 piles/ day PTS (L_{pk})	2 piles/ day Behavior (L_p) [a]	2 piles/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	1.87	0	3.25	3.26	1.86	0	3.22	3.27
LF	Humpback whale	1.65	0	3.17	3.18	1.76	0	3.17	3.20
LF	Common minke whale (migrating)	1.17	0	2.93	7.97	1.19	<0.01	3.13	7.95
LF	North Atlantic right whale [c]	1.34	<0.01	3.15	3.17	1.48	<0.01	3.00	3.01
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.01	1.36	0	0	3.08	1.39
MF	Atlantic white sided dolphin	0	0	3.05	1.34	0	0	3.12	1.39
MF	Common bottlenose dolphin	0	0	2.78	1.28	0	0	2.79	1.22
MF	Long-finned pilot whale	0	0	3.05	1.39	0	0	3.04	1.37
MF	Short-finned pilot whale	0	0	3.06	1.47	0	0	3.09	1.38
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	3.04	1.42	0	0	3.06	1.35
MF	Common dolphin	0	0	3.13	1.44	0	0	3.09	1.43
HF	Harbor porpoise (sensitive)	0	0.14	2.84	8.77	0	0.15	2.83	8.91
PW	Gray seal	0.23	0	3.31	2.35	0.22	0	3.27	2.36
PW	Harbor seal	0	0	3.06	2.04	0	<0.01	2.83	1.95

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

Table 63. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, winter): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	1 pile/ day PTS ($L_{E,w,24h}$)	1 pile/ day PTS (L_{pk})	1 pile/ day Behavior (L_p) [a]	1 pile/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	1.94	0	3.75	3.75
LF	Humpback whale	1.74	0	3.74	3.71
LF	Common minke whale (migrating)	1.18	0	3.67	11.36
LF	North Atlantic right whale [c]	1.49	<0.01	3.65	3.65
LF	Sei whale [c] (migrating)	0	0	0	0
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.60	1.41
MF	Atlantic white sided dolphin	0	0	3.53	1.38
MF	Common bottlenose dolphin	0	0	3.36	1.31
MF	Long-finned pilot whale	0	0	3.56	1.44
MF	Short-finned pilot whale	0	0	3.61	1.52
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	3.56	1.47
MF	Common dolphin	0	0	3.63	1.52
HF	Harbor porpoise (sensitive)	0	0.07	3.32	16.07
PW	Gray seal	0.23	0	3.84	2.49
PW	Harbor seal	0	0	3.23	2.26

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

Table 64. Scenario B4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	1 pile/ day PTS ($L_{E,w,24h}$)	1 pile/ day PTS (L_{pk})	1 pile/ day Behavior (L_p) [a]	1 pile/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	1.68	0	3.22	3.22
LF	Humpback whale	1.55	0	3.14	3.13
LF	Common minke whale (migrating)	1.13	0	2.89	7.89
LF	North Atlantic right whale [c]	1.39	0	3.03	3.09
LF	Sei whale [c] (migrating)	0	0	0	0
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	2.97	1.33
MF	Atlantic white sided dolphin	0	0	3.01	1.27
MF	Common bottlenose dolphin	0	0	2.64	1.25
MF	Long-finned pilot whale	0	0	2.99	1.31
MF	Short-finned pilot whale	0	0	3.04	1.42
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	3.05	1.41
MF	Common dolphin	0	0	3.08	1.39
HF	Harbor porpoise (sensitive)	0	0.14	2.91	8.74
PW	Gray seal	0.23	0	3.28	2.35
PW	Harbor seal	0	0	2.90	1.98

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

Table 65. Scenario B4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, winter): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	1 pile/ day PTS ($L_{E,w,24h}$)	1 pile/ day PTS (L_{pk})	1 pile/ day Behavior (L_p) [a]	1 pile/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	1.92	0	3.69	3.66
LF	Humpback whale	1.78	0	3.72	3.71
LF	Common minke whale (migrating)	1.17	0	3.58	11.29
LF	North Atlantic right whale [c]	1.50	0	3.50	3.45
LF	Sei whale [c] (migrating)	0	0	0	0
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.43	1.38
MF	Atlantic white sided dolphin	0	0	3.50	1.32
MF	Common bottlenose dolphin	0	0	3.18	1.30
MF	Long-finned pilot whale	0	0	3.49	1.41
MF	Short-finned pilot whale	0	0	3.58	1.48
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	3.53	1.43
MF	Common dolphin	0	0	3.55	1.50
HF	Harbor porpoise (sensitive)	0	0.07	3.28	15.81
PW	Gray seal	0.23	0	3.75	2.39
PW	Harbor seal	0	0	3.25	2.32

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

Table 66. Scenario B6, Jacket foundation (4.25 m diameter, 3500 kJ hammer, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	4 pin piles/ day PTS ($L_{E,w,24h}$)	4 pin piles/ day PTS (L_{pk})	4 pin piles/ day Behavior (L_p) [a]	4 pin piles/ day Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	2.89	<0.01	3.25	3.28
LF	Humpback whale	2.57	<0.01	3.06	3.13
LF	Common minke whale (migrating)	1.60	0	2.91	14.65
LF	North Atlantic right whale [c]	1.96	0	2.77	2.78
LF	Sei whale [c] (migrating)	0	0	0	0
MF	Sperm whale [c]	0	0	0	0
MF	Atlantic spotted dolphin	0	0	2.77	1.29
MF	Atlantic white sided dolphin	0	0	2.83	1.26
MF	Common bottlenose dolphin	0	0	2.34	1.13
MF	Long-finned pilot whale	0	0	2.76	1.22
MF	Short-finned pilot whale	0	0	2.80	1.26
MF	Goose-beaked whale	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0
MF	Striped dolphin	0	0	0	0
MF	Risso's dolphin	0	0	2.97	1.22
MF	Common dolphin	0	0	2.80	1.29
HF	Harbor porpoise (sensitive)	0	0.05	2.45	47.18
PW	Gray seal	0.90	<0.01	3.64	2.69
PW	Harbor seal	0.21	<0.01	2.56	1.69

[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA. L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

4.4.1.2. Vibratory + Impact Piling

Table 67. Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	1.95	0.01	3.41	3.43	9.62
LF	Humpback whale	1.70	0	3.39	3.40	9.72
LF	Common minke whale (migrating)	1.17	0	3.39	8.28	9.50
LF	North Atlantic right whale [c]	1.47	<0.01	3.28	3.33	9.25
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.26	1.44	9.29
MF	Atlantic white sided dolphin	0	0	3.27	1.50	9.40
MF	Common bottlenose dolphin	0	0	3.08	1.39	8.75
MF	Long-finned pilot whale	0	0	3.21	1.44	9.21
MF	Short-finned pilot whale	0	0	3.33	1.51	9.48
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	3.25	1.52	9.41
MF	Common dolphin	0	0	3.41	1.52	9.60
HF	Harbor porpoise (sensitive)	0	0.16	3.08	9.21	8.61
PW	Gray seal	0.23	0	3.49	2.46	9.61
PW	Harbor seal	0.01	<0.01	3.16	2.19	8.86

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 68. Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	2.24	0.01	4.00	4.00	14.10
LF	Humpback whale	1.85	0	3.93	3.98	14.15
LF	Common minke whale (migrating)	1.23	0	3.90	12.03	14.01
LF	North Atlantic right whale [c]	1.64	<0.01	3.87	3.87	13.47
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.85	1.52	13.68
MF	Atlantic white sided dolphin	0	0	3.84	1.54	13.76
MF	Common bottlenose dolphin	0	0	3.62	1.45	12.93
MF	Long-finned pilot whale	0	0	3.79	1.46	13.78
MF	Short-finned pilot whale	0	0	3.86	1.56	13.94
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	3.90	1.53	13.91
MF	Common dolphin	0	0	3.88	1.61	13.79
HF	Harbor porpoise (sensitive)	0	0.16	3.53	17.27	12.86
PW	Gray seal	0.23	0	4.06	2.62	14.31
PW	Harbor seal	0.01	<0.01	3.44	2.41	12.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 69. Scenario BV2, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	1.82	0	3.36	3.34	10.00
LF	Humpback whale	1.65	0	3.40	3.37	9.98
LF	Common minke whale (migrating)	1.17	0	3.26	8.19	9.77
LF	North Atlantic right whale [c]	1.49	0	3.21	3.19	9.50
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.20	1.42	9.61
MF	Atlantic white sided dolphin	0	0	3.27	1.36	9.73
MF	Common bottlenose dolphin	0	0	3.02	1.33	9.04
MF	Long-finned pilot whale	0	0	3.13	1.44	9.51
MF	Short-finned pilot whale	0	0	3.22	1.49	9.75
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	3.23	1.44	9.62
MF	Common dolphin	0	0	3.36	1.50	9.89
HF	Harbor porpoise (sensitive)	0	0.13	3.00	9.13	8.72
PW	Gray seal	0.23	0	3.48	2.39	9.92
PW	Harbor seal	0	0	3.14	2.13	9.35

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 70. Scenario BV2, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	1.94	0	3.92	3.92	14.55
LF	Humpback whale	1.83	0	3.90	3.91	14.62
LF	Common minke whale (migrating)	1.26	0	3.89	12.01	14.45
LF	North Atlantic right whale [c]	1.53	0	3.70	3.70	13.89
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.71	1.48	14.15
MF	Atlantic white sided dolphin	0	0	3.77	1.45	14.27
MF	Common bottlenose dolphin	0	0	3.62	1.36	13.47
MF	Long-finned pilot whale	0	0	3.71	1.45	14.26
MF	Short-finned pilot whale	0	0	3.78	1.55	14.56
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	3.81	1.46	14.36
MF	Common dolphin	0	0	3.83	1.55	14.42
HF	Harbor porpoise (sensitive)	0	0.13	3.50	17.13	13.31
PW	Gray seal	0.23	0	3.96	2.58	14.72
PW	Harbor seal	0	0	3.45	2.40	13.33

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 71. Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	1.81	0	3.26	3.25	9.62
LF	Humpback whale	1.54	0	3.18	3.19	9.72
LF	Common minke whale (migrating)	1.12	0	3.11	8.05	9.50
LF	North Atlantic right whale [c]	1.41	<0.01	3.15	3.15	9.25
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.06	1.41	9.29
MF	Atlantic white sided dolphin	0	0	3.06	1.35	9.40
MF	Common bottlenose dolphin	0	0	2.88	1.30	8.75
MF	Long-finned pilot whale	0	0	3.05	1.42	9.21
MF	Short-finned pilot whale	0	0	3.08	1.46	9.48
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	3.04	1.43	9.41
MF	Common dolphin	0	0	3.16	1.45	9.60
HF	Harbor porpoise (sensitive)	0	0.16	2.85	8.85	8.61
PW	Gray seal	0.23	0	3.35	2.33	9.61
PW	Harbor seal	0.01	<0.01	3.03	2.06	8.86

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 72. Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	2.07	0	3.74	3.71	14.10
LF	Humpback whale	1.72	0	3.77	3.75	14.15
LF	Common minke whale (migrating)	1.17	0	3.71	11.43	14.01
LF	North Atlantic right whale [c]	1.46	<0.01	3.68	3.69	13.47
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.60	1.44	13.68
MF	Atlantic white sided dolphin	0	0	3.61	1.44	13.76
MF	Common bottlenose dolphin	0	0	3.35	1.40	12.93
MF	Long-finned pilot whale	0	0	3.57	1.44	13.78
MF	Short-finned pilot whale	0	0	3.65	1.51	13.94
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	3.61	1.46	13.91
MF	Common dolphin	0	0	3.66	1.52	13.79
HF	Harbor porpoise (sensitive)	0	0.07	3.40	16.20	12.86
PW	Gray seal	0.23	0	3.84	2.47	14.31
PW	Harbor seal	0.01	<0.01	3.37	2.23	12.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 73. Scenario BV4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	1.51	0	3.19	3.22	10.00
LF	Humpback whale	1.56	0	3.19	3.19	9.98
LF	Common minke whale (migrating)	1.13	0	2.93	7.98	9.77
LF	North Atlantic right whale [c]	1.40	0	3.12	3.13	9.50
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.03	1.34	9.61
MF	Atlantic white sided dolphin	0	0	3.06	1.33	9.73
MF	Common bottlenose dolphin	0	0	2.78	1.28	9.04
MF	Long-finned pilot whale	0	0	3.04	1.31	9.51
MF	Short-finned pilot whale	0	0	3.08	1.45	9.75
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville’s beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso’s dolphin	0	0	3.05	1.41	9.62
MF	Common dolphin	0	0	3.14	1.40	9.89
HF	Harbor porpoise (sensitive)	0	0.14	2.90	8.84	8.72
PW	Gray seal	0.23	0	3.29	2.35	9.92
PW	Harbor seal	0	0	2.96	1.98	9.35

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 74. Scenario BV4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	1.88	0	3.72	3.69	14.55
LF	Humpback whale	1.71	0	3.74	3.73	14.62
LF	Common minke whale (migrating)	1.17	0	3.62	11.39	14.45
LF	North Atlantic right whale [c]	1.49	0	3.51	3.45	13.89
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	3.46	1.41	14.15
MF	Atlantic white sided dolphin	0	0	3.53	1.36	14.27
MF	Common bottlenose dolphin	0	0	3.28	1.34	13.47
MF	Long-finned pilot whale	0	0	3.54	1.41	14.26
MF	Short-finned pilot whale	0	0	3.60	1.49	14.56
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	3.59	1.44	14.36
MF	Common dolphin	0	0	3.59	1.50	14.42
HF	Harbor porpoise (sensitive)	0	0.07	3.36	16.07	13.31
PW	Gray seal	0.23	0	3.75	2.39	14.72
PW	Harbor seal	0	0	3.41	2.36	13.33

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

Table 75. Scenario BV6, Jacket foundation (4.25 m diameter, post-piled, 3500 kJ hammer, four per day, summer): Vibratory setting (CV320, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with 10 dB attenuation.

Hearing group	Species	PTS Vibratory + impact piling ($L_{E,w,24h}$)	PTS Vibratory + impact piling (L_{pk})	Behavior Impact piling (L_p [a])	Behavior Impact piling ($L_{p,w}$ [b])	Behavior Vibratory piling (L_p [a])
LF	Fin whale [c]	2.02	<0.01	2.68	2.70	11.33
LF	Humpback whale	1.79	0	2.58	2.59	11.39
LF	Common minke whale (migrating)	1.15	0	2.37	8.23	11.15
LF	North Atlantic right whale [c]	1.49	0	2.52	2.54	10.83
LF	Sei whale [c] (migrating)	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	2.43	1.18	11.18
MF	Atlantic white sided dolphin	0	0	2.48	1.18	11.19
MF	Common bottlenose dolphin	0	0	2.02	1.07	10.48
MF	Long-finned pilot whale	0	0	2.31	1.13	10.95
MF	Short-finned pilot whale	0	0	2.45	1.19	11.19
MF	Goose-beaked whale	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0
MF	Risso's dolphin	0	0	2.43	1.09	10.97
MF	Common dolphin	0	0	2.51	1.20	11.28
HF	Harbor porpoise (sensitive)	0	0.03	2.12	11.07	10.08
PW	Gray seal	0.61	0	3.01	2.24	11.28
PW	Harbor seal	0.15	0	2.31	1.64	10.17

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

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

4.4.2. Sea Turtles

Similar to the results presented for marine mammals (see Section 4.4), Sections 4.4.2.1 and 4.4.2.2 summarize the exposure ranges ($ER_{95\%}$) for sea turtles.

4.4.2.1. Impact Piling Only

Table 76. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)	2 piles/ day Injury ($L_{E,w,24h}$)	2 piles/ day Injury (L_{pk})	2 piles/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.74	0.28	0	0.88
Leatherback turtle [a]	0.64	0	1.13	0.63	0	1.17
Loggerhead turtle	0.37	0	1.00	0.40	0	1.02
Green turtle	0.16	0	1.04	0.21	0	1.04

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 77. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, winter): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.86
Leatherback turtle [a]	0.68	0	1.18
Loggerhead turtle	0.37	0	1.00
Green turtle	0.25	0	1.09

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 78. Scenario B2, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 8000 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.81
Leatherback turtle [a]	0.55	0	1.13
Loggerhead turtle	0.13	0	0.98
Green turtle	0.17	0	1.05

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 79. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)	2 piles/ day Injury ($L_{E,w,24h}$)	2 piles/ day Injury (L_{pk})	2 piles/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.20	0	0.70	0.17	0	0.89
Leatherback turtle [a]	0.55	0	1.10	0.53	0	1.07
Loggerhead turtle	0.42	0	0.98	0.41	0	0.96
Green turtle	0.16	0	0.99	0.21	0	1.00

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 80. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, winter): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.20	0	0.74
Leatherback turtle [a]	0.55	0	1.13
Loggerhead turtle	0.40	0	0.98
Green turtle	0.16	0	0.98

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 81. Scenario B4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.82
Leatherback turtle [a]	0.35	0	1.09
Loggerhead turtle	0	0	0.97
Green turtle	0.17	0	0.88

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 82. Scenario B4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, winter): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.20	0	0.81
Leatherback turtle [a]	0.35	0	1.09
Loggerhead turtle	0	0	0.98
Green turtle	0.17	0	0.88

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 83. Scenario B6, Jacket foundation (4.25 m diameter, 3500 kJ hammer, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	4 piles/ day Injury ($L_{E,w,24h}$)	4 piles/ day Injury (L_{pk})	4 piles/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.29	0	0.48
Leatherback turtle [a]	1.08	0	0.91
Loggerhead turtle	0.42	0	0.57
Green turtle	0.29	0	0.52

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

4.4.2.2. Vibratory + Impact Piling

Table 84. Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, summer): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.74
Leatherback turtle [a]	0.64	0	1.13
Loggerhead turtle	0.22	0	0.98
Green turtle	0.17	0	0.94

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 85. Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, winter): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.88
Leatherback turtle [a]	0.68	0	1.16
Loggerhead turtle	0.22	0	0.98
Green turtle	0.24	0	0.94

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 86. Scenario BV2, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 8000 kJ, summer): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.90
Leatherback turtle [a]	0.55	0	1.13
Loggerhead turtle	0.39	0	0.99
Green turtle	0.17	0	1.06

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 87. Scenario BV2, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 8000 kJ, winter): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.91
Leatherback turtle [a]	0.55	0	1.13
Loggerhead turtle	0.38	0	1.01
Green turtle	0.17	0	1.09

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 88. Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, summer): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.20	0	0.75
Leatherback turtle [a]	0.56	0	1.13
Loggerhead turtle	0.17	0	0.98
Green turtle	0.17	0	0.87

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 89. Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, winter): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.20	0	0.74
Leatherback turtle [a]	0.64	0	1.13
Loggerhead turtle	0.16	0	0.98
Green turtle	0.17	0	0.90

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 90. Scenario BV4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, summer): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.91
Leatherback turtle [a]	0.35	0	1.09
Loggerhead turtle	0	0	0.99
Green turtle	0.17	0	0.88

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 91. Scenario BV4, Monopile foundation (12.5 m diameter, normal, 5500 kJ hammer scaled to 6600 kJ, winter): Vibratory setting (TR-CV640, 30 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	1 pile/ day Injury ($L_{E,w,24h}$)	1 pile/ day Injury (L_{pk})	1 pile/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.21	0	0.90
Leatherback turtle [a]	0.35	0	1.09
Loggerhead turtle	0	0	0.99
Green turtle	0.17	0	0.88

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table 92. Scenario BV6, Jacket foundation (4.25 m diameter, post-piled, 3500 kJ hammer, summer): Vibratory setting (TR-CV640, 60 min) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with 10 dB attenuation.

Species	4 piles/ day Injury ($L_{E,w,24h}$)	4 piles/ day Injury (L_{pk})	4 piles/ day Behavior (L_p)
Kemp's ridley turtle [a]	0.16	0	0.42
Leatherback turtle [a]	1.03	0	0.59
Loggerhead turtle	0.42	0	0.42
Green turtle	0.19	0	0.50

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

5. Discussion

This study predicted underwater sound levels associated with installing piles during impact piling and vibratory pile setting followed by impact pile driving. The piles installed will support the WTGs and ESP(s). The monopile diameter of 12.5 m was considered for normal and difficult to drive scenarios. The jacket foundations use 4.25 diameter pin piles. Sound fields produced during pile driving for the monopile and jacket foundations were determined using a three-step process. First, the force applied by the hammer at the top of the pile was computed. Second, JASCO's PDSM was used to model the vibration of the pile and to obtain a point-source array representation of the sound radiating from the pile due to such vibrations. Third, JASCO's FWRAM model was used to propagate this sound field into the environment. Acoustic ranges to injury and behavioral thresholds were calculated for installing the monopile and jacket foundations (see Section 4.2 and Supplements F and G).

Sound fields were sampled by simulating animal movement within the acoustic fields and determining if marine mammal and sea turtle animats (simulated animals) exceed regulatory thresholds. For those animats that exceeded thresholds, the closest point of approach to the source was found and the distance accounting for 95% of exceedances was reported as the exposure range, $ER_{95\%}$. The species-specific $ER_{95\%}$ (see tables in Section 4.2) were determined with different broadband attenuation levels (0, 6, 10, and 12 dB) to account for the use of noise abatement systems, such as bubble curtains. $ER_{95\%}$ can be used for mitigation purposes such as establishing monitoring areas or shutdown zones. Exposure estimates (see Section 4.2) and exposure ranges (see Section 4.4) for monopile and jacket foundation installation were calculated for the different construction schedules over various years of construction (see Section 1.4).

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 Supplements F.4 and G.3).

5.1. Exposure Estimates for Marine Mammals and Sea Turtles

The potential risk of exposure for marine mammals and sea turtles was estimated from the sound levels received by each animat over the course of the JASMINE simulation, comparing those levels with the relevant regulatory thresholds, scaling by the mean monthly densities for each marine mammal species (Roberts et al. 2016, 2023, 2024) and sea turtle species (DiMatteo et al. 2024), and then summing over the construction period to get the total number of individual animals that may experience sound levels exceeding regulatory thresholds. Section 1.3 details these thresholds. The thresholds for injurious exposures are based on cumulative SEL and maximum PK pressure level (NMFS 2018). Thresholds for behavioral disruption are based on maximum SPL (NOAA 2005, Wood et al. 2012, Finneran et al. 2017).

Based on this modeling exercise and assuming 10dB of attenuation, the endangered NARW is predicted to experience no more than 1 injury-level exposure per year during any construction schedule. This corresponds to approximately 0.3% of the total species abundance (Table 27 provides abundances for all species). The Proponent is expected to implement several monitoring and mitigation measures to prevent injurious exposures to NARW and no injurious exposures are anticipated. The predicted number of exposures above SEL injury threshold for all low-frequency cetaceans, assuming 10 dB attenuation, varies from less than one individual per year (North Atlantic right whale) to 22 individuals (minke whale; Schedule A.1). No injury-level acoustic exposures are predicted for mid-frequency and high frequency cetacean species at 10 dB attenuation, but up to one gray seal and harbor seal injury-level exposure is expected.

For NARW, up to 5 animals per year are predicted to experience sound levels exceeding the 160 dB behavioral threshold, which corresponds to 1.5% of the total population. Due to their relatively high local monthly densities, common dolphins have the highest predicted number of exposures above behavioral thresholds with up to approximately 4100 animals (approximately 4.4% of the population) per year. Using the Wood et al. (2012) criteria, behavioral exposure estimates for NARW are lower than for other low-frequency species, with a maximum annual prediction of up to 1 animal per year. Minke whales consistently have the highest predicted number of exposures for low-frequency species for this metric, with a maximum of 156 animals per year. The largest behavior exposure estimate for pinnipeds is the harbor seal, at 554 animals per year.

Fewer than 2 sea turtles of all species per year are predicted to be exposed to sound levels exceeding injury or behavior thresholds during any proposed construction schedule.

These values are maximum annual estimates. The total numbers for the entire project will be less than these values for Schedule A.1 or multiplied by two for the construction schedules A.2 and A.3 (see Section 4.3). 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, monitoring, and mitigation will reduce the number of marine mammal and sea turtle exposures.

5.2. Exposure Ranges for Marine Mammals and Sea Turtles

The maximum $ER_{95\%}$ NARW exposure range across all foundation types to injury thresholds for any source with 10 dB attenuation is 1.96 km. The maximum NARW exposure range for potential behavioral disruption is 13.89 km. For all low frequency cetaceans, the maximum $ER_{95\%}$ exposure range to injury thresholds is 2.89 and 14.62 km for behavioral thresholds. Exposure ranges ($ER_{95\%}$) are not expected to exceed injury thresholds for mid-frequency cetaceans. The maximum $ER_{95\%}$ exposure range to behavioral thresholds for mid-frequency cetaceans is 17.27 km for the Wood et al. (2012) criteria and 14.56 km for the NMFS (2018) criteria. For harbor porpoise, the exposure range to injury thresholds is up to 0.16 km and the maximum exposure range to behavioral thresholds for the Wood et al. (2012) criteria is 17.27 km and is 47.18 km for the NMFS (2018) criteria. Tables 93 and 94 summarize the exposure ranges for each marine mammals species for impact only to PTS criteria. Tables 95 and 96 present the summary ranges for vibratory and impact driving. The maximum exposure range for sea turtle injury for any foundation type is 1.08 km. Sea turtle maximum exposure range for behavioral disruption is approximately 1.26 km.

Table 93. PTS: One foundation per day, Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria in summer with 10 dB attenuation.

Hearing group	Species	B1. MP PTS ($L_{E,w,24h}$)	B1. MP PTS (L_{pk})	B2. MP PTS ($L_{E,w,24h}$)	B2. MP PTS (L_{pk})	B3. MP PTS ($L_{E,w,24h}$)	B3. MP PTS (L_{pk})	B4. MP PTS ($L_{E,w,24h}$)	B4. MP PTS (L_{pk})	B6. PP PTS ($L_{E,w,24h}$)	B6. PP PTS (L_{pk})
LF	Fin whale [c]	1.91	0	1.81	0	1.87	0	1.68	0	2.89	<0.01
LF	Humpback whale	1.72	0	1.65	0	1.65	0	1.55	0	2.57	<0.01
LF	Common minke whale (migrating)	1.18	0	1.17	0	1.17	0	1.13	0	1.60	0
LF	North Atlantic right whale [c]	1.47	<0.01	1.48	0	1.34	<0.01	1.39	0	1.96	0
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	0	0	0	0	0	0
MF	Common dolphin	0	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0.13	0	0.13	0	0.14	0	0.14	0	0.05
PW	Gray seal	0.23	0	0.23	0	0.23	0	0.23	0	0.90	<0.01
PW	Harbor seal	0	0	0	0	0	0	0	0	0.21	<0.01

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL; MP = monopile; PP = pin pile

B1 and B2 = 12.5 m, 8000 kJ

B3 and B4 = 12.5 m, 6600 kJ

B5 and B6 = 4.5 m, 3500 kJ

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

Table 94. PTS: One foundation per day, Vibratory + Impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria in summer with 10 dB attenuation.

Hearing group	Species	BV1. MP PTS ($L_{E,w,24h}$)	BV1. MP PTS (L_{pk})	BV2. MP PTS ($L_{E,w,24h}$)	BV2. MP PTS (L_{pk})	BV3. MP PTS ($L_{E,w,24h}$)	BV3. MP PTS (L_{pk})	BV4. MP PTS ($L_{E,w,24h}$)	BV4. MP PTS (L_{pk})	BV6. PP PTS ($L_{E,w,24h}$)	BV6. PP PTS (L_{pk})
LF	Fin whale [c]	1.95	0.01	1.82	0	1.81	0	1.51	0	2.02	<0.01
LF	Humpback whale	1.70	0	1.65	0	1.54	0	1.56	0	1.79	0
LF	Common minke whale (migrating)	1.17	0	1.17	0	1.12	0	1.13	0	1.15	0
LF	North Atlantic right whale [c]	1.47	<0.01	1.49	0	1.41	<0.01	1.40	0	1.49	0
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	0	0	0	0	0	0
MF	Common dolphin	0	0	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0.16	0	0.13	0	0.16	0	0.14	0	0.03
PW	Gray seal	0.23	0	0.23	0	0.23	0	0.23	0	0.61	0
PW	Harbor seal	0.01	<0.01	0	0	0.01	<0.01	0	0	0.15	0

L_{pk}—peak sound pressure level (dB re 1 μPa), L_E—sound exposure level (dB re 1 μPa^2·s), L_p—root mean square sound pressure level (dB re 1 μPa^2), w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

BV1 and BV2 = 12.5 m, 8000 kJ

BV3 and BV4 = 12.5 m, 6600 kJ

BV5 and BV6 = 4.5 m, 3500 kJ

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

Table 95. Behavior: One foundation per day, Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria in summer with 10 dB attenuation.

Hearing group	Species	B1. MP Behavior (L_p) [a]	B1. MP Behavior ($L_{p,w}$) [b]	B2. MP Behavior (L_p) [a]	B2. MP Behavior ($L_{p,w}$) [b]	B3. MP Behavior (L_p) [a]	B3. MP Behavior ($L_{p,w}$) [b]	B4. MP Behavior (L_p) [a]	B4. MP Behavior ($L_{p,w}$) [b]	B6. PP Behavior (L_p) [a]	B6. PP Behavior ($L_{p,w}$) [b]
LF	Fin whale [c]	3.38	3.42	3.31	3.28	3.25	3.26	3.22	3.22	3.25	3.28
LF	Humpback whale	3.40	3.41	3.40	3.35	3.17	3.18	3.14	3.13	3.06	3.13
LF	Common minke whale (migrating)	3.41	8.19	3.21	8.19	2.93	7.97	2.89	7.89	2.91	14.65
LF	North Atlantic right whale [c]	3.29	3.29	3.16	3.14	3.15	3.17	3.03	3.09	2.77	2.78
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	3.24	1.44	3.13	1.39	3.01	1.36	2.97	1.33	2.77	1.29
MF	Atlantic white sided dolphin	3.29	1.45	3.25	1.32	3.05	1.34	3.01	1.27	2.83	1.26
MF	Common bottlenose dolphin	3.02	1.33	2.96	1.31	2.78	1.28	2.64	1.25	2.34	1.13
MF	Long-finned pilot whale	3.23	1.44	3.09	1.44	3.05	1.39	2.99	1.31	2.76	1.22
MF	Short-finned pilot whale	3.26	1.52	3.20	1.49	3.06	1.47	3.04	1.42	2.80	1.26
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	3.24	1.51	3.17	1.43	3.04	1.42	3.05	1.41	2.97	1.22
MF	Common dolphin	3.36	1.52	3.28	1.46	3.13	1.44	3.08	1.39	2.80	1.29
HF	Harbor porpoise (sensitive)	2.94	9.05	2.93	9.05	2.84	8.77	2.91	8.74	2.45	47.18
PW	Gray seal	3.48	2.47	3.47	2.39	3.31	2.35	3.28	2.35	3.64	2.69
PW	Harbor seal	3.16	2.19	3.02	2.12	3.06	2.04	2.90	1.98	2.56	1.69

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2). The w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL; MP = monopile; PP = pin pile

B1 and B2 = 12.5 m, 8000 kJ

B3 and B4 = 12.5 m, 6600 kJ

B5 and B6 = 4.5 m, 3500 kJ

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

Table 96. Behavior: One foundation per day, Vibratory + Impact exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria in summer with 10 dB attenuation.

Hearing group	Species	BV1. MP Impact piling Behavior (L_p) [a]	BV1. MP Impact piling Behavior ($L_{p,w}$) [b]	BV1. MP Vibratory piling Behavior (L_p) [a]	BV2. MP Impact piling Behavior (L_p) [a]	BV2. MP Impact piling Behavior ($L_{p,w}$) [b]	BV2. MP Vibratory piling Behavior (L_p) [a]	BV3. MP Impact piling Behavior (L_p) [a]	BV3. MP Impact piling Behavior ($L_{p,w}$) [b]	BV3. MP Vibratory piling Behavior (L_p) [a]	BV4. MP Impact piling Behavior (L_p) [a]	BV4. MP Impact piling Behavior ($L_{p,w}$) [b]	BV4. MP Vibratory piling Behavior (L_p) [a]	BV6. PP Impact piling Behavior (L_p) [a]	BV6. PP Impact piling Behavior ($L_{p,w}$) [b]	BV6. PP Vibratory piling Behavior (L_p) [a]
LF	Fin whale [c]	3.41	3.43	9.62	3.36	3.34	10.00	3.26	3.25	9.62	3.19	3.22	10.00	2.68	2.70	11.33
LF	Humpback whale	3.39	3.40	9.72	3.40	3.37	9.98	3.18	3.19	9.72	3.19	3.19	9.98	2.58	2.59	11.39
LF	Common minke whale (migrating)	3.39	8.28	9.50	3.26	8.19	9.77	3.11	8.05	9.50	2.93	7.98	9.77	2.37	8.23	11.15
LF	North Atlantic right whale [c]	3.28	3.33	9.25	3.21	3.19	9.50	3.15	3.15	9.25	3.12	3.13	9.50	2.52	2.54	10.83
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	3.26	1.44	9.29	3.20	1.42	9.61	3.06	1.41	9.29	3.03	1.34	9.61	2.43	1.18	11.18
MF	Atlantic white sided dolphin	3.27	1.50	9.40	3.27	1.36	9.73	3.06	1.35	9.40	3.06	1.33	9.73	2.48	1.18	11.19
MF	Common bottlenose dolphin	3.08	1.39	8.75	3.02	1.33	9.04	2.88	1.30	8.75	2.78	1.28	9.04	2.02	1.07	10.48
MF	Long-finned pilot whale	3.21	1.44	9.21	3.13	1.44	9.51	3.05	1.42	9.21	3.04	1.31	9.51	2.31	1.13	10.95
MF	Short-finned pilot whale	3.33	1.51	9.48	3.22	1.49	9.75	3.08	1.46	9.48	3.08	1.45	9.75	2.45	1.19	11.19
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	3.25	1.52	9.41	3.23	1.44	9.62	3.04	1.43	9.41	3.05	1.41	9.62	2.43	1.09	10.97
MF	Common dolphin	3.41	1.52	9.60	3.36	1.50	9.89	3.16	1.45	9.60	3.14	1.40	9.89	2.51	1.20	11.28
HF	Harbor porpoise (sensitive)	3.08	9.21	8.61	3.00	9.13	8.72	2.85	8.85	8.61	2.90	8.84	8.72	2.12	11.07	10.08
PW	Gray seal	3.49	2.46	9.61	3.48	2.39	9.92	3.35	2.33	9.61	3.29	2.35	9.92	3.01	2.24	11.28
PW	Harbor seal	3.16	2.19	8.86	3.14	2.13	9.35	3.03	2.06	8.86	2.96	1.98	9.35	2.31	1.64	10.17

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), w in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function. The 24h in $L_{E,w,24h}$ indicates that a 24 h period was used to calculate cumulative SEL.

BV1 and BV2 = 12.5 m, 8000 kJ

BV3 and BV4 = 12.5 m, 6600 kJ

BV5 and BV6 = 4.5 m, 3500 kJ

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

5.3. Acoustic Ranges for Fish

Acoustic ranges are the only results calculated for fish, for which no density estimates currently exist. Therefore, fish are not considered for animat modeling or exposure estimates. Using exposure guidelines defined by Popper et al. (2014), acoustic results indicate that ranges to potential injury for fish without swim bladders are short, less than 1 km. The maximum range to the SEL threshold defining potential injury across all hearing groups occurs for fish of less than 2 g in winter and reaches 8.64 km for 4 post-piled pin piles, assuming 10 dB of attenuation. NMFS (2023) defines a broad behavioral criterion for all fish of 150 dB re 1 µPa^2 SPL ($R_{95\%}$), which corresponds to a maximum range to threshold of 7.84 km among all the modeled pile installations. The maximum range to threshold to the 150 dB re 1 µPa^2 for vibratory pile driving is considerably shorter than that of the impact pile driving.

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Glossary of Acoustics Terms

Unless otherwise stated in an entry, these definitions are consistent with ISO 18405 (2017).

Light blue text indicates related terms that might be in this glossary. Dark blue text indicates clickable links to related terms in this glossary

absorption

The conversion of sound energy to heat energy. Specifically, the reduction of sound pressure amplitude due to particle motion energy converting to heat in the propagation medium.

acoustic impedance

The product of the density and speed of sound for a medium. It is a measure of how well sound propagates through a particular 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 (ISO 18405:2017). It is 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.

auditory frequency weighting

The process of applying an auditory frequency-weighting 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.

attenuation

The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium. Attenuation depends on frequency—higher frequency sounds are attenuated faster than lower frequency sounds.

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.

bandwidth

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

broadband level

The total level measured over a specified frequency range. If the frequency range is unspecified, the term refers to the entire measured frequency range.

cetacean

Member of the order Cetacea. Cetaceans are aquatic mammals and include whales, dolphins, and porpoises.

continuous sound

A sound whose sound pressure level remains above the background noise during the observation period and may gradually vary 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). For example, one decade up from 1000 Hz is 10,000 Hz, and one decade down is 100 Hz.

decibel (dB)

Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale. Especially suited to quantify variables with a large dynamic range.

decidecade

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

decidecade band

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

delphinid

Member of the family of oceanic dolphins (Delphinidae), composed of approximately 35 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 $\mu Pa^2 m^2 s$.

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 (ISO 18405:2017). 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, which typically consists of a hydrophone, one or more amplifiers, and an analog-to-digital converter.

functional hearing group

Category of animal species when classified according to their hearing sensitivity, hearing anatomy, and susceptibility to sound. For marine mammals, initial groupings were proposed by Southall et al. (2007), and revised groupings are developed as new research/data becomes available. Revised groupings proposed by Southall et al. (2019) include low-frequency cetaceans, high-frequency cetaceans, very high-frequency cetaceans, phocid carnivores in water, other carnivores in water, and sirenians. Example hearing groups 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). See also auditory frequency-weighting functions, which are often applied to these groups.

geoacoustic

Relating to the acoustic properties of the seabed.

hearing threshold

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

hertz (Hz)

Unit of frequency defined as one cycle per second. Often expressed in multiples such as kilohertz (1 kHz = 1000 Hz).

high-frequency (HF) cetaceans

See functional hearing group. The mid- and high-frequency cetaceans groups proposed by Southall et al. (2007) were renamed high- and very-high-frequency cetaceans, respectively, by Southall et al. (2019).

hydrostatic pressure

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).

intermittent sound

A sound whose level abruptly drops below the background noise level multiple 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. Sources of impulsive sound include, among others, explosives, seismic airguns, and impact pile drivers.

isopleth

A line drawn on a map through all points having the same value of some specified quantity (e.g., sound pressure level isopleth).

kilonewton

A unit of force equivalent to 1000 kg·m/s^2. Unit abbreviation: kN.

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 functional hearing group.

mid-frequency (MF) cetaceans

See **functional hearing group**. The mid-frequency cetaceans group proposed by Southall et al. (2007) was renamed high-frequency cetaceans by Southall et al. (2019).

M-weighting

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

mysticete

Member of the Mysticeti, a suborder of cetaceans. Also known as baleen whales, mysticetes have baleen plates (rather than teeth) that they use to filter food from water (or from sediment as for gray whales). This group includes rorquals (Balaenopteridae, such as blue, fin, humpback, and minke whales), right and bowhead whales (Balaenidae), and gray whales (*Eschrichtius robustus*).

non-impulsive sound

Sound that is not an impulsive sound. 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

Member of Odontoceti, a suborder of cetaceans. These whales, dolphins, and porpoises have teeth (rather than baleen plates). Their skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid

Member of the family Otariidae, one of the three groupings of pinnipeds (along with phocids and walrus). These eared seals, commonly called fur seals and sea lions, are adapted to semi-aquatic life; they use their large fore flippers for propulsion underwater and can walk on all four limbs on land.

particle acceleration, particle displacement, particle motion, particle velocity

See sound particle acceleration, sound particle displacement, sound particle motion, and 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} = 10log$_{10}$(p_{pk}^2/p_0^2) = 20log$_{10}$(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 with temporary threshold shift.

phocid

Member of the family Phocidae, one of the three groupings of pinnipeds (along with otariids and walrus). 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 underwater.

pinniped

Member of the superfamily Pinnipedia, which is composed of 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, sound particle displacement).

power spectral density level

The level ($L_{P,f}$) of the power spectral density (P_f) in a stated frequency band and time window. Defined as: $L_{P,f}$ = 10log$_{10}$($P_f / P_{f,0}$). Unit: decibel (dB).

As with power spectral density, power spectral density level can be expressed in terms of various field variables (e.g., sound pressure, sound particle displacement). The reference value ($P_{f,0}$) for power spectral density level depends on the nature of the field variable.

power spectral density source level

A property of a sound source equal to the power spectral density level of the sound pressure 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/Hz.

propagation loss (PL)

Difference between a source level (SL) and the level at a specified location, PL(x) = SL − 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 given 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	δ_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. In common meaning, a form of energy that propagates through media (e.g., water, air, ground) as pressure waves.

sound exposure

Time integral of squared sound pressure over a stated time interval in a stated frequency band. 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: $L_E = 10\log_{10}(E/E_0)$ (ISO 18405:2017). 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 displacement

Displacement of a material element caused by the action of sound, where a material element is the smallest element of the medium that represents the medium's mean density (ISO 18405:2017). Unit: meter (m). Symbol: δ.

sound particle motion

Movement caused by the action of sound of the smallest volume of a medium that represents its mean physical properties. Important for determining effects of underwater noise on fishes and invertebrates because their hearing organs sense particle motion rather than sound pressure.

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 ($p^2_{\rm rms}$) in a stated frequency band and time window: L_p = $10\log_{10}(p^2_{\rm rms}/p^2_0)$ = $20\log_{10}(p_{\rm rms}/p_0)$, where rms is the abbreviation for root-mean-square. Unit: decibel (dB). Reference value (p^2_0) for sound in water: 1 μPa^2. SPL can also be expressed in terms of the root-mean-square (rms) with a reference value of p_0 = 1 μPa. The two definitions are equivalent.

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

Distribution of acoustic signal content over frequency, where the signal's content is represented by its power, energy, mean-square sound pressure, or sound exposure.

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: $\mathrm{TL}(x_1,x_2) = L(x_1) - L(x_2)$ (ISO 18405:2017). Unit: decibel (dB). See also propagation loss.

unweighted

Term indicating that no frequency-weighting function is applied.

Supplement 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 and driving pressure. Maximum sound levels from pile installation usually occur during the last stage of driving (Betke 2008). For the present study, the client provided JASCO with representative makes and models of impact and vibratory hammers, and the hammering energy schedule.

Vineyard Mid-Atlantic is expected to install different WTG monopile foundations consisting of single uniform piles. For monopile foundation models, piles are assumed to be vertical and driven to penetration depths of 45 m (148 ft) for uniform 12.5-m piles. Jacket foundations are also expected to be installed in the Lease Area. For such installations, uniform pin piles are assumed to be vertical and driven to penetration depths of 50 m (164 ft) and 80 m (263 ft) within the lease area.

While monopile and pin pile penetrations across the Lease Area 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 evaluations were performed assuming that only one pile is driven at a time. Table A-1 lists the modeling input, assumptions, and methods for monopiles. Table A-2 list the same for jackets. Table A-3 lists environmental assumptions. Table A-4 lists propagation modeling assumptions.

Table A-1. 12.5 m monopile foundation: Details of model inputs, assumptions, and methods for the expected installation scenarios. A difficult-to-drive scenario with drivability analysis containing higher hammer energies was modeled and appears in parentheses following the typical Scenario B assumptions.

Parameter	Description
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; Hammer forcing functions computed using GRLWEAP
Vibratory hammer frequency	23.3 Hz
Number of clamps	16
Weight of individual clamps	65.7 kN
Time of vibratory installation	30 min, 60 min
Impact hammer energy	Menck 5500 kJ (scaled to 6600, and 8000 kJ)
Ram weight	2726 kN
Helmet weight	2351 kN
Strike rate (min-1)	30
Estimated number of strikes to drive pile	6049, 5563 (with vibratory – 5058, 4090)
Expected maximum penetration	45 m
Modeled seabed penetration per energy level	6, 8, 4, 27(with vibratory – 6, 10, 2, 27)
Pile length	126 m
Pile diameter	12.5 m
Pile wall thickness	20 cm (uniform)

Table A-2. 4.25 m jacket: Details of model inputs, assumptions, and methods for the expected installation scenarios.

Parameter	Description
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; Hammer forcing functions computed using GRLWEAP
Vibratory hammer frequency	23.3 Hz
Number of clamps	6
Weight of individual clamps	65.7 kN
Time of vibratory installation	60 min
Impact hammer energy	3500 kJ
Ram weight	1719 kN
Helmet weight	1830 kN
Strike rate (min-1)	28 or 44 for 4 pin piles; (with Vibratory - 27 or 50 for 4 pin piles)
Estimated number of strikes to drive pile	9700, 15,400 (with Vibratory – 7500, 14000)
Expected maximum penetration	50, 80 m
Modeled seabed penetration per energy level	5, 5, 5, 5, 5, 25 m; 10, 10, 10, 10, 10, 10, 10, 10 m; (with Vibratory - 10, 5, 5, 5, 5, 5, 15 m; 10, 10, 10, 10, 10, 10, 10, 10 m)
Pile length	60, 90 m
Pile diameter	4.25 m
Pile wall thickness	10 cm (uniform)

Table A-3. Environmental parameters for all pile types for the expected installation scenarios.

Parameter	Description
Sound speed profile	GDEM data averaged over region
Bathymetry	US Coastal Relief Model, National Centers for Environmental Information NOAA (September 2010) (NGDC 2003)
Geoacoustics	Elastic seabed properties based on client-supplied description of seabed layering
Quake (shaft and toe)	2.54 mm
Shaft damping	0.164 s/m
Toe damping	0.49 s/m

Table A-4. Propagation model used for all pile types for the expected installation scenarios.

Parameter	Description
Modeling method	FWRAM full-waveform parabolic equation propagation model with 22.5° azimuthal resolution and 10 m range resolution
Source representation	Vertical line array
Frequency range	10–25,000 Hz
Synthetic trace length	Monopiles: Impact, 500 ms; Vibratory, 1100 ms Jacket: Impact, 500 ms; Vibratory, 1100 ms
Maximum modeled range	120 km

Supplement B. Underwater Acoustics

This section provides a detailed description of the acoustic metrics and decidecade frequency bands 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 in water and p_0 = 20 μPa in air. Because the perceived loudness of sound, especially impulsive noise 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 noise and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow ISO standard definitions and symbols for sound metrics (e.g., ISO 2017).

The zero-to-peak sound pressure level, or peak sound pressure level (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, $p(t)$:

$$L_{p,\mathrm{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \quad \text{(B-1)}$$

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 a noise 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 a rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right)\ \mathrm{dB}\,, \quad \text{(B-2)}$$

where $g(t)$ 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 L_p 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 $g(t)$ 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 L_p ($L_{p,\mathrm{fast}}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,\mathrm{boxcar\ 125ms}}$. Another approach, historically used to evaluate L_p of impulsive signals underwater, defines $g(t)$ 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 µPa²·s) is the time-integral of the squared acoustic pressure over a duration (T):

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

where T_0 is a reference time interval of 1 s. L_E 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 in terms of relevance for 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 impulsive 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:

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

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 decidecade bands, which are approximately one-tenth of a decade wide and often referred to as 1/3-octave-bands. Each octave represents a doubling in sound frequency. The center frequency of the *i* th band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{\frac{i}{10}}\ \text{kHz} \quad \text{(B-5)}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the *i* th decade band are defined as:

$$f_{lo,i} = 10^{\frac{-1}{20}} f_c(i) \quad \text{and} \quad f_{hi,i} = 10^{\frac{1}{20}} f_c(i) \quad \text{(B-6)}$$

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 −20 (f_c (−20) = 0.010 kHz) to band 14 (f_c (14) = 25 kHz).

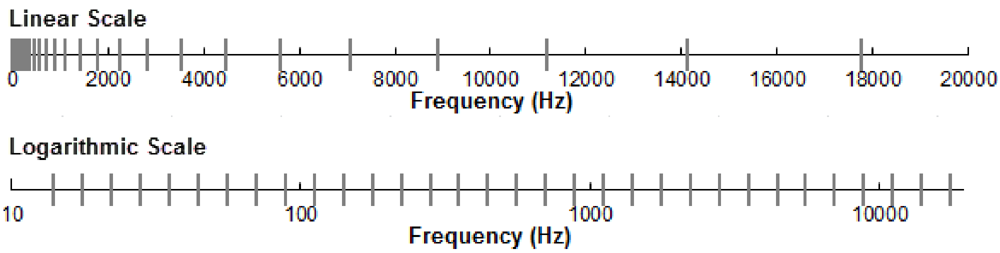


Figure B-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and on a logarithmic scale.

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

$$L_{p,i} = 10 \log_{10} \int_{f_{\text{lo},i}}^{f_{\text{hi},i}} S(f)\, df \quad \text{(B-7)}$$

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

$$\text{Broadband SPL} = 10 \log_{10} \sum_{i} 10^{\frac{L_{p,i}}{10}} \quad \text{(B-8)}$$

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 require less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

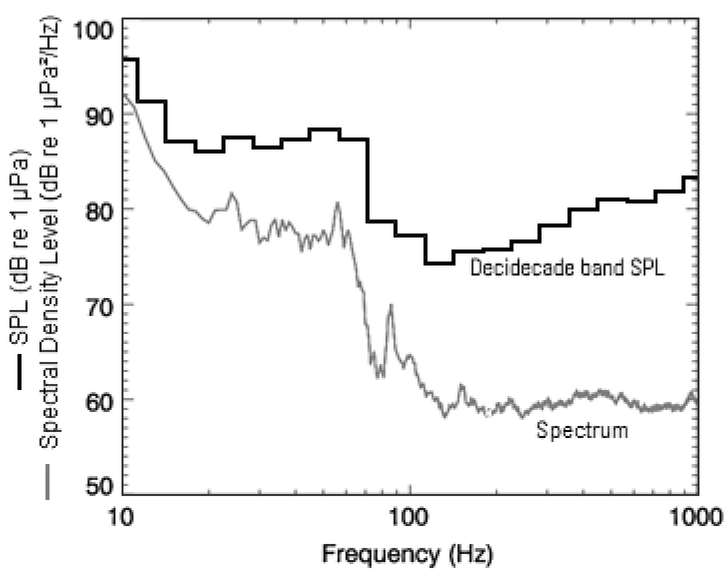


Figure B-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

Supplement C. Auditory (Frequency) Weighting Functions

Weighting functions are applied to the sound spectra under consideration to weight the importance of received sound levels at particular frequencies in a manner reflective of an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007). Southall et al. (2007) were first to suggest weighting functions and functional hearing groups for marine mammals. The Technical Guidance issued by NOAA (NMFS 2018) includes weighting functions and associated thresholds, and is used here for determining the ranges for potential Level A harassment to marine mammals.

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 overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. This frequency-weighting function is expressed as:

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

Finneran (2015) proposed five hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, 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 noise impacts on marine mammals (NMFS 2018). Table C-1 lists the frequency-weighting parameters for each hearing group. Figure C-1 shows the resulting frequency-weighting curves.

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	8,800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds in water	1.0	2	1,900	30,000	0.75
Otariid pinnipeds in water	2.0	2	940	25,000	0.64

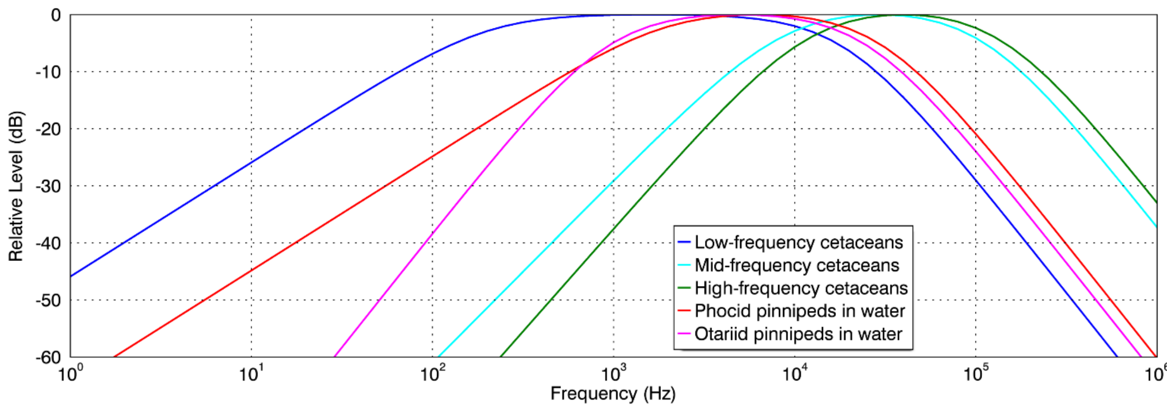


Figure C-1. Auditory weighting functions for marine mammal hearing groups included in NMFS (2018).

C.2. Frequency Weighting Functions – Southall et al. (2007)

Auditory weighting functions for marine mammals were proposed by Southall et al. (2007). These so-called M-weighting functions are applied in a similar way as A-weighting for noise level assessments for humans. Functions were defined for five hearing groups of marine mammals:

- Low-frequency (LF) cetaceans—mysticetes (baleen whales)
- Mid-frequency (MF) cetaceans—some odontocetes (toothed whales)
- High-frequency (HF) cetaceans—odontocetes specialized for using high-frequencies.
- Pinnipeds in water (Pw)—seals, sea lions, and walrus
- Pinnipeds in air (not addressed here)

The M-weighting functions have unity gain (0 dB) through the passband and their high- and low-frequency roll-offs are approximately –12 dB per octave. The amplitude response in the frequency domain of each M-weighting function is defined by:

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

Where $G(f)$ is the weighting function amplitude (in dB) at the frequency f (in Hz), and a and b are the estimated lower and upper hearing limits, respectively, which control the roll-off and passband of the weighting function. The parameters a and b are defined uniquely for each hearing group (Table C-2). Figure C-1 shows the auditory weighting functions.

Table C-2. Parameters for the auditory weighting functions recommended by Southall et al. (2007).

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

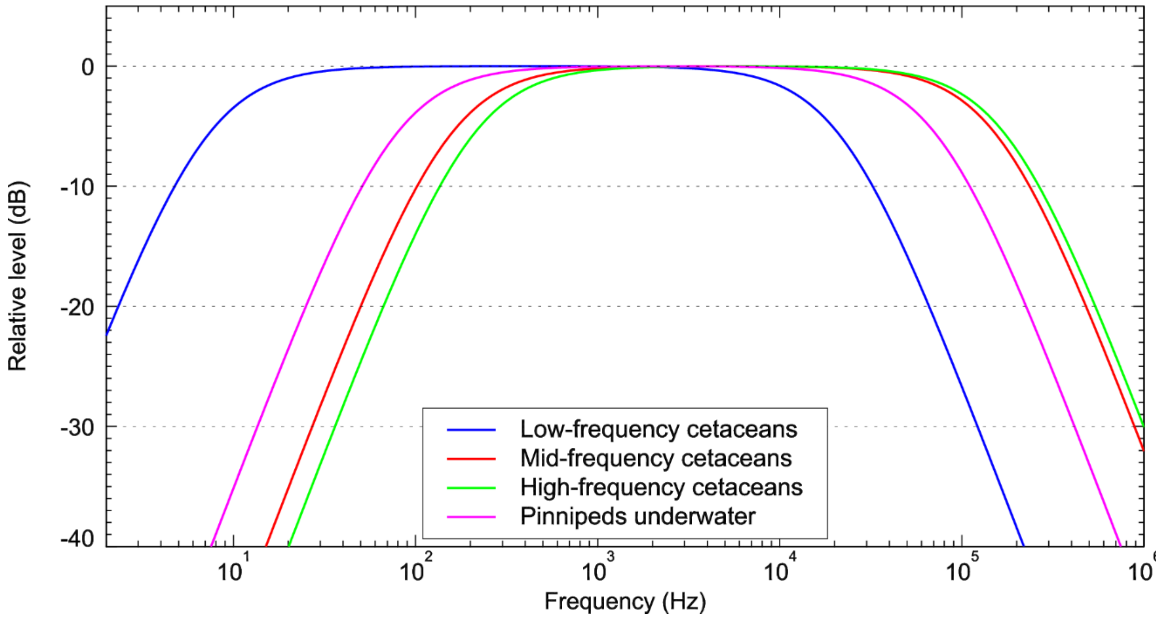


Figure C-2. Auditory weighting functions for the marine mammal hearing groups as recommended by Southall et al. (2007).

Supplement D. Source Models

D.1. 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 (see 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 2010), which includes a large database of simulated hammers—both impact and vibratory—based on the manufacturer's specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

The sound radiating from the pile itself is simulated using a vertical array of discrete point sources. The point sources are centered on the pile axis. Their amplitudes are derived using an inverse technique, such that their collective particle velocity, calculated using a near-field wave-number integration model, matches the particle velocity in the water at the pile wall. The sound field propagating away from the vertical source array is then calculated using a time-domain acoustic propagation model (see Supplement E.3). MacGillivray (2014) describes the theory behind the physical model in more detail.

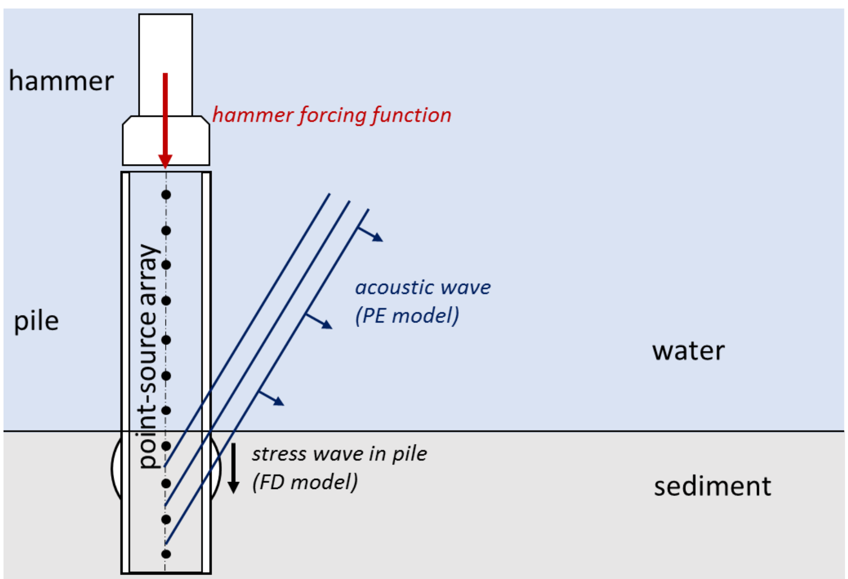


Figure D-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical array of point sources is used with the parabolic equation (PE)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

Supplement E. Sound Propagation Modeling Methodology

E.1. Environmental Parameters

E.1.1. Bathymetry

A bathymetry grid for the acoustic propagation model was extracted from NGDC's 1 arc-second US Coastal Relief Model (CRM) created by the National Centers for Environmental Information (NCEI).

E.1.2. Geoacoustics

In shallow water environments, where there is increased interaction with the seafloor, the properties of the substrate have more influence over the sound propagation. Based on samples from nearby study sites, the surficial sediment in the Lease Area is expected to be predominantly composed of sand. A geoacoustic profile for the area has been developed from geotechnical studies of surficial sediments within the project area and from regional studies for deeper sediments (Tang et al. 2002, Lyu et al. 2021). The Vineyard Mid-Atlantic geotechnical studies provide lithology of extracted cores through at least the top 50 m of seabed sediments across the project area. Surficial sediments here are primarily silty sand to dense sand. The core samples provided density, grain size, and porosity versus depth below seafloor. Tables E-1 and E-2 shows the sediment layer geoacoustic property profiles for locations L01 and L02 for a representative sandy seabed based on the geotechnical studies. The same geoacoustics profile has been used at both modeling sites.

Table E-1. Location L01: 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/cm^3)	Compressional wave speed (m/s)	Compressional wave attenuation (dB/λ)
0–11.34	Fine sand	2.000–2.014	1694.87–1709.57	0.820–0.816
11.34–28.74	Sandy silt	1.839–1.863	1613.35–1635.53	1.190–1.091
28.74–39.70	Silty sand	1.864–1.878	1632.57–1646.32	1.106–1.044
39.70–48.50	Very fine sand	1.965–1.976	1701.09–1712.00	0.835–0.833
48.50–50	Very fine sand	1.976–1.978	1712.00–1713.85	0.833–0.833
50–64	Silty sand	1.892–1.910	1659.08–1676.19	0.985–0.903
64–500	Fine sand	2.084–2.547	1775.36–2193.75	0.803–0.628
>500	Sand	2.547	2193.75	0.628

Table E-2. Location L02: 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/cm^3)	Compressional wave speed (m/s)	Compressional wave attenuation (dB/λ)
0–19.07	Fine sand	2.000–2.025	1694.87–1719.47	0.820–0.814
19.07–21.63	Sand-silt-clay	1.669–1.673	1553.68–1556.95	0.474–0.491
21.63–32.00	Fine sand	2.028–2.042	1722.74–1735.85	0.814–0.811
32.00–62.10	Fine sand	2.042–2.081	1735.85–1773.06	0.811–0.804
62.10–84.08	Sandy silt	1.906–1.934	1676.84–1703.21	0.897–0.854
84.08–91.00	Fine sand	2.109–2.118	1799.42–1807.60	0.797–0.795
91.00–500	Fine sand	2.118–2.547	1807.60–2193.75	0.795–0.628
>500	Fine sand	2.547	2193.75	0.628

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 US Navy's Generalized Digital Environmental Model (GDEM; NAVO 2003). Considering the greater area around the lease area and deep waters, the sound speed profiles in summer and winter assumed to be representative of typical propagation conditions annually (see Figure E-1). Figure E-1 shows an average profile, obtained by calculating the mean of June to September for the summer profile and December (which was the most conversative monthly history SSP in winter) for winter. The profiles are shown to 100 m, but the profiles used extend up to 2.8 km which encompasses all depths within the sound impact area (<120 km). These profiles were assumed to be representative of the entire area for modeling purposes

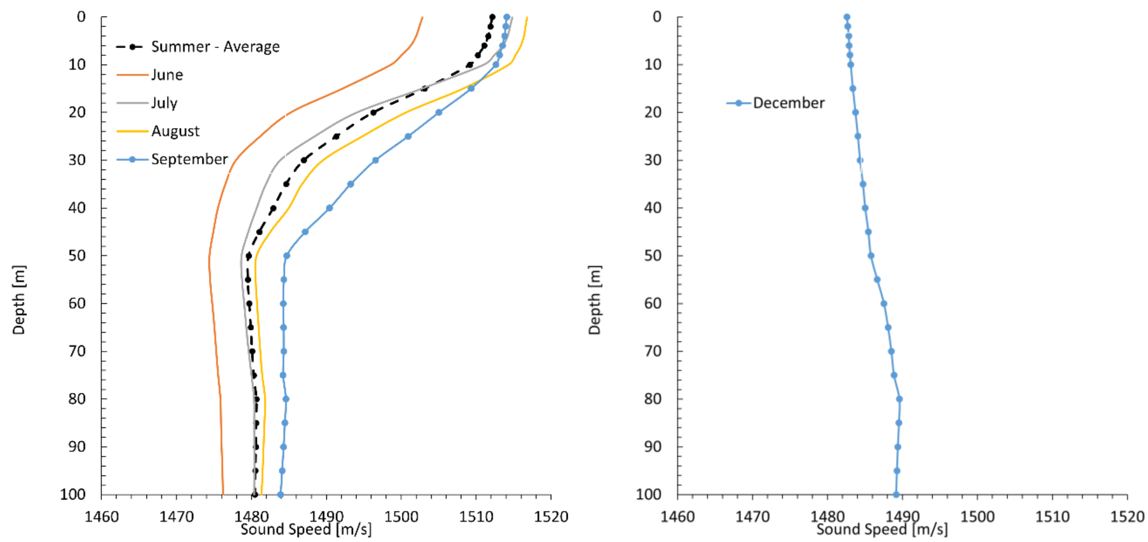


Figure E-1. Sound speed profiles up to 100 m for the modeled seasons for (left) summer and (right) winter.

E.2. Propagation Loss

The propagation of sound through the environment can be modeled by predicting the acoustic propagation loss, which is 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 energy source level $(L_{S,E})$, expressed in dB re 1 µPa²m²s, and energy propagation loss ($N_{PL,E}$), in units of dB, at a given frequency are known, then the received level $(L_{E,p})$, at a receiver location can be calculated in dB re 1 µPa²s by:

$$L_{E,p}(\theta,r) = L_{S,E}(\theta) - N_{PL,E}(\theta,r), \tag{E-1}$$

where θ defines the specific direction, and r is the range of the receiver from the source.

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 L_{pk} metrics versus range and depth from the source.

The acoustic field is extended to higher frequencies (up to 25,000 Hz) by applying a 20 dB/decade decay rate to match 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.

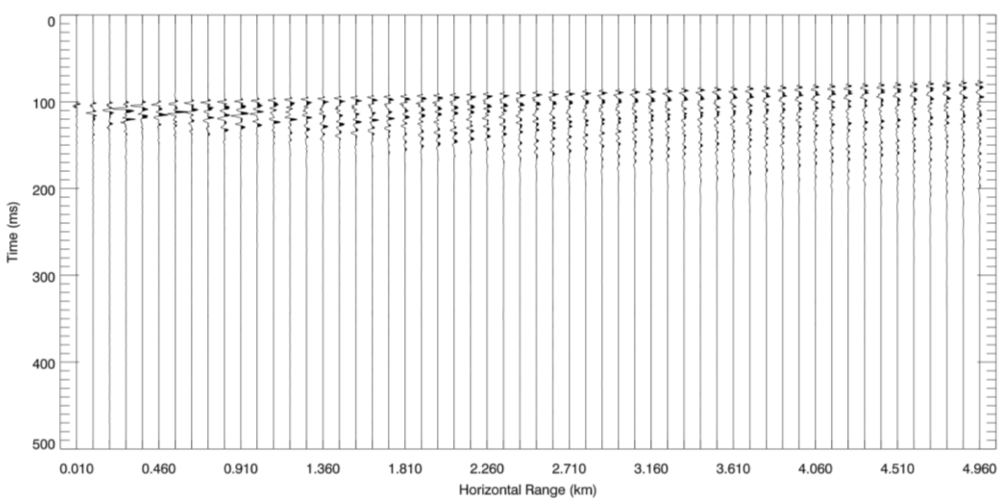


Figure E-2. Example of synthetic pressure waveforms computed by FWRAM at multiple range offsets. Receiver depth is 35 m and the amplitudes of the pressure traces have been normalized for display purposes.

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.

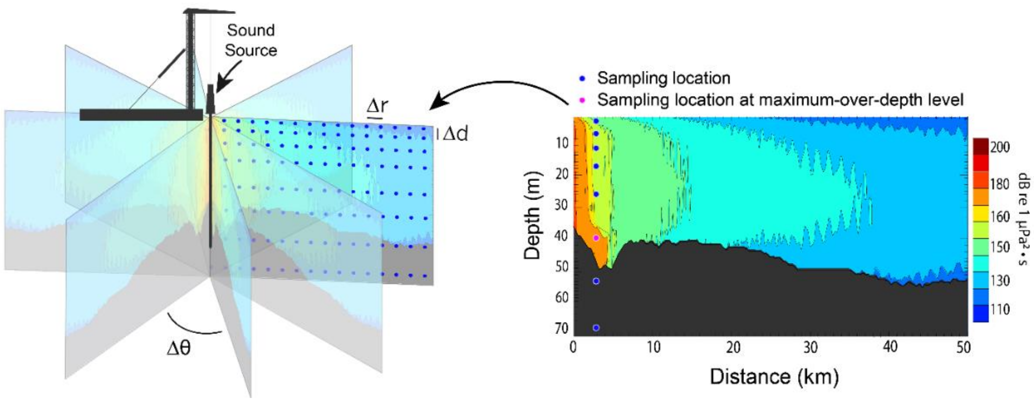


Figure E-3. Modeled three-dimensional sound field (N×2-D method) and maximum-over-depth modeling approach. Sampling locations are shown as blue dots on both figures. On the right panel, the pink dot represents the sampling location where the sound level is maximum over the water column. This maximum-over-depth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

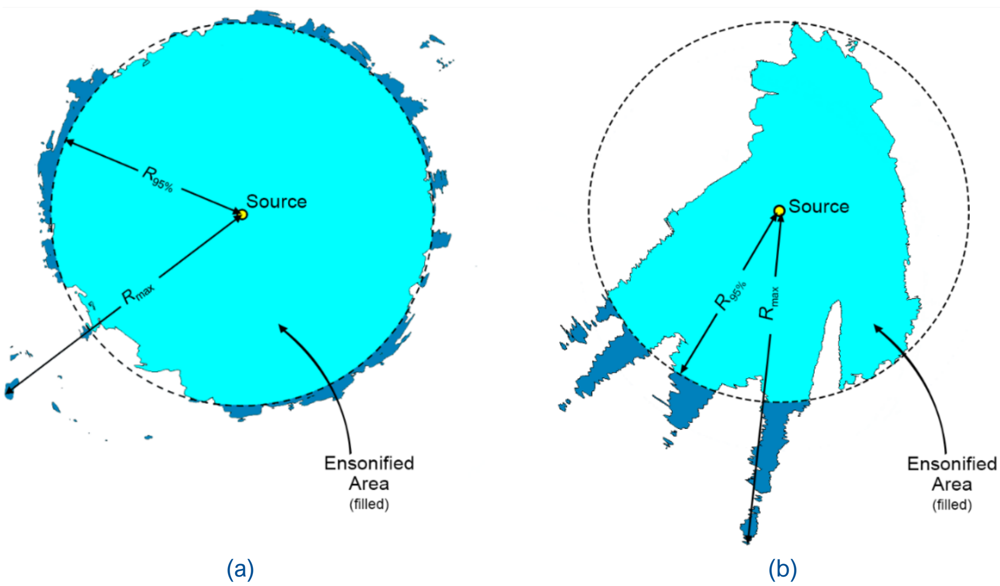


Figure E-4. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified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

E.5. Model Validation Information

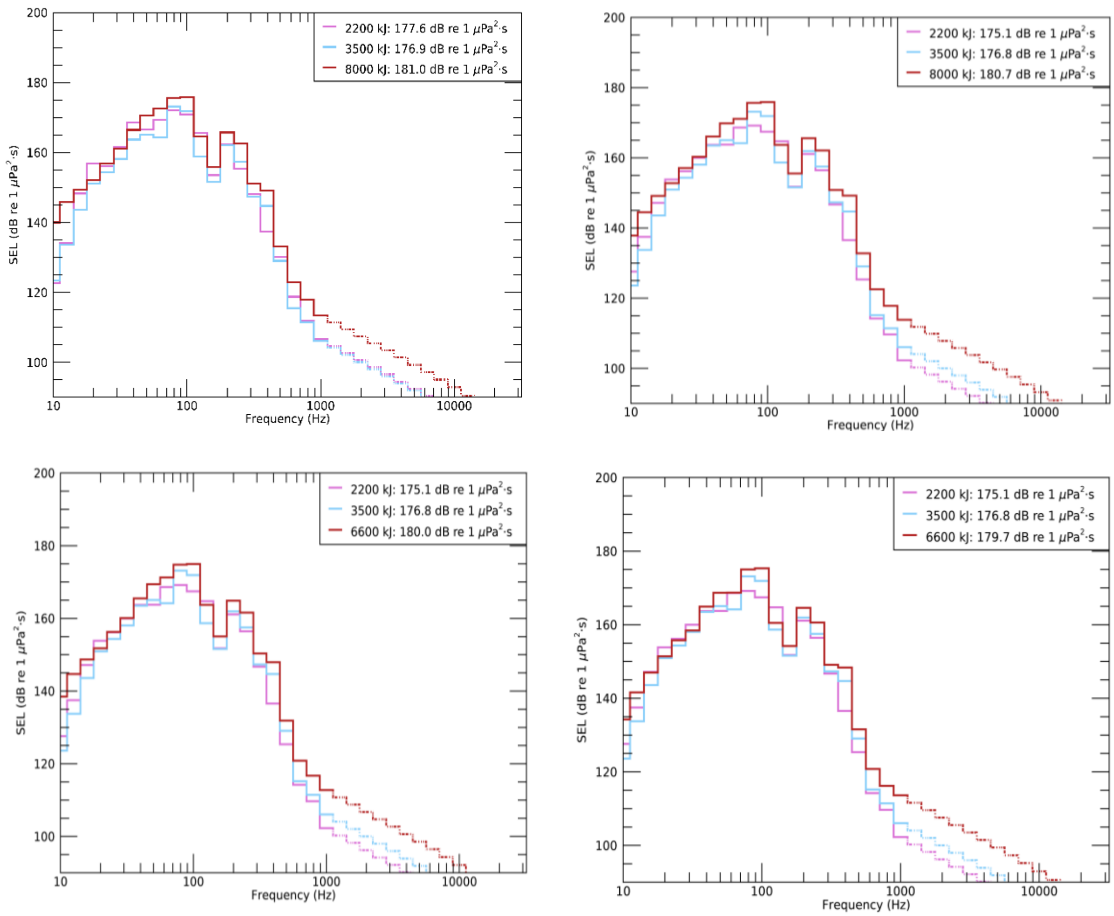
Predictions from JASCO's propagation model (FWRAM) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Arctic, Canadian and southern United States waters, Greenland, Russia and Australia (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, 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, 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).

Supplement F. Acoustic Range Results - Impact Pile Driving

F.1. Decidecade SEL at 750 m

F.1.1. 12.5 m Monopile Foundation



VV

Figure F-1. Decidecade band levels at 750 m from location L01 in winter for a 12.5 m monopile for (top left) Scenario B1 (MHU 8000); (top right) Scenario B2 (MHU 6600, with difficult-to-drive scenario); (bottom left) Scenario B3 (MHU 6600); and (bottom right) Scenario B4 (MHU 4400). Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate.

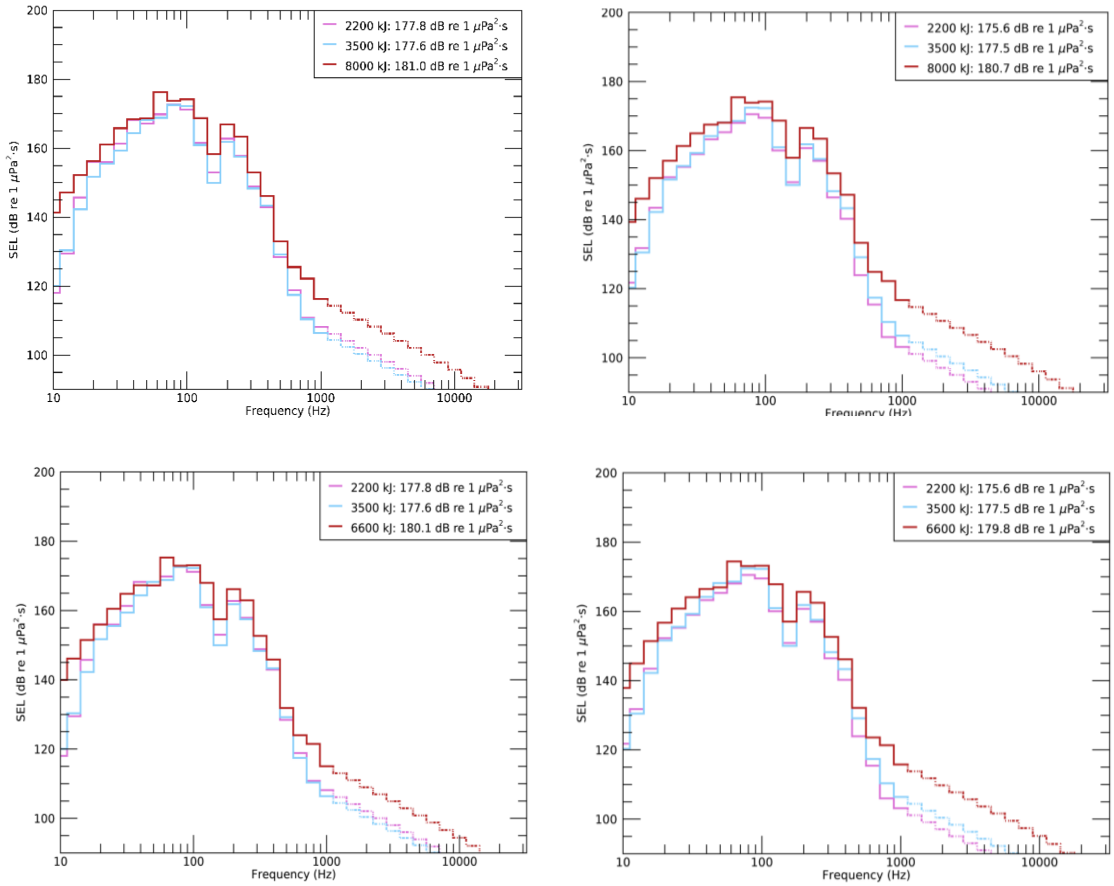


Figure F-2. Decidecade band levels at 750 m from location L02 in winter for a 12.5 m monopile for (top left) Scenario B1 (MHU 8000); (top right) Scenario B2 (MHU 6600, with difficult-to-drive scenario); (bottom left) Scenario B3 (MHU 6600); and (bottom right) Scenario B4 (MHU 4400). Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate.

F.1.2. 4.25 m Jacket Foundation

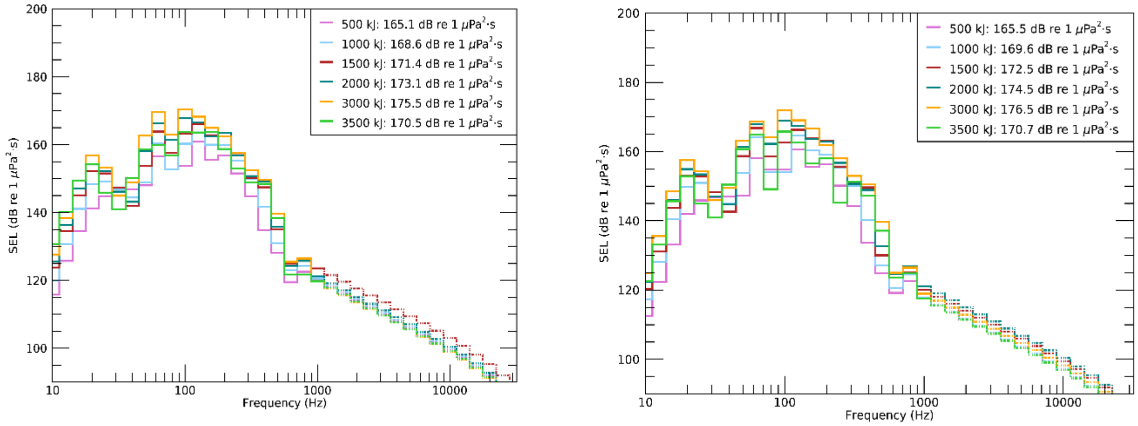


Figure F-3. Scenario B5, decidecade band levels at 750 m from locations (left) L01 and (right) L02 in winter for a 4.25 m diameter pin pile assuming an expected installation scenario using an MHU 3500S hammer. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate.

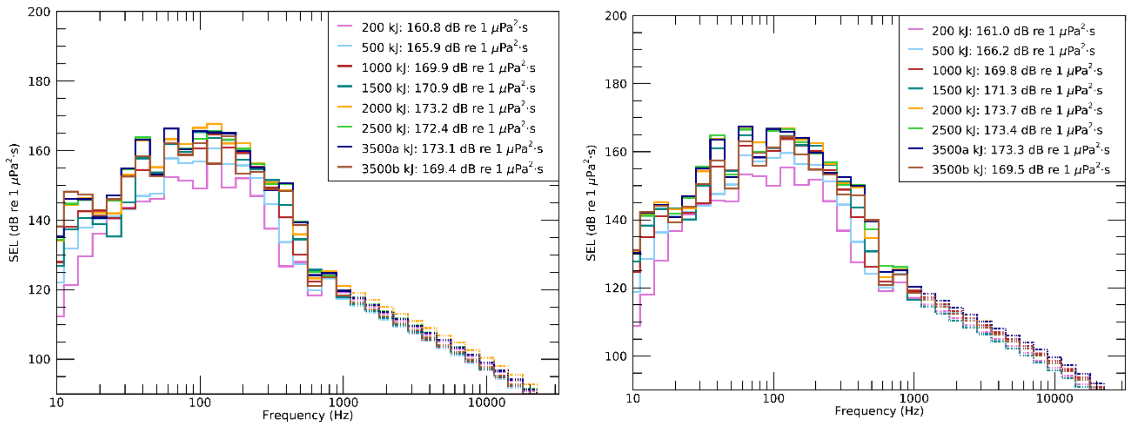


Figure F-4. Scenario B6, decidecade band levels at 750 m from locations (left) L01 and (right) L02 in winter for a 4.25 m diameter pin pile assuming an expected installation scenario using an MHU 3500S hammer. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate.

F.2. Single-Strike PK Acoustic Ranges

F.2.1. 12.5 m Monopile Foundation

Table F-1. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.05	0.06	0.09
MFC	230	-	-	-
HFC	202	0.40	0.44	0.67
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-2. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.04	0.06	0.09
MFC	230	-	-	-
HFC	202	0.35	0.44	0.68
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-3. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.04	0.06	0.08
MFC	230	<0.01	<0.01	<0.01
HFC	202	0.44	0.44	0.72
PW	218	0.05	0.07	0.09
TU	232	-	-	<0.01

Table F-4. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.04	0.06	0.08
MFC	230	-	<0.01	<0.01
HFC	202	0.39	0.44	0.72
PW	218	0.05	0.07	0.09
TU	232	-	-	<0.01

Table F-5. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	0.03
MFC	230	-	-	-
HFC	202	0.20	0.21	0.37
PW	218	-	-	0.05
TU	232	-	-	-

Table F-6. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	0.03
MFC	230	-	-	-
HFC	202	0.14	0.21	0.37
PW	218	-	-	0.05
TU	232	-	-	-

Table F-7. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	0.01	0.04
MFC	230	-	-	-
HFC	202	0.20	0.22	0.41
PW	218	0.01	0.01	0.04
TU	232	-	-	-

Table F-8. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	0.01	0.04
MFC	230	-	-	-
HFC	202	0.16	0.22	0.41
PW	218	<0.01	0.01	0.04
TU	232	-	-	-

Table F-9. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.12	0.19
PW	218	-	-	-
TU	232	-	-	-

Table F-10. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.12	0.18
PW	218	-	-	-
TU	232	-	-	-

Table F-11. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.18
PW	218	<0.01	<0.01	0.01
TU	232	-	-	-

Table F-12. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.18
PW	218	<0.01	<0.01	0.01
TU	232	-	-	-

Table F-13. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-14. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-15. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-16. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	<0.01	<0.01
TU	232	-	-	-

Table F-17. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.05	0.06	0.09
MFC	230	-	-	-
HFC	202	0.39	0.45	0.64
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-18. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.04	0.06	0.09
MFC	230	-	-	-
HFC	202	0.35	0.45	0.64
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-19. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.04	0.06	0.08
MFC	230	<0.01	<0.01	<0.01
HFC	202	0.44	0.48	0.68
PW	218	0.05	0.07	0.09
TU	232	-	-	<0.01

Table F-20. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	0.04	0.06	0.08
MFC	230	-	<0.01	<0.01
HFC	202	0.40	0.47	0.68
PW	218	0.05	0.07	0.09
TU	232	-	-	<0.01

Table F-21. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	0.03
MFC	230	-	-	-
HFC	202	0.19	0.20	0.34
PW	218	-	-	0.05
TU	232	-	-	-

Table F-22. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	0.03
MFC	230	-	-	-
HFC	202	0.14	0.20	0.34
PW	218	-	-	0.05
TU	232	-	-	-

Table F-23. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	0.01	0.03
MFC	230	-	-	-
HFC	202	0.19	0.20	0.41
PW	218	0.01	0.01	0.04
TU	232	-	-	-

Table F-24. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	0.01	0.03
MFC	230	-	-	-
HFC	202	0.15	0.20	0.41
PW	218	<0.01	0.01	0.04
TU	232	-	-	-

Table F-25. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.13	0.16
PW	218	-	-	-
TU	232	-	-	-

Table F-26. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.13	0.15
PW	218	-	-	-
TU	232	-	-	-

Table F-27. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.16
PW	218	<0.01	<0.01	0.01
TU	232	-	-	-

Table F-28. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.16
PW	218	<0.01	<0.01	0.01
TU	232	-	-	-

Table F-29. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-30. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-31. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-32. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	8000 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	<0.01	<0.01
TU	232	-	-	-

Table F-33. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.05	0.06	0.07
MFC	230	-	-	-
HFC	202	0.40	0.44	0.62
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-34. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.04	0.06	0.07
MFC	230	-	-	-
HFC	202	0.35	0.44	0.62
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-35. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.04	0.06	0.08
MFC	230	<0.01	<0.01	<0.01
HFC	202	0.44	0.44	0.66
PW	218	0.05	0.07	0.08
TU	232	-	-	<0.01

Table F-36. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.04	0.06	0.08
MFC	230	-	<0.01	<0.01
HFC	202	0.39	0.44	0.65
PW	218	0.05	0.07	0.08
TU	232	-	-	<0.01

Table F-37. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	0.02
MFC	230	-	-	-
HFC	202	0.20	0.21	0.26
PW	218	-	-	0.04
TU	232	-	-	-

Table F-38. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	0.02
MFC	230	-	-	-
HFC	202	0.14	0.21	0.26
PW	218	-	-	0.04
TU	232	-	-	-

Table F-39. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	0.01	0.02
MFC	230	-	-	-
HFC	202	0.20	0.22	0.38
PW	218	0.01	0.01	0.04
TU	232	-	-	-

Table F-40. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	0.01	0.02
MFC	230	-	-	-
HFC	202	0.16	0.22	0.38
PW	218	<0.01	0.01	0.04
TU	232	-	-	-

Table F-41. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.12	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-42. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.12	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-43. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.14
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-44. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.14
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-45. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.12
PW	218	-	-	-
TU	232	-	-	-

Table F-46. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.12
PW	218	-	-	-
TU	232	-	-	-

Table F-47. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.12
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-48. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.12
PW	218	-	<0.01	<0.01
TU	232	-	-	-

Table F-49. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.05	0.06	0.07
MFC	230	-	-	-
HFC	202	0.39	0.45	0.60
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-50. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.04	0.06	0.07
MFC	230	-	-	-
HFC	202	0.35	0.45	0.59
PW	218	0.05	0.06	0.09
TU	232	-	-	-

Table F-51. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.04	0.06	0.08
MFC	230	<0.01	<0.01	<0.01
HFC	202	0.44	0.48	0.65
PW	218	0.05	0.07	0.08
TU	232	-	-	<0.01

Table F-52. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	0.04	0.06	0.08
MFC	230	-	<0.01	<0.01
HFC	202	0.40	0.47	0.65
PW	218	0.05	0.07	0.08
TU	232	-	-	<0.01

Table F-53. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	0.02
MFC	230	-	-	-
HFC	202	0.19	0.20	0.29
PW	218	-	-	0.03
TU	232	-	-	-

Table F-54. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	0.02
MFC	230	-	-	-
HFC	202	0.14	0.20	0.29
PW	218	-	-	0.03
TU	232	-	-	-

Table F-55. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	0.01	0.02
MFC	230	-	-	-
HFC	202	0.19	0.20	0.38
PW	218	0.01	0.01	0.04
TU	232	-	-	-

Table F-56. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	0.01	0.02
MFC	230	-	-	-
HFC	202	0.15	0.20	0.38
PW	218	<0.01	0.01	0.04
TU	232	-	-	-

Table F-57. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.13	0.14
PW	218	-	-	-
TU	232	-	-	-

Table F-58. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.11	0.13	0.14
PW	218	-	-	-
TU	232	-	-	-

Table F-59. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.14
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-60. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	<0.01	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.11	0.12	0.14
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-61. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-62. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	-	-
MFC	230	-	-	-
HFC	202	0.09	0.11	0.13
PW	218	-	-	-
TU	232	-	-	-

Table F-63. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, difficult to drive) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.12
PW	218	<0.01	<0.01	<0.01
TU	232	-	-	-

Table F-64. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer, normal) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	2200 kJ	3500 kJ	6600 kJ
LFC	219	-	<0.01	<0.01
MFC	230	-	-	-
HFC	202	0.09	0.11	0.12
PW	218	-	<0.01	<0.01
TU	232	-	-	-

F.2.2. 4.25 m Jacket Foundation

Table F-65. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	0.02	0.05	0.06	0.02
MFC	230	-	-	-	-	-	-
HFC	202	0.22	0.37	0.42	0.46	0.49	0.30
PW	218	-	-	0.06	0.06	0.07	0.03
TU	232	-	-	-	-	-	-

Table F-66. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	<0.01	0.01	0.01	0.05	0.07	0.02
MFC	230	-	-	-	-	<0.01	-
HFC	202	0.22	0.37	0.42	0.45	0.51	0.33
PW	218	<0.01	0.01	0.06	0.07	0.07	0.02
TU	232	-	-	-	-	-	-

Table F-67. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.11	0.13	0.15	0.22	0.24	0.10
PW	218	-	-	-	-	-	-
TU	232	-	-	-	-	-	-

Table F-68. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	<0.01	<0.01	<0.01	<0.01	<0.01
MFC	230	-	-	-	-	-	-
HFC	202	0.11	0.13	0.19	0.23	0.26	0.10
PW	218	-	<0.01	<0.01	<0.01	0.01	<0.01
TU	232	-	-	-	-	-	-

Table F-69. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.08	0.10	0.12	0.12	0.13	0.06
PW	218	-	-	-	-	-	-
TU	232	-	-	-	-	-	-

Table F-70. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	<0.01	<0.01
MFC	230	-	-	-	-	-	-
HFC	202	0.08	0.10	0.12	0.12	0.13	0.06
PW	218	-	-	-	<0.01	<0.01	<0.01
TU	232	-	-	-	-	-	-

Table F-71. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.03	0.09	0.09	0.10	0.11	0.05
PW	218	-	-	-	-	-	-
TU	232	-	-	-	-	-	-

Table F-72. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.03	0.09	0.10	0.10	0.11	0.04
PW	218	-	-	-	-	<0.01	-
TU	232	-	-	-	-	-	-

Table F-73. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	0.02	0.05	0.06	0.02
MFC	230	-	-	-	-	-	-
HFC	202	0.21	0.37	0.42	0.44	0.46	0.32
PW	218	-	-	0.03	0.06	0.07	0.03
TU	232	-	-	-	-	-	-

Table F-74. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	<0.01	0.01	0.01	0.04	0.07	0.02
MFC	230	-	-	-	-	<0.01	-
HFC	202	0.22	0.37	0.41	0.43	0.46	0.34
PW	218	<0.01	0.01	0.03	0.07	0.08	0.03
TU	232	-	-	-	-	-	-

Table F-75. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.12	0.14	0.16	0.17	0.23	0.10
PW	218	-	-	-	-	-	-
TU	232	-	-	-	-	-	-

Table F-76. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	<0.01	<0.01	<0.01	<0.01	<0.01
MFC	230	-	-	-	-	-	-
HFC	202	0.11	0.14	0.16	0.22	0.32	0.10
PW	218	-	<0.01	<0.01	<0.01	0.01	<0.01
TU	232	-	-	-	-	-	-

Table F-77. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.07	0.11	0.12	0.13	0.13	0.06
PW	218	-	-	-	-	-	-
TU	232	-	-	-	-	-	-

Table F-78. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	<0.01	<0.01
MFC	230	-	-	-	-	-	-
HFC	202	0.08	0.11	0.12	0.13	0.13	0.06
PW	218	-	-	-	-	<0.01	<0.01
TU	232	-	-	-	-	-	-

Table F-79. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.02	0.09	0.10	0.11	0.11	0.05
PW	218	-	-	-	-	-	-
TU	232	-	-	-	-	-	-

Table F-80. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	500 kJ	1000 kJ	1500 kJ	2000 kJ	3000 kJ	3500 kJ
LFC	219	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-
HFC	202	0.02	0.09	0.10	0.11	0.11	0.04
PW	218	-	-	-	-	<0.01	-
TU	232	-	-	-	-	-	-

Table F-81. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	0.02	0.05	0.06	0.05	0.02
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.13	0.22	0.36	0.42	0.46	0.44	0.42	0.30
PW	218	-	-	0.02	0.06	0.06	0.06	0.05	0.03
TU	232	-	-	-	-	-	-	-	-

Table F-82. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	<0.01	0.01	0.02	0.05	0.05	0.04	0.02
MFC	230	-	-	-	-	-	-	<0.01	-
HFC	202	0.12	0.23	0.37	0.41	0.44	0.43	0.41	0.33
PW	218	<0.01	<0.01	0.01	0.07	0.07	0.06	0.05	0.02
TU	232	-	-	-	-	-	-	-	-

Table F-83. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.07	0.11	0.13	0.15	0.22	0.18	0.17	0.10
PW	218	-	-	-	-	-	-	0.02	-
TU	232	-	-	-	-	-	-	-	-

Table F-84. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.08	0.11	0.13	0.15	0.22	0.19	0.17	0.10
PW	218	-	-	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
TU	232	-	-	-	-	-	-	-	-

Table F-85. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	-	0.08	0.11	0.12	0.12	0.11	0.09	0.06
PW	218	-	-	-	-	-	-	-	-
TU	232	-	-	-	-	-	-	-	-

Table F-86. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	<0.01	<0.01	<0.01
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.01	0.08	0.11	0.12	0.12	0.11	0.10	0.06
PW	218	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01
TU	232	-	-	-	-	-	-	-	-

Table F-87. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	-	0.03	0.09	0.10	0.10	0.09	0.08	0.05
PW	218	-	-	-	-	-	-	-	-
TU	232	-	-	-	-	-	-	-	-

Table F-88. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in summer at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	<0.01	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	<0.01	0.06	0.09	0.10	0.10	0.09	0.08	0.04
PW	218	-	-	-	-	-	-	<0.01	-
TU	232	-	-	-	-	-	-	-	-

Table F-89. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	0.02	0.05	0.05	0.05	0.02
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.13	0.22	0.35	0.42	0.44	0.42	0.40	0.32
PW	218	-	-	0.02	0.06	0.06	0.06	0.05	0.03
TU	232	-	-	-	-	-	-	-	-

Table F-90. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 0 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	<0.01	0.01	0.02	0.04	0.05	0.04	0.02
MFC	230	-	-	-	-	-	-	<0.01	-
HFC	202	0.13	0.22	0.36	0.41	0.43	0.41	0.39	0.34
PW	218	<0.01	<0.01	0.01	0.07	0.07	0.06	0.05	0.03
TU	232	-	-	-	-	-	-	-	-

Table F-91. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.07	0.12	0.14	0.16	0.17	0.16	0.17	0.10
PW	218	-	-	-	-	-	-	0.02	-
TU	232	-	-	-	-	-	-	-	-

Table F-92. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 6 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.07	0.12	0.14	0.16	0.17	0.16	0.17	0.10
PW	218	-	-	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
TU	232	-	-	-	-	-	-	-	-

Table F-93. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	-	0.08	0.11	0.13	0.13	0.11	0.09	0.06
PW	218	-	-	-	-	-	-	-	-
TU	232	-	-	-	-	-	-	-	-

Table F-94. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 10 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	<0.01	<0.01	<0.01
MFC	230	-	-	-	-	-	-	-	-
HFC	202	0.01	0.08	0.11	0.12	0.13	0.11	0.10	0.06
PW	218	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01
TU	232	-	-	-	-	-	-	-	-

Table F-95. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L01 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	-	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	-	0.03	0.09	0.11	0.11	0.09	0.08	0.05
PW	218	-	-	-	-	-	-	-	-
TU	232	-	-	-	-	-	-	-	-

Table F-96. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, with an MHU 3500S hammer) acoustic ranges to marine mammal and sea turtle injury peak thresholds (Finneran et al. 2017, NMFS 2018) in winter at location L02 for different energy levels and 12 dB attenuation.

Hearing group	Level (L_{pk})	200 kJ	500 kJ	1000 kJ	1500 kJ	2000 kJ	2500 kJ	3500a kJ	3500b kJ
LFC	219	-	-	-	-	-	-	<0.01	-
MFC	230	-	-	-	-	-	-	-	-
HFC	202	<0.01	0.03	0.09	0.10	0.11	0.09	0.08	0.04
PW	218	-	-	-	-	-	-	<0.01	-
TU	232	-	-	-	-	-	-	-	-

F.3. Per-Pile SEL Acoustic Ranges to Injury Thresholds

F.3.1. 12.5 m Monopile Foundation

Table F-97. Scenario B1, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	summer 0 dB	summer 6 dB	summer 10 dB	summer 12 dB	winter 0 dB	winter 6 dB	winter 10 dB	winter 12 dB
LF	183	5.01	3.68	2.79	2.50	6.39	4.33	3.20	2.70
MF	185	-	-	-	-	-	-	-	-
HF	155	0.28	0.13	0.09	0.05	0.28	0.13	0.09	0.05
PW	185	1.49	0.89	0.56	0.44	1.56	0.91	0.60	0.44
TU	204	1.99	1.27	0.89	0.71	2.16	1.34	0.91	0.72

Table F-98. Scenario B2, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.76	3.45	2.64	2.35	6.01	4.04	2.89	2.53
MF	185	-	-	-	-	-	-	-	-
HF	155	0.27	0.12	0.09	0.03	0.26	0.12	0.06	0.03
PW	185	1.38	0.76	0.48	0.40	1.45	0.82	0.51	0.41
TU	204	1.84	1.14	0.77	0.61	1.95	1.22	0.81	0.64

Table F-99. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.80	3.49	2.67	2.38	6.07	4.09	2.94	2.56
MF	185	-	-	-	-	-	-	-	-
HF	155	0.27	0.12	0.09	0.04	0.26	0.12	0.06	0.03
PW	185	1.40	0.80	0.50	0.41	1.47	0.84	0.53	0.41
TU	204	1.86	1.16	0.82	0.62	1.98	1.24	0.84	0.65

Table F-100. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.57	3.25	2.52	2.23	5.73	3.82	2.73	2.40
MF	185	-	-	-	-	-	-	-	-
HF	155	0.26	0.11	0.06	0.02	0.24	0.11	0.05	0.02
PW	185	1.29	0.71	0.45	0.38	1.36	0.74	0.46	0.38
TU	204	1.75	1.05	0.72	0.57	1.85	1.12	0.73	0.61

Table F-101. Scenario B1, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	5.01	3.70	2.82	2.55	6.41	4.39	3.22	2.72
MF	185	-	-	-	-	-	-	-	-
HF	155	0.29	0.12	0.09	0.04	0.33	0.13	0.09	0.04
PW	185	1.52	0.89	0.57	0.44	1.59	0.92	0.61	0.45
TU	204	2.08	1.33	0.90	0.74	2.20	1.38	0.92	0.78

Table F-102. Scenario B2, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.74	3.45	2.68	2.39	6.01	4.06	2.89	2.54
MF	185	-	-	-	-	-	-	-	-
HF	155	0.27	0.11	0.08	0.03	0.26	0.12	0.08	0.02
PW	185	1.40	0.82	0.49	0.41	1.47	0.84	0.52	0.41
TU	204	1.88	1.21	0.84	0.65	1.99	1.26	0.86	0.67

Table F-103. Scenario B3, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.80	3.51	2.71	2.43	6.09	4.13	2.96	2.57
MF	185	-	-	-	-	-	-	-	-
HF	155	0.27	0.11	0.08	0.04	0.26	0.12	0.08	0.03
PW	185	1.42	0.84	0.51	0.41	1.49	0.86	0.55	0.42
TU	204	1.91	1.24	0.86	0.67	2.03	1.28	0.87	0.68

Table F-104. Scenario B4, monopile foundation (12.5 m diameter, with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.55	3.27	2.56	2.26	5.73	3.84	2.74	2.42
MF	185	-	-	-	-	-	-	-	-
HF	155	0.26	0.11	0.07	0.02	0.25	0.11	0.05	0.02
PW	185	1.32	0.72	0.45	0.39	1.38	0.76	0.46	0.39
TU	204	1.79	1.11	0.74	0.59	1.87	1.17	0.77	0.62

F.3.2. 4.25 m Jacket Foundation

Table F-105. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Summer 12 dB
LF	183	7.42	5.34	4.20	3.71	10.99	6.37	4.56	3.90
MF	185	0.03	-	-	-	0.03	-	-	-
HF	155	0.74	0.37	0.22	0.12	0.74	0.38	0.20	0.13
PW	185	2.18	1.30	0.84	0.67	2.22	1.31	0.85	0.68
TU	204	2.62	1.60	1.10	0.87	2.70	1.62	1.09	0.88

Table F-106. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	7.46	5.47	4.36	3.88	12.58	7.55	5.36	4.54
MF	185	0.06	-	-	-	0.06	-	-	-
HF	155	0.86	0.47	0.26	0.22	0.89	0.42	0.26	0.22
PW	185	2.37	1.45	0.96	0.78	2.50	1.49	0.98	0.81
TU	204	2.82	1.79	1.26	1.02	3.19	1.85	1.28	1.03

Table F-107. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	7.35	5.35	4.23	3.73	10.90	6.45	4.61	3.94
MF	185	0.03	0.01	-	-	0.03	0.01	-	-
HF	155	0.74	0.32	0.22	0.11	0.72	0.33	0.21	0.12
PW	185	2.21	1.32	0.86	0.68	2.25	1.32	0.86	0.70
TU	204	2.64	1.64	1.13	0.89	2.72	1.64	1.14	0.90

Table F-108. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	7.32	5.43	4.35	3.87	12.13	7.47	5.37	4.55
MF	185	0.06	0.01	-	-	0.05	0.01	-	-
HF	155	0.84	0.49	0.25	0.22	0.87	0.46	0.25	0.22
PW	185	2.37	1.45	0.98	0.80	2.51	1.49	1.00	0.82
TU	204	2.83	1.80	1.27	1.04	3.20	1.86	1.30	1.05

F.4. Fish Acoustic Ranges to Thresholds

In this section, the table footnotes indicate the following:

- [a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008), and
- [b] Popper et al. (2014).

F.4.1. 12.5 m Monopile Foundation

Table F-109. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	6.04	4.61	3.76	3.31	7.92	5.62	4.39	3.86
Fish < 2 g	183	7.15	5.54	4.61	4.17	9.70	7.07	5.62	4.98
Fish without swim bladder	216	0.89	0.46	0.26	0.21	0.91	0.46	0.26	0.19
Fish with swim bladder	203	2.54	1.65	1.15	0.94	2.77	1.75	1.23	0.98

Table F-110. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.76	4.36	3.52	3.03	7.48	5.28	4.10	3.56
Fish < 2 g	183	6.82	5.27	4.36	3.94	9.14	6.64	5.28	4.66
Fish without swim bladder	216	0.81	0.39	0.23	0.14	0.83	0.38	0.23	0.15
Fish with swim bladder	203	2.37	1.50	1.02	0.88	2.58	1.59	1.09	0.91

Table F-111. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.81	4.41	3.57	3.09	7.55	5.33	4.15	3.62
Fish < 2 g	183	6.87	5.32	4.41	3.99	9.22	6.71	5.33	4.72
Fish without swim bladder	216	0.83	0.40	0.24	0.17	0.86	0.39	0.23	0.16
Fish with swim bladder	203	2.40	1.52	1.04	0.89	2.62	1.62	1.12	0.92

Table F-112. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.56	4.18	3.33	2.84	7.14	5.02	3.88	3.33
Fish < 2 g	183	6.57	5.08	4.18	3.77	8.83	6.35	5.02	4.43
Fish without swim bladder	216	0.71	0.35	0.22	0.13	0.72	0.35	0.20	0.14
Fish with swim bladder	203	2.24	1.41	0.95	0.82	2.45	1.49	1.00	0.85

Table F-113. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	6.05	4.66	3.84	3.40	7.80	5.64	4.45	3.92
Fish < 2 g	183	7.08	5.57	4.66	4.24	9.37	7.00	5.64	5.02
Fish without swim bladder	216	0.92	0.47	0.27	0.21	0.93	0.49	0.27	0.19
Fish with swim bladder	203	2.62	1.73	1.27	1.00	2.83	1.79	1.31	1.04

Table F-114. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.76	4.40	3.57	3.11	7.35	5.28	4.13	3.60
Fish < 2 g	183	6.73	5.29	4.40	3.99	8.92	6.58	5.28	4.68
Fish without swim bladder	216	0.85	0.43	0.24	0.16	0.87	0.43	0.23	0.15
Fish with swim bladder	203	2.44	1.58	1.11	0.91	2.62	1.65	1.17	0.93

Table F-115. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.83	4.47	3.64	3.19	7.45	5.36	4.20	3.68
Fish < 2 g	183	6.81	5.36	4.47	4.05	9.01	6.66	5.36	4.76
Fish without swim bladder	216	0.87	0.44	0.25	0.18	0.89	0.44	0.24	0.16
Fish with swim bladder	203	2.48	1.62	1.15	0.92	2.67	1.69	1.20	0.94

Table F-116. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.55	4.22	3.38	2.90	7.02	5.03	3.92	3.37
Fish < 2 g	183	6.52	5.09	4.22	3.82	8.61	6.30	5.03	4.45
Fish without swim bladder	216	0.77	0.40	0.21	0.14	0.79	0.40	0.20	0.14
Fish with swim bladder	203	2.31	1.48	1.01	0.87	2.48	1.54	1.07	0.88

F.4.2. 4.25 m Jacket Foundation

Table F-117. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	7.68	5.67	4.56	4.07	11.25	7.04	5.24	4.53
Fish < 2 g	183	9.10	6.94	5.67	5.09	15.18	9.41	7.04	6.06
Fish without swim bladder	216	0.98	0.52	0.29	0.22	0.97	0.50	0.30	0.22
Fish with swim bladder	203	3.06	1.90	1.37	1.13	3.31	1.98	1.38	1.13

Table F-118. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	7.95	5.97	4.87	4.37	12.79	8.21	6.10	5.27
Fish < 2 g	183	9.29	7.25	5.97	5.41	16.93	11.09	8.21	7.07
Fish without swim bladder	216	1.19	0.60	0.36	0.27	1.22	0.60	0.37	0.26
Fish with swim bladder	203	3.42	2.19	1.57	1.31	3.91	2.35	1.63	1.35

Table F-119. Scenario B5, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	7.59	5.69	4.60	4.11	11.01	7.04	5.29	4.57
Fish < 2 g	183	8.95	6.89	5.69	5.13	14.56	9.29	7.04	6.10
Fish without swim bladder	216	1.05	0.52	0.30	0.23	1.05	0.52	0.32	0.22
Fish with swim bladder	203	3.10	1.93	1.41	1.17	3.37	1.99	1.43	1.18

Table F-120. Scenario B6, Jacket foundation (post-piled 4.25 m diameter, 4 legs with an MHU 3500S hammer) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	7.81	5.95	4.89	4.39	12.24	8.05	6.09	5.29
Fish < 2 g	183	9.08	7.14	5.95	5.41	15.78	10.63	8.05	6.99
Fish without swim bladder	216	1.22	0.62	0.39	0.27	1.25	0.63	0.39	0.26
Fish with swim bladder	203	3.46	2.24	1.61	1.34	3.95	2.38	1.66	1.38

F.5. Single-Strike SPL Acoustic Ranges

F.5.1. 12.5 m Monopile Foundation

Table F-121. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.97	1.87	1.28	1.22	0.83	0.80	0.69	0.67
160	4.84	4.53	3.56	3.34	2.76	2.62	2.47	2.33
150	7.32	6.78	5.76	5.37	4.84	4.53	4.42	4.14

Table F-122. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.74	1.65	1.00	0.96	0.67	0.64	0.54	0.52
160	4.56	4.27	3.20	2.99	2.50	2.36	2.16	2.04
150	7.12	6.59	5.52	5.14	4.56	4.27	4.14	3.87

Table F-123. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.11	1.98	1.34	1.28	0.92	0.88	0.74	0.70
160	5.02	4.67	3.77	3.52	2.89	2.73	2.61	2.46
150	7.58	6.86	5.95	5.51	5.02	4.67	4.58	4.28

Table F-124. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.81	1.72	1.11	1.05	0.73	0.69	0.57	0.54
160	4.67	4.32	3.34	3.08	2.61	2.45	2.26	2.12
150	7.20	6.54	5.59	5.16	4.67	4.32	4.24	3.93

Table F-125. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.05	1.94	1.31	1.25	0.84	0.81	0.72	0.69
160	5.87	5.44	4.07	3.82	2.97	2.80	2.62	2.47
150	10.35	9.35	7.40	6.79	5.87	5.44	5.21	4.85

Table F-126. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.83	1.73	1.06	1.00	0.70	0.67	0.56	0.54
160	5.53	5.13	3.72	3.48	2.71	2.56	2.35	2.21
150	9.77	8.93	6.99	6.45	5.53	5.13	4.88	4.55

Table F-127. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.21	2.07	1.37	1.31	0.93	0.89	0.74	0.72
160	5.98	5.52	4.23	3.93	3.10	2.89	2.71	2.57
150	10.01	9.12	7.45	6.78	5.98	5.52	5.36	4.95

Table F-128. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.87	1.78	1.15	1.10	0.74	0.71	0.60	0.58
160	5.62	5.12	3.82	3.51	2.78	2.60	2.41	2.26
150	9.56	8.66	6.96	6.37	5.62	5.12	4.99	4.56

Table F-129. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.93	1.83	1.21	1.14	0.78	0.75	0.64	0.61
160	5.06	4.70	3.66	3.42	2.78	2.62	2.44	2.30
150	7.92	7.30	6.10	5.65	5.06	4.70	4.58	4.26

Table F-130. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.92	1.83	1.20	1.14	0.78	0.74	0.64	0.61
160	5.06	4.70	3.66	3.42	2.78	2.61	2.44	2.30
150	7.91	7.30	6.10	5.65	5.06	4.70	4.56	4.26

Table F-131. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.03	1.91	1.29	1.23	0.90	0.86	0.70	0.67
160	5.15	4.74	3.78	3.49	2.86	2.68	2.55	2.40
150	7.94	7.18	6.14	5.65	5.15	4.74	4.68	4.31

Table F-132. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.02	1.91	1.28	1.22	0.90	0.85	0.70	0.67
160	5.14	4.73	3.77	3.48	2.85	2.68	2.54	2.39
150	7.93	7.18	6.13	5.65	5.14	4.73	4.67	4.31

Table F-133. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.07	1.95	1.27	1.21	0.81	0.78	0.67	0.64
160	6.34	5.86	4.30	4.03	3.09	2.89	2.67	2.53
150	11.34	10.25	8.06	7.40	6.34	5.86	5.60	5.20

Table F-134. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.06	1.95	1.27	1.20	0.81	0.77	0.67	0.64
160	6.33	5.85	4.30	4.02	3.08	2.89	2.67	2.52
150	11.31	10.22	8.05	7.39	6.33	5.85	5.59	5.19

Table F-135. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.18	2.04	1.33	1.27	0.91	0.88	0.72	0.69
160	6.38	5.83	4.43	4.05	3.22	2.93	2.75	2.57
150	10.99	9.69	8.02	7.26	6.38	5.83	5.71	5.20

Table F-136. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.17	2.03	1.32	1.26	0.91	0.87	0.72	0.69
160	6.37	5.82	4.43	4.04	3.21	2.93	2.74	2.57
150	10.95	9.66	8.01	7.24	6.37	5.82	5.70	5.19

Table F-137. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.64	2.48	1.67	1.58	1.15	1.09	0.96	0.92
160	6.17	5.71	4.64	4.31	3.72	3.47	3.18	2.97
150	9.28	8.54	7.34	6.74	6.17	5.71	5.63	5.22

Table F-138. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.58	2.43	1.63	1.54	1.12	1.05	0.95	0.90
160	6.09	5.64	4.56	4.25	3.64	3.40	3.10	2.89
150	9.19	8.46	7.24	6.66	6.09	5.64	5.56	5.15

Table F-139. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.71	2.55	1.76	1.68	1.27	1.21	0.98	0.94
160	6.20	5.72	4.74	4.37	3.83	3.53	3.33	3.06
150	9.19	8.37	7.33	6.69	6.20	5.72	5.71	5.25

Table F-140. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.65	2.49	1.71	1.63	1.21	1.16	0.97	0.93
160	6.11	5.63	4.65	4.29	3.74	3.44	3.22	2.96
150	9.10	8.27	7.22	6.59	6.11	5.63	5.61	5.16

Table F-141. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.88	2.71	1.78	1.69	1.23	1.16	0.99	0.94
160	7.98	7.32	5.60	5.18	4.32	4.03	3.74	3.49
150	13.56	12.31	9.80	8.95	7.98	7.32	7.08	6.51

Table F-142. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.82	2.66	1.74	1.64	1.20	1.13	0.98	0.93
160	7.89	7.23	5.52	5.11	4.24	3.96	3.65	3.41
150	13.46	12.23	9.72	8.88	7.89	7.23	6.98	6.43

Table F-143. Scenario B1, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.96	2.76	1.85	1.75	1.31	1.26	1.01	0.97
160	7.95	7.20	5.70	5.20	4.45	4.08	3.87	3.55
150	13.27	11.73	9.62	8.73	7.95	7.20	7.06	6.46

Table F-144. Scenario B2, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 8000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.88	2.70	1.79	1.70	1.27	1.21	0.99	0.95
160	7.83	7.08	5.60	5.11	4.36	3.99	3.77	3.44
150	13.15	11.62	9.52	8.62	7.83	7.08	6.94	6.37

Table F-145. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.97	1.87	1.28	1.22	0.83	0.80	0.69	0.67
160	4.84	4.53	3.56	3.34	2.76	2.62	2.47	2.33
150	7.32	6.78	5.76	5.37	4.84	4.53	4.42	4.14

Table F-146. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.74	1.65	1.00	0.96	0.67	0.64	0.54	0.52
160	4.56	4.27	3.20	2.99	2.50	2.36	2.16	2.04
150	7.12	6.59	5.52	5.14	4.56	4.27	4.14	3.87

Table F-147. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.11	1.98	1.34	1.28	0.92	0.88	0.74	0.70
160	5.02	4.67	3.77	3.52	2.89	2.73	2.61	2.46
150	7.58	6.86	5.95	5.51	5.02	4.67	4.58	4.28

Table F-148. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.81	1.72	1.11	1.05	0.73	0.69	0.57	0.54
160	4.67	4.32	3.34	3.08	2.61	2.45	2.26	2.12
150	7.20	6.54	5.59	5.16	4.67	4.32	4.24	3.93

Table F-149. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.05	1.94	1.31	1.25	0.84	0.81	0.72	0.69
160	5.87	5.44	4.07	3.82	2.97	2.80	2.62	2.47
150	10.35	9.35	7.40	6.79	5.87	5.44	5.21	4.85

Table F-150. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.83	1.73	1.06	1.00	0.70	0.67	0.56	0.54
160	5.53	5.13	3.72	3.48	2.71	2.56	2.35	2.21
150	9.77	8.93	6.99	6.45	5.53	5.13	4.88	4.55

Table F-151. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.21	2.07	1.37	1.31	0.93	0.89	0.74	0.72
160	5.98	5.52	4.23	3.93	3.10	2.89	2.71	2.57
150	10.01	9.12	7.45	6.78	5.98	5.52	5.36	4.95

Table F-152. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 2200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.87	1.78	1.15	1.10	0.74	0.71	0.60	0.58
160	5.62	5.12	3.82	3.51	2.78	2.60	2.41	2.26
150	9.56	8.66	6.96	6.37	5.62	5.12	4.99	4.56

Table F-153. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.93	1.83	1.21	1.14	0.78	0.75	0.64	0.61
160	5.06	4.70	3.66	3.42	2.78	2.62	2.44	2.30
150	7.92	7.30	6.10	5.65	5.06	4.70	4.58	4.26

Table F-154. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.92	1.83	1.20	1.14	0.78	0.74	0.64	0.61
160	5.06	4.70	3.66	3.42	2.78	2.61	2.44	2.30
150	7.91	7.30	6.10	5.65	5.06	4.70	4.56	4.26

Table F-155. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.03	1.91	1.29	1.23	0.90	0.86	0.70	0.67
160	5.15	4.74	3.78	3.49	2.86	2.68	2.55	2.40
150	7.94	7.18	6.14	5.65	5.15	4.74	4.68	4.31

Table F-156. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.02	1.91	1.28	1.22	0.90	0.85	0.70	0.67
160	5.14	4.73	3.77	3.48	2.85	2.68	2.54	2.39
150	7.93	7.18	6.13	5.65	5.14	4.73	4.67	4.31

Table F-157. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.07	1.95	1.27	1.21	0.81	0.78	0.67	0.64
160	6.34	5.86	4.30	4.03	3.09	2.89	2.67	2.53
150	11.34	10.25	8.06	7.40	6.34	5.86	5.60	5.20

Table F-158. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.06	1.95	1.27	1.20	0.81	0.77	0.67	0.64
160	6.33	5.85	4.30	4.02	3.08	2.89	2.67	2.52
150	11.31	10.22	8.05	7.39	6.33	5.85	5.59	5.19

Table F-159. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.18	2.04	1.33	1.27	0.91	0.88	0.72	0.69
160	6.38	5.83	4.43	4.05	3.22	2.93	2.75	2.57
150	10.99	9.69	8.02	7.26	6.38	5.83	5.71	5.20

Table F-160. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.17	2.03	1.32	1.26	0.91	0.87	0.72	0.69
160	6.37	5.82	4.43	4.04	3.21	2.93	2.74	2.57
150	10.95	9.66	8.01	7.24	6.37	5.82	5.70	5.19

Table F-161. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.48	2.34	1.54	1.46	1.03	0.98	0.91	0.87
160	5.91	5.47	4.40	4.11	3.46	3.23	2.96	2.79
150	8.97	8.26	7.01	6.47	5.91	5.47	5.38	4.99

Table F-162. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.42	2.29	1.51	1.43	1.02	0.96	0.89	0.85
160	5.84	5.41	4.34	4.05	3.38	3.16	2.92	2.75
150	8.90	8.19	6.93	6.41	5.84	5.41	5.32	4.93

Table F-163. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.56	2.40	1.63	1.55	1.12	1.06	0.93	0.89
160	5.96	5.49	4.51	4.16	3.59	3.30	3.06	2.84
150	8.91	8.10	7.00	6.44	5.96	5.49	5.46	5.02

Table F-164. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.51	2.35	1.59	1.51	1.08	1.02	0.92	0.88
160	5.88	5.40	4.43	4.09	3.51	3.22	2.97	2.79
150	8.82	8.01	6.93	6.36	5.88	5.40	5.38	4.94

Table F-165. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.70	2.55	1.63	1.54	1.10	1.05	0.93	0.89
160	7.56	6.93	5.28	4.89	4.04	3.78	3.44	3.21
150	13.01	11.84	9.39	8.59	7.56	6.93	6.72	6.19

Table F-166. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.65	2.50	1.60	1.51	1.08	1.02	0.91	0.87
160	7.47	6.85	5.20	4.83	3.97	3.71	3.36	3.14
150	12.94	11.78	9.32	8.53	7.47	6.85	6.64	6.12

Table F-167. Scenario B3, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.76	2.58	1.70	1.61	1.17	1.12	0.95	0.91
160	7.52	6.82	5.39	4.91	4.17	3.82	3.57	3.26
150	12.71	11.24	9.24	8.37	7.52	6.82	6.71	6.15

Table F-168. Scenario B4, monopile foundation (12.5 m diameter with an MHU 5500 hammer, 6600 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.71	2.53	1.66	1.57	1.14	1.09	0.94	0.90
160	7.43	6.73	5.31	4.83	4.09	3.74	3.48	3.16
150	12.63	11.15	9.16	8.28	7.43	6.73	6.63	6.07

F.5.2. 4.25 m Jacket Foundation

Table F-169. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.81	0.77	0.43	0.42	0.25	0.24	0.15	0.14
160	2.72	2.56	1.80	1.70	1.32	1.25	1.09	1.03
150	4.90	4.57	3.54	3.29	2.72	2.56	2.40	2.26

Table F-170. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.84	0.80	0.44	0.42	0.25	0.24	0.14	0.14
160	2.76	2.60	1.83	1.75	1.34	1.28	1.14	1.08
150	5.01	4.60	3.60	3.34	2.76	2.60	2.45	2.31

Table F-171. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.85	0.81	0.44	0.42	0.24	0.24	0.15	0.15
160	2.92	2.75	1.89	1.79	1.39	1.32	1.16	1.09
150	5.87	5.45	3.99	3.72	2.92	2.75	2.59	2.43

Table F-172. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.86	0.83	0.45	0.43	0.25	0.24	0.15	0.15
160	2.96	2.77	1.92	1.82	1.40	1.34	1.20	1.14
150	6.03	5.50	4.10	3.76	2.96	2.77	2.62	2.46

Table F-173. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.22	1.14	0.63	0.60	0.44	0.42	0.37	0.35
160	3.65	3.41	2.45	2.31	1.81	1.71	1.58	1.49
150	6.20	5.72	4.60	4.28	3.65	3.41	3.18	2.96

Table F-174. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.26	1.20	0.68	0.66	0.44	0.43	0.39	0.37
160	3.73	3.48	2.52	2.38	1.87	1.78	1.62	1.54
150	6.25	5.78	4.68	4.34	3.73	3.48	3.23	2.99

Table F-175. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.30	1.23	0.69	0.66	0.44	0.42	0.38	0.36
160	4.06	3.78	2.63	2.47	1.92	1.81	1.68	1.59
150	7.62	7.00	5.24	4.87	4.06	3.78	3.52	3.28

Table F-176. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.32	1.26	0.73	0.69	0.45	0.43	0.39	0.37
160	4.19	3.86	2.67	2.51	1.96	1.86	1.69	1.61
150	7.82	7.08	5.44	4.97	4.19	3.86	3.61	3.32

Table F-177. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.56	1.48	0.90	0.86	0.54	0.51	0.45	0.43
160	4.18	3.91	2.87	2.71	2.22	2.10	1.93	1.83
150	6.62	6.11	5.08	4.71	4.18	3.91	3.76	3.51

Table F-178. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.58	1.51	0.90	0.87	0.56	0.53	0.46	0.44
160	4.26	3.97	2.91	2.75	2.28	2.15	1.95	1.85
150	6.70	6.19	5.15	4.78	4.26	3.97	3.84	3.58

Table F-179. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.64	1.56	0.93	0.89	0.58	0.55	0.46	0.44
160	4.59	4.28	3.09	2.88	2.41	2.27	2.04	1.92
150	8.04	7.39	5.77	5.34	4.59	4.28	4.10	3.83

Table F-180. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.65	1.58	0.94	0.90	0.59	0.56	0.47	0.45
160	4.72	4.35	3.14	2.90	2.44	2.29	2.05	1.93
150	8.24	7.45	5.92	5.43	4.72	4.35	4.19	3.88

Table F-181. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.81	1.72	1.02	0.98	0.64	0.62	0.54	0.52
160	4.66	4.34	3.37	3.14	2.62	2.47	2.26	2.14
150	7.18	6.59	5.59	5.18	4.66	4.34	4.24	3.97

Table F-182. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.83	1.75	1.07	1.02	0.70	0.65	0.55	0.52
160	4.70	4.38	3.39	3.14	2.63	2.49	2.30	2.18
150	7.18	6.58	5.60	5.20	4.70	4.38	4.28	3.99

Table F-183. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.90	1.80	1.05	1.00	0.67	0.64	0.55	0.53
160	5.48	5.08	3.83	3.57	2.82	2.65	2.48	2.34
150	9.87	9.03	6.90	6.37	5.48	5.08	4.86	4.53

Table F-184. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.90	1.82	1.09	1.05	0.75	0.72	0.56	0.54
160	5.44	5.02	3.84	3.55	2.82	2.66	2.47	2.33
150	9.42	8.59	6.75	6.23	5.44	5.02	4.86	4.49

Table F-185. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.16	2.04	1.30	1.25	0.82	0.78	0.66	0.63
160	5.40	5.03	4.03	3.77	3.02	2.84	2.68	2.54
150	8.29	7.65	6.45	5.98	5.40	5.03	4.92	4.59

Table F-186. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.20	2.08	1.31	1.26	0.83	0.80	0.69	0.66
160	5.43	5.04	4.08	3.80	3.07	2.87	2.71	2.57
150	8.23	7.52	6.40	5.95	5.43	5.04	4.97	4.61

Table F-187. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.38	2.26	1.35	1.28	0.84	0.81	0.67	0.63
160	7.16	6.59	4.81	4.49	3.60	3.37	2.99	2.82
150	14.33	13.01	9.36	8.58	7.16	6.59	6.29	5.82

Table F-188. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.39	2.28	1.35	1.29	0.83	0.80	0.73	0.70
160	6.91	6.40	4.78	4.44	3.59	3.35	2.98	2.82
150	13.33	11.97	8.93	8.16	6.91	6.40	6.12	5.69

Table F-189. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.52	1.45	0.72	0.68	0.50	0.48	0.35	0.34
160	5.32	4.94	3.46	3.22	2.46	2.34	1.98	1.88
150	9.15	8.47	6.70	6.20	5.32	4.94	4.68	4.36

Table F-190. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.53	1.46	0.77	0.74	0.50	0.47	0.37	0.36
160	5.36	4.96	3.52	3.30	2.53	2.40	1.99	1.90
150	9.10	8.34	6.70	6.20	5.36	4.96	4.73	4.39

Table F-191. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.44	1.35	0.72	0.70	0.47	0.43	0.36	0.34
160	6.06	5.55	3.46	3.26	2.36	2.21	1.98	1.87
150	14.18	12.89	8.58	7.82	6.06	5.55	5.08	4.68

Table F-192. Scenario B5, Jacket foundation (50m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.52	1.45	0.76	0.73	0.47	0.45	0.37	0.35
160	6.22	5.70	3.61	3.38	2.39	2.27	1.99	1.88
150	14.47	12.76	8.77	7.92	6.22	5.70	5.24	4.81

Table F-193. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.49	0.47	0.24	0.23	0.12	0.12	0.11	0.11
160	2.04	1.92	1.32	1.25	0.89	0.85	0.69	0.67
150	3.94	3.68	2.71	2.55	2.04	1.92	1.79	1.70

Table F-194. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.49	0.47	0.24	0.23	0.12	0.12	0.11	0.10
160	2.10	1.98	1.33	1.28	0.92	0.87	0.74	0.70
150	4.03	3.74	2.76	2.60	2.10	1.98	1.83	1.74

Table F-195. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.51	0.48	0.23	0.22	0.13	0.13	0.11	0.11
160	2.19	2.07	1.37	1.30	0.92	0.88	0.74	0.71
150	4.40	4.11	2.88	2.71	2.19	2.07	1.88	1.78

Table F-196. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 200 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.51	0.49	0.23	0.22	0.13	0.12	0.11	0.11
160	2.24	2.10	1.39	1.33	0.94	0.90	0.76	0.73
150	4.55	4.17	2.93	2.75	2.24	2.10	1.90	1.81

Table F-197. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.88	0.84	0.44	0.42	0.25	0.24	0.19	0.14
160	2.84	2.68	1.90	1.80	1.42	1.35	1.19	1.13
150	5.05	4.70	3.73	3.47	2.84	2.68	2.56	2.42

Table F-198. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.88	0.85	0.45	0.43	0.26	0.25	0.20	0.19
160	2.88	2.73	1.92	1.83	1.44	1.38	1.21	1.15
150	5.14	4.75	3.80	3.53	2.88	2.73	2.59	2.45

Table F-199. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.91	0.87	0.45	0.43	0.24	0.24	0.16	0.15
160	3.06	2.85	1.99	1.89	1.48	1.40	1.24	1.18
150	5.97	5.52	4.14	3.86	3.06	2.85	2.71	2.56

Table F-200. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.91	0.87	0.46	0.44	0.25	0.24	0.16	0.15
160	3.13	2.89	2.01	1.91	1.49	1.43	1.26	1.21
150	6.08	5.58	4.26	3.92	3.13	2.89	2.74	2.58

Table F-201. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.27	1.20	0.67	0.64	0.43	0.41	0.31	0.28
160	3.60	3.37	2.46	2.32	1.83	1.73	1.62	1.53
150	5.94	5.51	4.48	4.18	3.60	3.37	3.11	2.90

Table F-202. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.27	1.22	0.70	0.67	0.44	0.42	0.34	0.32
160	3.71	3.45	2.52	2.38	1.89	1.79	1.62	1.55
150	6.04	5.57	4.56	4.24	3.71	3.45	3.21	2.97

Table F-203. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.30	1.24	0.73	0.69	0.43	0.42	0.34	0.31
160	3.98	3.72	2.61	2.46	1.92	1.83	1.67	1.59
150	7.42	6.83	5.11	4.77	3.98	3.72	3.47	3.24

Table F-204. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.31	1.25	0.74	0.71	0.44	0.42	0.35	0.34
160	4.10	3.80	2.65	2.51	1.96	1.86	1.69	1.61
150	7.55	6.84	5.30	4.85	4.10	3.80	3.56	3.28

Table F-205. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.49	1.40	0.86	0.82	0.51	0.49	0.43	0.42
160	3.98	3.71	2.73	2.56	2.07	1.94	1.84	1.74
150	6.43	5.92	4.84	4.49	3.98	3.71	3.51	3.26

Table F-206. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.50	1.44	0.90	0.86	0.55	0.53	0.44	0.42
160	4.06	3.79	2.79	2.63	2.17	2.04	1.87	1.78
150	6.45	5.98	4.94	4.57	4.06	3.79	3.62	3.37

Table F-207. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.54	1.46	0.92	0.87	0.56	0.54	0.44	0.42
160	4.35	4.05	2.88	2.70	2.25	2.11	1.92	1.82
150	8.16	7.47	5.57	5.16	4.35	4.05	3.85	3.58

Table F-208. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 1500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.59	1.51	0.92	0.89	0.59	0.56	0.45	0.43
160	4.52	4.16	2.92	2.75	2.27	2.12	1.95	1.86
150	8.27	7.53	5.75	5.29	4.52	4.16	3.97	3.68

Table F-209. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.71	1.63	0.96	0.92	0.62	0.59	0.52	0.50
160	4.48	4.18	3.14	2.93	2.48	2.34	2.12	2.02
150	6.95	6.43	5.40	5.01	4.48	4.18	4.06	3.80

Table F-210. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.73	1.66	1.01	0.96	0.64	0.61	0.51	0.49
160	4.53	4.21	3.21	2.97	2.52	2.38	2.17	2.05
150	6.98	6.42	5.46	5.03	4.53	4.21	4.12	3.83

Table F-211. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.82	1.73	0.99	0.94	0.64	0.62	0.51	0.50
160	5.27	4.90	3.61	3.37	2.67	2.52	2.34	2.21
150	9.73	8.91	6.75	6.22	5.27	4.90	4.65	4.34

Table F-212. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2000 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.82	1.73	1.05	1.00	0.67	0.65	0.53	0.50
160	5.28	4.84	3.63	3.34	2.69	2.53	2.34	2.20
150	9.32	8.49	6.61	6.08	5.28	4.84	4.69	4.31

Table F-213. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.81	1.72	0.97	0.93	0.63	0.61	0.44	0.43
160	5.25	4.91	3.70	3.48	2.74	2.60	2.34	2.21
150	8.43	7.78	6.38	5.94	5.25	4.91	4.72	4.42

Table F-214. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.85	1.76	1.01	0.96	0.66	0.63	0.46	0.44
160	5.28	4.89	3.77	3.53	2.76	2.62	2.38	2.26
150	8.30	7.59	6.35	5.89	5.28	4.89	4.76	4.42

Table F-215. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.97	1.88	1.01	0.97	0.60	0.58	0.46	0.44
160	7.16	6.61	4.57	4.28	3.18	2.99	2.68	2.54
150	14.81	13.47	9.55	8.76	7.16	6.61	6.20	5.75

Table F-216. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 2500 kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.99	1.89	1.04	1.00	0.64	0.61	0.46	0.44
160	7.01	6.47	4.60	4.26	3.22	3.00	2.70	2.55
150	14.15	12.58	9.25	8.44	7.01	6.47	6.13	5.68

Table F-217. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500a kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.04	1.93	1.10	1.04	0.65	0.62	0.49	0.47
160	6.18	5.74	4.36	4.08	3.16	2.97	2.71	2.57
150	9.89	9.14	7.60	7.02	6.18	5.74	5.54	5.16

Table F-218. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500a kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.06	1.95	1.09	1.04	0.66	0.63	0.50	0.48
160	6.10	5.69	4.35	4.07	3.16	2.97	2.71	2.58
150	9.73	8.91	7.53	6.89	6.10	5.69	5.50	5.13

Table F-219. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500a kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.10	2.00	1.05	1.00	0.61	0.59	0.48	0.46
160	8.48	7.84	5.20	4.85	3.62	3.39	2.88	2.74
150	18.39	16.65	11.74	10.72	8.48	7.84	7.22	6.66

Table F-220. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500a kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	2.17	2.04	1.07	1.02	0.63	0.61	0.48	0.46
160	8.52	7.73	5.28	4.87	3.68	3.43	2.92	2.77
150	18.07	15.58	11.51	10.32	8.52	7.73	7.24	6.62

Table F-221. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500b kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.40	1.34	0.67	0.65	0.44	0.43	0.32	0.31
160	5.04	4.69	3.20	2.98	2.28	2.16	1.88	1.80
150	8.80	8.14	6.40	5.93	5.04	4.69	4.44	4.14

Table F-222. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500b kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.43	1.37	0.69	0.67	0.44	0.42	0.36	0.34
160	5.08	4.72	3.24	3.04	2.33	2.20	1.90	1.81
150	8.76	8.02	6.37	5.92	5.08	4.72	4.47	4.16

Table F-223. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500b kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.32	1.26	0.68	0.65	0.41	0.40	0.32	0.31
160	5.60	5.19	3.20	2.98	2.16	2.04	1.81	1.72
150	13.16	12.06	7.94	7.28	5.60	5.19	4.72	4.38

Table F-224. Scenario B6, Jacket foundation (80m pile, post-piled 4.25 m diameter, with an MHU 5500 hammer, 3500b kJ) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	1.40	1.32	0.70	0.67	0.42	0.40	0.35	0.34
160	5.74	5.30	3.24	3.04	2.22	2.10	1.84	1.76
150	13.39	11.94	8.13	7.36	5.74	5.30	4.83	4.47

Supplement G. Acoustic Range Results - Vibratory + Impact Pile Driving

G.1. Decidecade SEL at 750 m

G.1.1. 12.5 m Monopile Foundation

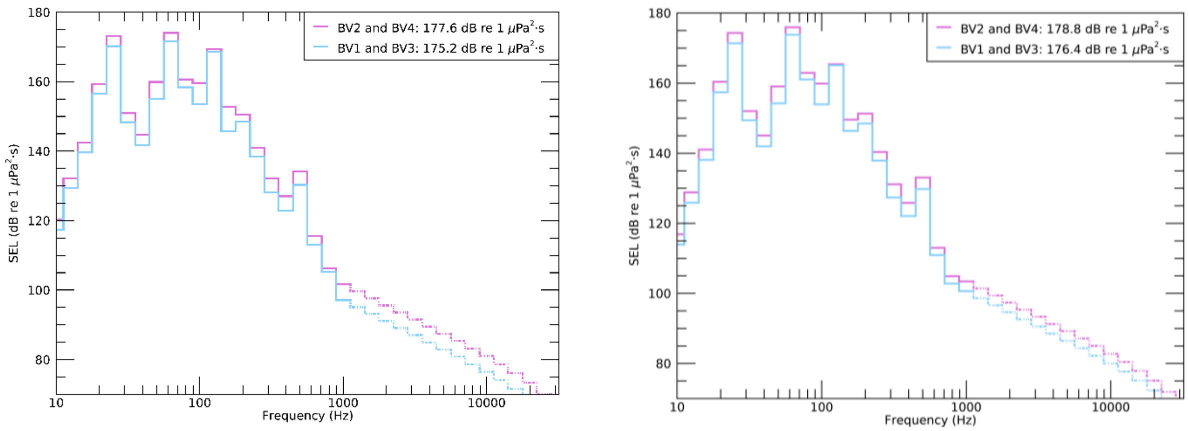


Figure G-1. Decidecade band levels at 750 m from locations (top row) L01 (shallow) and (bottom row) L02 (deep) for a 12.5 m monopile assuming an installation scenario with the TR-CV640 hammer with varying durations of 60 min (Scenarios BV1 and BV3) and 30 min (Scenarios BV2 and BV4) of vibratory piling, with an average sound speed profiles for winter. Values at higher frequencies (1–25 kHz, dashed lines) have been extrapolated using a constant decay rate.

G.1.2. 4.25 m Jacket Foundation

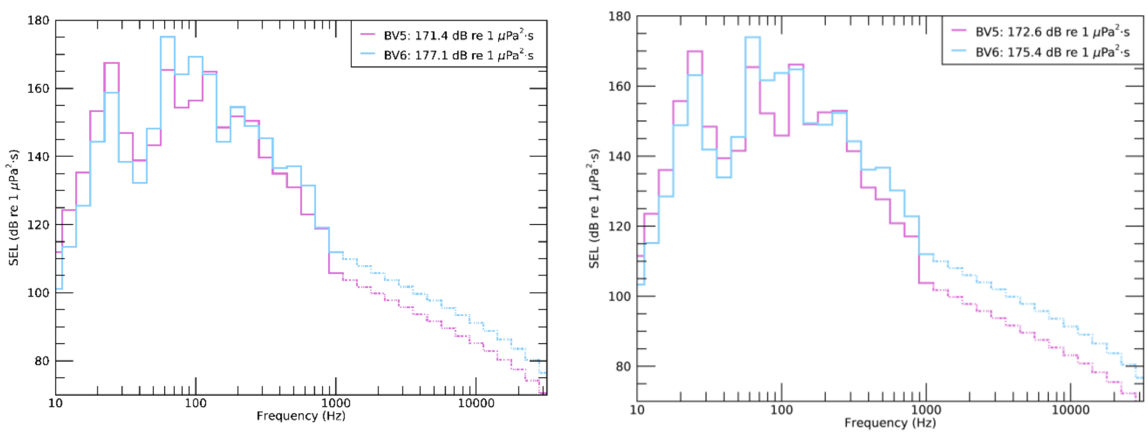


Figure G-2. Scenario BV5 and BV6: Decidecade band levels at 750 m from locations (left) L01 (shallow) and (right) L02 (deep) for a 4.25 m jacket assuming an installation scenario with the TR-CV320 hammer with average sound speed profiles for winter.

G.2. Per-Pile SEL Acoustic Ranges to Injury Thresholds

G.2.1. 12.5 m Monopile Foundation

Table G-1. Scenarios BV1 and BV3, monopile foundation (12.5 m diameter, with a TR CV640 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	199	0.83	0.45	0.26	0.15	0.83	0.45	0.24	0.16
MF	198	-	-	-	-	-	-	-	-
HF	173	-	-	-	-	-	-	-	-
PW	201	0.07	-	-	-	0.07	-	-	-
TU	220	0.12	0.06	-	-	0.12	0.06	-	-

Table G-2. Scenarios BV1 and BV3, monopile foundation (12.5 m diameter, with a TR CV640 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	199	0.86	0.44	0.27	0.19	0.88	0.44	0.26	0.16
MF	198	-	-	-	-	-	-	-	-
HF	173	-	-	-	-	-	-	-	-
PW	201	0.08	<0.01	-	-	0.07	<0.01	-	-
TU	220	0.12	0.06	0.01	-	0.12	0.06	0.01	-

Table G-3. Scenarios BV2 and BV4, monopile foundation (12.5 m diameter, with a TR CV640 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	199	0.74	0.42	0.20	0.14	0.77	0.42	0.17	0.14
MF	198	-	-	-	-	-	-	-	-
HF	173	-	-	-	-	-	-	-	-
PW	201	0.06	-	-	-	0.06	-	-	-
TU	220	0.11	0.04	-	-	0.11	0.03	-	-

Table G-4. Scenarios BV2 and BV4, monopile foundation (12.5 m diameter, with a TR CV640 hammer) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	199	0.74	0.42	0.21	0.14	0.77	0.43	0.19	0.15
MF	198	-	-	-	-	-	-	-	-
HF	173	-	-	-	-	-	-	-	-
PW	201	0.06	-	-	-	0.06	-	-	-
TU	220	0.11	0.05	0.01	-	0.11	0.05	0.01	-

Table G-5. Scenario BV1, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.24	2.88	2.28	1.97	5.20	3.42	2.49	2.14
MF	185	-	-	-	-	-	-	-	-
HF	155	0.14	0.09	0.02	-	0.14	0.09	0.02	-
PW	185	1.12	0.59	0.39	0.27	1.17	0.62	0.40	0.27
TU	204	1.57	0.92	0.60	0.48	1.67	0.94	0.63	0.49

Table G-6. Scenario BV1, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.22	2.88	2.33	2.00	5.19	3.39	2.50	2.15
MF	185	-	-	-	-	-	-	-	-
HF	155	0.13	0.09	0.01	0.01	0.15	0.09	0.01	0.01
PW	185	1.15	0.62	0.40	0.28	1.20	0.66	0.41	0.28
TU	204	1.62	0.96	0.65	0.50	1.69	1.00	0.67	0.52

Table G-7. Scenario BV2, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	3.89	2.63	2.04	1.76	4.65	2.92	2.21	1.85
MF	185	-	-	-	-	-	-	-	-
HF	155	0.13	0.06	-	-	0.13	0.05	-	-
PW	185	0.94	0.48	0.30	0.24	0.98	0.50	0.30	0.23
TU	204	1.38	0.80	0.52	0.44	1.46	0.84	0.54	0.46

Table G-8. Scenario BV2, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	3.89	2.71	2.08	1.82	4.64	2.90	2.23	1.90
MF	185	-	-	-	-	-	-	-	-
HF	155	0.12	0.07	0.01	-	0.13	0.05	0.01	-
PW	185	1.00	0.52	0.31	0.24	1.02	0.53	0.32	0.23
TU	204	1.49	0.88	0.56	0.44	1.54	0.90	0.58	0.45

Table G-9. Scenario BV3, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.23	2.87	2.27	1.96	5.17	3.40	2.47	2.13
MF	185	-	-	-	-	-	-	-	-
HF	155	0.14	0.09	0.02	-	0.14	0.09	0.02	-
PW	185	1.11	0.58	0.39	0.27	1.16	0.62	0.40	0.27
TU	204	1.56	0.91	0.60	0.48	1.66	0.94	0.62	0.48

Table G-10. Scenario BV3, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	4.20	2.88	2.32	1.99	5.17	3.37	2.49	2.13
MF	185	-	-	-	-	-	-	-	-
HF	155	0.13	0.09	0.01	0.01	0.14	0.09	0.01	<0.01
PW	185	1.15	0.62	0.40	0.27	1.19	0.65	0.40	0.27
TU	204	1.61	0.96	0.64	0.50	1.68	0.99	0.67	0.51

Table G-11. Scenario BV4, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	3.88	2.62	2.03	1.75	4.62	2.89	2.20	1.84
MF	185	-	-	-	-	-	-	-	-
HF	155	0.13	0.05	-	-	0.13	0.05	-	-
PW	185	0.93	0.48	0.29	0.24	0.97	0.50	0.30	0.22
TU	204	1.37	0.79	0.51	0.44	1.45	0.83	0.53	0.45

Table G-12. Scenario BV4, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to marine mammal and sea turtle injury SEL thresholds (Finneran et al. 2017, NMFS 2018) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
LF	183	3.88	2.69	2.07	1.81	4.61	2.88	2.22	1.89
MF	185	-	-	-	-	-	-	-	-
HF	155	0.12	0.07	0.01	-	0.13	0.04	0.01	-
PW	185	0.99	0.51	0.30	0.24	1.01	0.52	0.31	0.23
TU	204	1.48	0.87	0.55	0.44	1.53	0.89	0.57	0.45

G.3. Fish Acoustic Ranges to Thresholds

In this section, the table footnotes indicate the following:

- [a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008), and
- [b] Popper et al. (2014).

G.3.1. 12.5 m Monopile Foundation

Table G-13. Scenario BV1, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.25	3.93	3.01	2.66	6.58	4.65	3.57	3.00
Fish < 2 g	183	6.24	4.79	3.93	3.52	8.23	5.89	4.65	4.09
Fish without swim bladder	216	0.63	0.29	0.16	0.13	0.67	0.30	0.16	0.13
Fish with swim bladder	203	2.04	1.30	0.89	0.73	2.23	1.37	0.91	0.77

Table G-14. Scenario BV1, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.28	4.02	3.18	2.78	6.51	4.67	3.62	3.07
Fish < 2 g	183	6.21	4.84	4.02	3.62	8.04	5.87	4.67	4.14
Fish without swim bladder	216	0.72	0.35	0.17	0.13	0.74	0.34	0.17	0.13
Fish with swim bladder	203	2.17	1.40	0.95	0.79	2.30	1.44	0.97	0.81

Table G-15. Scenario BV3, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.23	3.91	3.00	2.65	6.55	4.63	3.55	2.98
Fish < 2 g	183	6.22	4.77	3.91	3.50	8.20	5.87	4.63	4.08
Fish without swim bladder	216	0.62	0.28	0.16	0.13	0.66	0.29	0.16	0.13
Fish with swim bladder	203	2.03	1.29	0.88	0.73	2.22	1.36	0.91	0.76

Table G-16. Scenario BV3, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	5.27	4.01	3.16	2.77	6.49	4.65	3.60	3.05
Fish < 2 g	183	6.20	4.83	4.01	3.61	8.02	5.84	4.65	4.12
Fish without swim bladder	216	0.72	0.33	0.17	0.12	0.73	0.33	0.17	0.13
Fish with swim bladder	203	2.15	1.39	0.95	0.78	2.29	1.43	0.96	0.81

Table G-17. Scenario BV2, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	4.90	3.64	2.77	2.49	6.01	4.20	3.14	2.68
Fish < 2 g	183	5.86	4.46	3.64	3.16	7.53	5.36	4.20	3.68
Fish without swim bladder	216	0.58	0.26	0.14	0.12	0.61	0.26	0.15	0.12
Fish with swim bladder	203	1.85	1.22	0.84	0.71	2.02	1.28	0.87	0.73

Table G-18. Scenario BV2, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	4.99	3.82	2.94	2.67	5.98	4.27	3.28	2.81
Fish < 2 g	183	5.88	4.58	3.82	3.40	7.39	5.37	4.27	3.78
Fish without swim bladder	216	0.71	0.28	0.15	0.12	0.72	0.29	0.15	0.12
Fish with swim bladder	203	2.04	1.32	0.92	0.76	2.12	1.36	0.92	0.78

Table G-19. Scenario BV4, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L01 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	4.88	3.62	2.76	2.47	5.98	4.17	3.12	2.67
Fish < 2 g	183	5.84	4.44	3.62	3.14	7.49	5.33	4.17	3.66
Fish without swim bladder	216	0.58	0.26	0.14	0.12	0.61	0.26	0.15	0.12
Fish with swim bladder	203	1.84	1.21	0.83	0.70	2.00	1.27	0.86	0.72

Table G-20. Scenario BV4, monopile foundation (12.5 m diameter, with a TR CV640 and MHU5500 hammers) acoustic ranges ($R_{95\%}$ in km) to fish injury SEL thresholds (FHWG 2008, Popper et al. 2014) at location L02 for different attenuations and seasons.

Hearing group	Level ($L_{E,W}$)	Summer 0 dB	Summer 6 dB	Summer 10 dB	Summer 12 dB	Winter 0 dB	Winter 6 dB	Winter 10 dB	Winter 12 dB
Fish ≥ 2 g	187	4.97	3.80	2.92	2.65	5.95	4.25	3.26	2.80
Fish < 2 g	183	5.86	4.56	3.80	3.38	7.35	5.34	4.25	3.76
Fish without swim bladder	216	0.70	0.28	0.15	0.12	0.72	0.29	0.15	0.12
Fish with swim bladder	203	2.03	1.32	0.92	0.75	2.11	1.36	0.92	0.78

G.4. Single-Second SPL Ranges

G.4.1. 12.5 m Monopile Foundation

Table G-21. Scenarios BV1 and BV3, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.75	0.72	0.30	0.29	0.16	0.16	0.13	0.13
150	4.68	4.37	3.24	3.02	2.51	2.37	2.18	2.04
120	14.77	13.46	12.47	11.42	10.64	9.72	9.79	9.05

Table G-22. Scenarios BV1 and BV3, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.79	0.75	0.42	0.40	0.17	0.16	0.13	0.13
150	4.88	4.47	3.55	3.27	2.68	2.53	2.39	2.25
120	14.65	12.84	12.33	10.89	10.47	9.35	9.73	8.81

Table G-23. Scenarios BV1 and BV3, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.78	0.74	0.31	0.30	0.17	0.16	0.13	0.13
150	5.69	5.22	3.87	3.60	2.80	2.62	2.38	2.23
120	26.07	22.97	19.09	17.07	16.01	14.34	14.61	13.11

Table G-24. Scenarios BV1 and BV3, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.82	0.78	0.41	0.39	0.17	0.17	0.14	0.13
150	5.71	5.21	3.97	3.65	2.88	2.69	2.54	2.36
120	24.09	20.31	18.39	15.81	15.53	13.52	14.21	12.49

Table G-25. Scenarios BV2 and BV4, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.86	0.83	0.47	0.45	0.21	0.20	0.16	0.16
150	4.84	4.51	3.46	3.23	2.70	2.54	2.36	2.21
120	15.26	13.89	12.82	11.78	11.04	10.11	9.99	9.26

Table G-26. Scenarios BV2 and BV4, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in summer for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.97	0.92	0.48	0.46	0.25	0.24	0.17	0.17
150	5.09	4.66	3.80	3.56	2.96	2.78	2.65	2.50
120	15.13	13.23	12.73	11.25	10.92	9.64	9.97	9.02

Table G-27. Scenarios BV2 and BV4, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L01 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.90	0.86	0.48	0.46	0.21	0.20	0.17	0.17
150	5.81	5.33	4.00	3.72	2.89	2.72	2.55	2.38
120	27.70	24.38	19.93	17.81	16.69	14.93	15.16	13.61

Table G-28. Scenarios BV2 and BV4, monopile foundation (12.5 m diameter with a TR CV640 hammer) acoustic ranges (R_{max} and $R_{95\%}$ in km) to unweighted SPL thresholds (GARFO 2020, NMFS 2023) at location L02 in winter for different attenuations.

Level (L_p)	0 dB R_{max}	0 dB $R_{95\%}$	6 dB R_{max}	6 dB $R_{95\%}$	10 dB R_{max}	10 dB $R_{95\%}$	12 dB R_{max}	12 dB $R_{95\%}$
175	0.95	0.91	0.49	0.47	0.25	0.23	0.18	0.18
150	5.87	5.36	4.18	3.86	3.17	2.89	2.77	2.59
120	25.63	21.95	19.33	16.65	16.29	14.12	14.85	12.99

Supplement H. Animal Movement and Exposure Modeling

H.1. Animal Movement Parameters

H.1.1. Exposure Integration Time

The time interval over which acoustic exposure (SEL) should be integrated and the 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 individuals that would be exposed. This is because individuals can be counted multiple times during the subsequent days of an operation. The animal movement model used in this study simulates realistic movement using swimming behavior collected over relatively short periods (hours to days). It does not include large-scale movement such as migratory circulation patterns. Therefore, simulation time should be limited to no more than a few weeks, the approximate time scale of the collected data (e.g., marine mammal tag data) (Houser 2006). One-week simulations (i.e., 7 days) were modeled for this study.

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 Offshore Development Area during sound-producing activities is included. However, there are practical limits, and computational overhead increases with the size of the simulation area. Therefore, the simulation area is limited in this analysis to a maximum distance of 70 km from the Vineyard Mid-Atlantic Lease Area (see figures in Section H.5). In the simulation, every animat that moves out of the simulation area is replaced by another animat entering at an opposite border. For example, 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. If this action would position the animat in an inappropriate water depth, the animat is then randomly placed on the map at a depth suited to its species definition. The records of all animats (including those leaving the simulation and those entering) are stored 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 levels of sound exposure (Ellison et al. 2012). Proximity and received levels are both important factors in aversive responses (Dunlop et al. 2017). As the received sound level generally decreases with distance from a source, this aspect of natural behavior can strongly influence the predicted maximum sound received levels of an animal and significantly affects the probability of more pronounced physiological or subsequent behavioral effects. Additionally, an animal is less likely to respond to sound levels distant from a source, even when those same levels elicit response at closer distances. As a supplement to this modeling study, and only for comparison purposes, parameters determining aversion at specified sound levels for North Atlantic right whale were applied (in recognition of its Endangered species status) and for harbor porpoise (a species with a strong aversive response to loud sounds).

JASMINE applies aversion by defining a new behavioral state that an animat may transition into when a specified received sound level is exceeded. There are very few data that describe aversive behavior in response to sound. Therefore, the aversion probability and threshold is based on the Wood et al. (2012) step function. Animats are 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). 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 updated (Tables H-1 and H-2). Depending on the current level of exposure the animat either begins another aversion interval or transitions to a non-aversive behavior.

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 $L_{p,w}$ (dB re 1 µPa^2)	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 $L_{p,w}$ (dB re 1 µPa^2)	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 and for continuous 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., common bottlenose dolphins found in water deeper than 20 m.

H.2. Exposure Estimates

H.2.1. Marine Mammals

This section contains mean predicted marine mammal exposure estimates using the proposed construction schedules described in Section 1.2.2. Tables H-3 to H-7 show exposure estimates, assuming 0, 6, 10, and 12 dB of broadband attenuation. Construction schedules A.2 and A.3 include a combination of foundations installed with vibratory setting of piles followed by impact pile driving and foundations installed with impact pile driving alone, while construction schedule A.1 includes foundations installed with vibratory setting of piles followed by impact pile driving only.

Table H-3. Construction Schedule A.1, Full build out of piles in 1 year: Mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	12.89	7.11	4.59	3.69	0.16	0.06	0.02	<0.01	150.81	112.28	87.09	75.45	26.45	16.77	12.19	10.25
LF	Humpback whale	8.14	4.58	3.16	2.67	0.05	<0.01	0	0	78.93	57.43	44.72	39.70	15.66	10.06	7.47	6.35
LF	Common minke whale (migrating)	48.67	30.26	21.56	17.14	0.39	0.04	0	0	347.38	255.17	205.10	183.26	262.73	191.18	155.40	140.45
LF	North Atlantic right whale [c]	0.87	0.52	0.34	0.27	<0.01	<0.01	<0.01	<0.01	7.80	5.62	4.49	3.91	1.67	1.11	0.82	0.69
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0.10	<0.01	<0.01	<0.01
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0.04	0	0	0	248.65	192.26	149.67	135.04	34.86	23.25	16.57	14.32
MF	Atlantic white sided dolphin	0	0	0	0	0.18	0	0	0	810.88	607.02	493.23	436.69	110.04	71.30	50.46	43.98
MF	Common bottlenose dolphin	0	0	0	0	0.29	0	0	0	1439.74	1066.09	831.09	742.88	201.86	133.44	96.27	80.20
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	87.62	64.56	50.86	45.55	11.26	7.38	5.26	4.68
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	6.50	4.81	3.80	3.42	0.78	0.50	0.36	0.30
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	0.01	0.01	0	0	43.33	30.46	22.76	20.00	3.95	2.40	1.63	1.38
MF	Common dolphin	0	0	0	0	2.93	0.98	0	0	7213.30	5406.92	4100.01	3656.61	912.00	612.21	446.28	387.22
HF	Harbor porpoise (sensitive)	0	0	0	0	10.67	4.21	2.46	0.02	611.21	424.46	329.44	288.14	593.12	374.09	283.82	246.97
PW	Gray seal	5.06	2.02	0.30	0.30	<0.01	0	0	0	762.35	537.06	410.37	358.89	78.90	44.13	29.30	23.92
PW	Harbor seal	15.80	4.34	0.29	0.28	0.57	0.56	0.42	0.14	1050.12	728.65	553.53	477.33	136.09	84.97	58.66	48.93

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-4. Construction Schedule A.2, 50% build out of piles in Year 1: Mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	6.79	3.65	2.39	1.89	0.10	0.02	<0.01	<0.01	38.24	26.59	19.98	17.03	13.12	8.04	5.83	4.90
LF	Humpback whale	4.91	2.69	1.86	1.55	0.03	<0.01	<0.01	<0.01	24.02	16.62	12.61	10.97	8.92	5.65	4.15	3.51
LF	Common minke whale (migrating)	25.86	16.32	11.57	9.28	0.20	0.05	<0.01	0	112.06	79.73	62.77	55.42	158.19	113.45	90.22	79.95
LF	North Atlantic right whale [c]	0.60	0.35	0.23	0.18	<0.01	<0.01	<0.01	<0.01	3.24	2.25	1.75	1.50	1.18	0.78	0.57	0.48
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0.34	0.27	0.19	0.08
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0.03	0	0	0	90.49	65.73	50.61	44.78	25.47	16.60	11.87	10.13
MF	Atlantic white sided dolphin	0	0	0	0	0.10	0.01	0	0	292.95	213.51	170.06	148.76	67.58	42.95	30.34	26.32
MF	Common bottlenose dolphin	0	0	0	0	0.19	0	0	0	476.83	334.44	254.07	224.24	122.16	79.08	56.74	47.75
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	28.76	20.18	15.61	13.72	6.80	4.37	3.09	2.74
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	2.10	1.48	1.13	1.00	0.47	0.30	0.21	0.18
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.15	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.08	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	17.81	11.94	8.89	7.71	2.73	1.63	1.11	0.93
MF	Common dolphin	0	0	0	0	1.55	0.45	0	0	2663.66	1875.03	1413.00	1242.74	579.34	381.54	276.41	237.09
HF	Harbor porpoise (sensitive)	<0.01	0	0	0	7.16	3.01	1.44	0.12	247.02	168.23	129.09	111.65	541.61	335.37	226.68	191.15
PW	Gray seal	3.96	1.54	0.24	0.23	<0.01	<0.01	<0.01	<0.01	334.23	223.78	166.51	142.42	61.40	34.01	22.50	18.39
PW	Harbor seal	11.88	3.20	0.15	0.13	0.24	0.24	0.17	0.05	472.58	320.68	241.41	206.13	106.28	66.44	45.71	38.34

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-5. Construction Schedule A.2, 50% build out of piles in Year 2: Mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	6.79	3.65	2.39	1.89	0.10	0.02	<0.01	<0.01	38.24	26.59	19.98	17.03	13.12	8.04	5.83	4.90
LF	Humpback whale	4.91	2.69	1.86	1.55	0.03	<0.01	<0.01	<0.01	24.02	16.62	12.61	10.97	8.92	5.65	4.15	3.51
LF	Common minke whale (migrating)	25.86	16.32	11.57	9.28	0.20	0.05	<0.01	0	112.06	79.73	62.77	55.42	158.19	113.45	90.22	79.95
LF	North Atlantic right whale [c]	0.60	0.35	0.23	0.18	<0.01	<0.01	<0.01	<0.01	3.24	2.25	1.75	1.50	1.18	0.78	0.57	0.48
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0.34	0.27	0.19	0.08
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0.03	0	0	0	90.49	65.73	50.61	44.78	25.47	16.60	11.87	10.13
MF	Atlantic white sided dolphin	0	0	0	0	0.10	0.01	0	0	292.95	213.51	170.06	148.76	67.58	42.95	30.34	26.32
MF	Common bottlenose dolphin	0	0	0	0	0.19	0	0	0	476.83	334.44	254.07	224.24	122.16	79.08	56.74	47.75
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	28.76	20.18	15.61	13.72	6.80	4.37	3.09	2.74
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	2.10	1.48	1.13	1.00	0.47	0.30	0.21	0.18
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.15	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.08	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	17.81	11.94	8.89	7.71	2.73	1.63	1.11	0.93
MF	Common dolphin	0	0	0	0	1.55	0.45	0	0	2663.66	1875.03	1413.00	1242.74	579.34	381.54	276.41	237.09
HF	Harbor porpoise (sensitive)	<0.01	0	0	0	7.16	3.01	1.44	0.12	247.02	168.23	129.09	111.65	541.61	335.37	226.68	191.15
PW	Gray seal	3.96	1.54	0.24	0.23	<0.01	<0.01	<0.01	<0.01	334.23	223.78	166.51	142.42	61.40	34.01	22.50	18.39
PW	Harbor seal	11.88	3.20	0.15	0.13	0.24	0.24	0.17	0.05	472.58	320.68	241.41	206.13	106.28	66.44	45.71	38.34

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.
[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-6. Construction Schedule A.3, 70% build out of piles in Year 1: Mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	9.52	5.21	3.40	2.69	0.14	0.03	<0.01	<0.01	59.94	41.85	31.37	26.87	18.81	11.65	8.48	7.13
LF	Humpback whale	6.06	3.33	2.30	1.91	0.04	<0.01	<0.01	<0.01	32.42	22.35	16.91	14.72	11.22	7.15	5.26	4.45
LF	Common minke whale (migrating)	33.09	20.92	14.80	11.87	0.26	0.07	0.01	0	151.54	108.08	85.06	75.12	199.82	143.72	114.80	102.18
LF	North Atlantic right whale [c]	0.74	0.43	0.28	0.22	<0.01	<0.01	<0.01	<0.01	4.72	3.27	2.54	2.18	1.49	0.98	0.72	0.60
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0.40	0.27	0.19	0.08
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0.03	0	0	0	110.66	80.44	61.95	54.83	29.92	19.64	14.06	12.03
MF	Atlantic white sided dolphin	0	0	0	0	0.13	0.02	0	0	386.29	280.05	222.28	194.35	83.23	52.88	37.30	32.36
MF	Common bottlenose dolphin	0	0	0	0	0.27	0	0	0	678.90	473.46	358.33	316.19	160.41	104.17	74.88	63.20
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	41.39	28.68	22.09	19.42	8.87	5.73	4.05	3.58
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	3.03	2.10	1.61	1.43	0.62	0.39	0.28	0.23
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.15	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.08	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	27.66	18.34	13.69	11.84	3.61	2.15	1.45	1.22
MF	Common dolphin	0	0	0	0	2.08	0.67	0	0	3746.67	2596.85	1951.76	1717.69	736.66	485.80	351.94	302.22
HF	Harbor porpoise (sensitive)	<0.01	0	0	0	9.15	3.87	2.00	0.15	381.32	257.71	196.66	169.53	713.36	430.11	295.01	248.89
PW	Gray seal	4.53	1.80	0.27	0.26	<0.01	<0.01	<0.01	<0.01	496.08	331.32	247.22	211.55	74.06	40.92	26.77	21.85
PW	Harbor seal	13.66	3.72	0.18	0.15	0.29	0.29	0.22	0.07	690.36	462.51	346.98	295.32	126.25	78.31	53.73	44.68

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-7. Construction Schedule A.3, 30% build out of piles in Year 2: Mean number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	4.94	2.65	1.72	1.39	0.07	0.02	<0.01	<0.01	27.12	19.05	14.36	12.33	9.13	5.53	4.01	3.40
LF	Humpback whale	3.30	1.80	1.26	1.05	0.02	<0.01	<0.01	<0.01	14.73	10.25	7.83	6.85	5.64	3.54	2.60	2.21
LF	Common minke whale (migrating)	16.19	10.34	7.36	6.01	0.13	0.04	<0.01	0	71.61	51.16	40.50	35.80	103.21	73.36	57.49	50.40
LF	North Atlantic right whale [c]	0.35	0.21	0.14	0.11	<0.01	<0.01	<0.01	<0.01	1.78	1.25	0.98	0.85	0.66	0.43	0.32	0.27
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0.34	0.27	0.19	0.08
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0.03	0	0	0	60.45	44.20	34.27	30.50	19.01	12.36	8.85	7.55
MF	Atlantic white sided dolphin	0	0	0	0	0.10	<0.01	0	0	169.23	123.75	99.37	87.20	41.02	25.94	18.22	15.83
MF	Common bottlenose dolphin	0	0	0	0	0.24	0	0	0	315.22	223.28	171.30	151.30	85.23	54.70	39.36	33.23
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	19.10	13.59	10.57	9.36	4.83	3.10	2.18	1.95
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	1.39	0.99	0.76	0.68	0.33	0.21	0.15	0.13
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.15	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.08	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	9.61	6.53	4.88	4.24	1.56	0.94	0.63	0.54
MF	Common dolphin	0	0	0	0	1.15	0.51	0	0	1613.88	1153.70	877.75	776.49	379.73	249.17	180.01	155.39
HF	Harbor porpoise (sensitive)	<0.01	0	0	0	4.37	1.82	1.14	0.10	141.87	96.15	74.17	64.53	362.58	222.74	141.27	116.05
PW	Gray seal	1.86	0.86	0.13	0.11	<0.01	<0.01	<0.01	<0.01	178.23	121.64	92.26	79.58	30.16	16.81	10.98	8.99
PW	Harbor seal	5.96	1.76	0.11	0.08	0.15	0.14	0.14	0.07	252.19	172.36	130.87	112.31	51.93	32.42	22.60	18.68

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

H.2.2. Sea Turtles

This section contains mean predicted sea turtle exposure estimates using the proposed construction schedules described in Section 1.2.2. Tables H-8 to H-12 show exposure estimates, assuming 0, 6, 10, and 12 dB of broadband attenuation. Construction schedules A.2 and A.3 include a combination of foundations installed with vibratory setting of piles followed by impact pile driving and foundations installed with impact pile driving alone, while construction schedule A.1 includes foundations installed with vibratory setting of piles followed by impact pile driving only.

Table H-8. Construction Schedule A.1, Full build out of piles in 1 year: Mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.08	0.03	0.02	<0.01	0	0	0	0	0.20	0.11	0.06	0.04
Leatherback turtle [a]	1.43	0.53	0.16	0.07	0	0	0	0	2.93	1.25	0.74	0.52
Loggerhead turtle	1.15	0.42	0.09	<0.01	0	0	0	0	2.67	1.53	1.00	0.77
Green turtle	2.46	0.96	0.50	0.20	0	0	0	0	5.69	3.16	2.07	1.43

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.
[a] Listed as Endangered under the ESA.

Table H-9. Construction Schedule A.2, 50% build out of piles in Year 1: Mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.05	0.02	<0.01	<0.01	0	0	0	0	0.10	0.05	0.03	0.02
Leatherback turtle [a]	0.99	0.39	0.12	0.07	0	0	0	0	1.60	0.66	0.38	0.26
Loggerhead turtle	0.62	0.26	0.08	0.03	<0.01	0	0	0	1.33	0.76	0.51	0.40
Green turtle	1.63	0.75	0.37	0.19	0	0	0	0	3.17	1.88	1.24	0.97

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.
[a] Listed as Endangered under the ESA.

Table H-10. Construction Schedule A.2, 50% build out of piles in Year 2: Mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.05	0.02	<0.01	<0.01	0	0	0	0	0.10	0.05	0.03	0.02
Leatherback turtle [a]	0.99	0.39	0.12	0.07	0	0	0	0	1.60	0.66	0.38	0.26
Loggerhead turtle	0.62	0.26	0.08	0.03	<0.01	0	0	0	1.33	0.76	0.51	0.40
Green turtle	1.63	0.75	0.37	0.19	0	0	0	0	3.17	1.88	1.24	0.97

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-11. Construction Schedule A.3, 70% build out of piles in Year 1: Mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.06	0.02	0.01	<0.01	0	0	0	0	0.14	0.08	0.04	0.03
Leatherback turtle [a]	1.31	0.50	0.15	0.08	0	0	0	0	2.26	0.96	0.54	0.38
Loggerhead turtle	0.81	0.34	0.10	0.04	<0.01	0	0	0	1.81	1.04	0.70	0.55
Green turtle	2.17	0.94	0.47	0.24	0	0	0	0	4.56	2.68	1.79	1.41

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-12. Construction Schedule A.3, 30% build out of piles in Year 2: Mean number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation. Construction schedule assumptions are summarized in Section 1.2.2.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.04	0.01	<0.01	<0.01	0	0	0	0	0.08	0.04	0.02	0.02
Leatherback turtle [a]	0.85	0.35	0.12	0.06	0	0	0	0	1.17	0.49	0.26	0.19
Loggerhead turtle	0.47	0.22	0.09	0.03	<0.01	0	0	0	0.92	0.54	0.35	0.29
Green turtle	1.45	0.67	0.33	0.20	0	0	0	0	2.60	1.56	1.05	0.84

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

H.3. Exposure Ranges – Marine Mammals

This section contains marine mammal exposure ranges for each of the modeled foundation types and seasons assuming 0, 6, 10, and 12 dB broadband attenuation.

H.3.1. Impact Pile Driving

Table H-13. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	3.60	2.60	1.91	1.55	0.03	0.02	0	0	5.68	4.25	3.38	3.06	5.66	4.26	3.42	3.07
LF	Humpback whale	3.29	2.24	1.72	1.52	0.05	0	0	0	5.66	4.16	3.40	3.06	5.72	4.16	3.41	3.06
LF	Common minke whale (migrating)	2.50	1.69	1.18	1.00	0.02	0.02	0	0	5.52	4.10	3.41	2.80	11.66	9.57	8.19	7.77
LF	North Atlantic right whale [c]	2.94	2.12	1.47	1.19	<0.01	<0.01	<0.01	<0.01	5.33	4.17	3.29	2.90	5.35	4.21	3.29	2.94
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0	5.38	3.97	3.24	2.85	2.93	2.00	1.44	1.25
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0	5.41	4.03	3.29	2.81	2.96	2.07	1.45	1.28
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0	5.06	3.79	3.02	2.58	2.62	1.76	1.33	1.18
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	5.35	3.98	3.23	2.90	2.98	2.00	1.44	1.27
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	5.50	4.08	3.26	2.91	2.96	2.02	1.52	1.20
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	5.38	4.12	3.24	2.84	3.01	2.04	1.51	1.32
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0	5.48	4.09	3.36	2.99	3.02	2.06	1.52	1.35
HF	Harbor porpoise (sensitive)	0	0	0	0	0.64	0.23	0.13	0	5.02	3.75	2.94	2.62	12.70	10.64	9.05	8.61
PW	Gray seal	1.10	0.61	0.23	0.23	0	0	0	0	5.75	4.28	3.48	3.02	4.30	3.04	2.47	2.13
PW	Harbor seal	0.62	0.31	0	0	0	0	0	0	4.91	3.45	3.16	2.62	3.94	2.87	2.19	1.99

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.
[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-14. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	4.33	2.96	2.28	1.87	0.03	0.02	0	0	7.27	5.14	3.97	3.49	7.22	5.14	3.98	3.45
LF	Humpback whale	4.04	2.63	1.85	1.63	0.05	0	0	0	7.31	5.11	3.94	3.47	7.30	5.12	3.98	3.41
LF	Common minke whale (migrating)	2.94	1.86	1.30	1.17	0.02	0.02	0	0	7.09	5.07	3.91	3.43	18.60	14.36	11.87	10.94
LF	North Atlantic right whale [c]	3.53	2.33	1.63	1.32	<0.01	<0.01	<0.01	<0.01	7.04	4.83	3.75	3.29	7.06	4.90	3.75	3.29
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0	6.92	4.93	3.83	3.28	3.28	2.10	1.51	1.34
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0	7.03	5.00	3.81	3.34	3.37	2.18	1.52	1.34
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0	6.49	4.47	3.58	3.07	3.07	1.83	1.38	1.19
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	7.02	4.81	3.75	3.39	3.34	2.16	1.45	1.31
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	6.97	5.00	3.78	3.33	3.32	2.14	1.55	1.32
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville’s beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso’s dolphin	0	0	0	0	<0.01	<0.01	0	0	7.02	4.98	3.87	3.35	3.38	2.23	1.53	1.41
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0	7.05	5.00	3.85	3.41	3.41	2.16	1.57	1.37
HF	Harbor porpoise (sensitive)	0	0	0	0	0.61	0.27	0.13	0	6.59	4.69	3.52	2.97	37.90	22.34	17.04	15.03
PW	Gray seal	1.10	0.61	0.44	0.23	0	0	0	0	7.36	5.23	4.04	3.56	5.50	3.71	2.61	2.34
PW	Harbor seal	0.64	0.31	0	0	0	0	0	0	6.59	4.48	3.43	3.22	4.90	3.24	2.48	2.06

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-15. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, two per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	3.57	2.49	1.96	1.80	0.04	0.03	0	0	5.63	4.20	3.42	2.95	5.61	4.23	3.45	2.98
LF	Humpback whale	3.36	2.40	1.83	1.45	0.07	0.03	0	0	5.61	4.18	3.41	2.96	5.63	4.21	3.42	2.97
LF	Common minke whale (migrating)	2.60	1.76	1.29	1.01	0.01	0.01	<0.01	0	5.56	4.13	3.32	2.95	11.66	9.56	8.27	7.74
LF	North Atlantic right whale [c]	3.03	2.01	1.56	1.31	0.02	0.02	<0.01	<0.01	5.36	4.04	3.27	2.86	5.45	4.06	3.28	2.87
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0	5.37	4.04	3.28	2.93	2.96	2.02	1.48	1.31
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	<0.01	0	0	5.48	4.05	3.28	2.92	2.96	1.99	1.50	1.28
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0	4.96	3.71	2.93	2.59	2.66	1.72	1.31	1.13
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	5.34	3.97	3.22	2.80	2.93	2.03	1.48	1.29
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	5.46	4.02	3.25	2.90	2.93	2.04	1.50	1.30
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	0	0	0	5.36	4.07	3.29	2.88	2.97	2.00	1.49	1.30
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0	5.48	4.10	3.29	2.89	2.95	2.08	1.51	1.30
HF	Harbor porpoise (sensitive)	0	0	0	0	0.70	0.26	0.16	0.04	4.84	3.63	2.91	2.65	12.67	10.68	9.11	8.56
PW	Gray seal	1.19	0.66	0.40	0.22	0	0	0	0	5.60	4.23	3.47	3.11	4.32	3.15	2.39	2.06
PW	Harbor seal	0.80	0.24	0.19	0	<0.01	<0.01	<0.01	<0.01	4.89	3.73	3.11	2.58	4.05	2.79	2.08	1.70

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.
[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

Table H-16. Scenario B2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	3.49	2.46	1.81	1.38	0.03	0	0	0	5.57	4.14	3.31	2.97	5.58	4.14	3.28	2.97
LF	Humpback whale	3.19	2.10	1.65	1.51	0	0	0	0	5.54	4.12	3.40	2.98	5.56	4.13	3.35	3.03
LF	Common minke whale (migrating)	2.44	1.64	1.17	0.99	0.02	0.02	0	0	5.39	4.06	3.21	2.80	11.64	9.46	8.19	7.68
LF	North Atlantic right whale [c]	2.84	1.94	1.48	1.34	0	0	0	0	5.20	3.89	3.16	2.77	5.28	3.95	3.14	2.77
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0	5.27	3.93	3.13	2.77	2.88	1.94	1.39	1.18
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0	5.28	3.91	3.25	2.72	2.83	1.93	1.32	1.23
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0	4.89	3.68	2.96	2.48	2.52	1.73	1.31	1.18
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	5.17	3.89	3.09	2.77	2.94	1.96	1.44	1.18
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	5.34	3.98	3.20	2.86	2.96	2.00	1.49	1.20
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	5.31	4.04	3.17	2.83	2.96	2.02	1.43	1.25
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0	5.41	4.00	3.28	2.83	2.91	2.00	1.46	1.30
HF	Harbor porpoise (sensitive)	0	0	0	0	0.61	0.24	0.13	0	4.97	3.57	2.93	2.59	12.52	10.47	9.05	8.53
PW	Gray seal	1.10	0.44	0.23	0.23	0	0	0	0	5.65	4.17	3.47	2.99	4.29	3.01	2.39	2.11
PW	Harbor seal	0.60	0.38	0	0	0	0	0	0	4.97	3.49	3.02	2.64	3.85	2.65	2.12	1.84

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-17. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	3.49	2.45	1.87	1.37	0.03	0.02	0	0	5.36	4.09	3.25	2.75	5.36	4.07	3.26	2.72
LF	Humpback whale	3.15	2.11	1.65	1.42	0.05	0	0	0	5.44	4.04	3.17	2.84	5.44	3.98	3.18	2.85
LF	Common minke whale (migrating)	2.44	1.60	1.17	0.92	0.02	0	0	0	5.19	3.91	2.93	2.64	11.32	9.28	7.97	7.46
LF	North Atlantic right whale [c]	2.80	1.93	1.34	1.13	<0.01	<0.01	<0.01	<0.01	5.02	3.88	3.15	2.66	5.05	3.84	3.17	2.65
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	5.13	3.84	3.01	2.64	2.72	1.81	1.36	1.12
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	5.20	3.82	3.05	2.58	2.68	1.86	1.34	1.22
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0	4.79	3.63	2.78	2.39	2.46	1.69	1.28	1.13
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	5.05	3.75	3.05	2.61	2.73	1.84	1.39	1.18
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	5.21	3.87	3.06	2.69	2.75	1.97	1.47	1.17
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	5.17	3.84	3.04	2.69	2.76	1.92	1.42	1.12
MF	Common dolphin	0	0	0	0	<0.01	0	0	0	5.24	3.89	3.13	2.69	2.76	1.96	1.44	1.23
HF	Harbor porpoise (sensitive)	0	0	0	0	0.57	0.23	0.14	0	4.84	3.53	2.84	2.53	12.39	10.37	8.77	8.35
PW	Gray seal	1.10	0.44	0.23	0.23	0	0	0	0	5.41	4.11	3.31	2.91	4.14	2.95	2.35	1.94
PW	Harbor seal	0.60	0.31	0	0	0	0	0	0	4.81	3.41	3.06	2.50	3.61	2.56	2.04	1.71

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-18. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	4.10	2.83	1.94	1.55	0.03	0.02	0	0	6.88	4.87	3.75	3.25	6.88	4.87	3.75	3.26
LF	Humpback whale	3.84	2.46	1.74	1.53	0.05	0	0	0	6.91	4.82	3.74	3.18	6.91	4.84	3.71	3.18
LF	Common minke whale (migrating)	2.81	1.76	1.18	1.00	0.02	0	0	0	6.69	4.80	3.67	3.00	17.57	13.66	11.36	10.32
LF	North Atlantic right whale [c]	3.38	2.24	1.49	1.19	<0.01	<0.01	<0.01	<0.01	6.67	4.58	3.65	3.15	6.70	4.60	3.65	3.17
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	6.41	4.62	3.60	3.04	3.09	1.97	1.41	1.14
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	6.60	4.71	3.53	3.14	3.14	1.98	1.38	1.22
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0	6.17	4.28	3.36	2.81	2.79	1.79	1.31	1.16
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	6.55	4.66	3.56	3.08	3.09	1.96	1.44	1.15
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	6.67	4.71	3.61	3.07	3.11	2.03	1.52	1.19
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	6.68	4.70	3.56	3.12	3.16	1.99	1.47	1.15
MF	Common dolphin	0	0	0	0	<0.01	0	0	0	6.61	4.68	3.63	3.16	3.18	2.03	1.52	1.26
HF	Harbor porpoise (sensitive)	0	0	0	0	0.51	0.22	0.07	0	6.18	4.31	3.32	2.89	34.71	20.83	16.07	14.21
PW	Gray seal	1.10	0.61	0.23	0.23	0	0	0	0	7.03	4.94	3.84	3.34	5.23	3.40	2.49	2.13
PW	Harbor seal	0.60	0.31	0	0	0	0	0	0	6.29	4.17	3.23	3.10	4.53	3.17	2.26	1.94

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-19. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, two per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	3.46	2.39	1.86	1.64	0.04	0.01	0	0	5.44	3.93	3.22	2.77	5.44	3.93	3.27	2.77
LF	Humpback whale	3.16	2.23	1.76	1.30	0.04	0	0	0	5.39	4.01	3.17	2.75	5.40	4.01	3.20	2.73
LF	Common minke whale (migrating)	2.51	1.61	1.19	0.94	0.01	0.01	<0.01	0	5.27	3.83	3.13	2.66	11.39	9.27	7.95	7.40
LF	North Atlantic right whale [c]	2.81	1.90	1.48	1.23	0.02	<0.01	<0.01	<0.01	5.06	3.82	3.00	2.71	5.13	3.83	3.01	2.67
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	5.11	3.78	3.08	2.63	2.74	1.84	1.39	1.19
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	<0.01	0	0	5.22	3.82	3.12	2.70	2.73	1.83	1.39	1.17
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0	4.74	3.47	2.79	2.45	2.47	1.62	1.22	1.03
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	5.12	3.78	3.04	2.60	2.70	1.85	1.37	1.16
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	5.23	3.89	3.09	2.67	2.74	1.89	1.38	1.18
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	0	0	0	0	5.20	3.85	3.06	2.67	2.77	1.89	1.35	1.18
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0	5.27	3.87	3.09	2.70	2.77	1.92	1.43	1.20
HF	Harbor porpoise (sensitive)	0	0	0	0	0.57	0.26	0.15	0.04	4.64	3.50	2.83	2.50	12.42	10.24	8.91	8.25
PW	Gray seal	1.07	0.57	0.22	0.22	0	0	0	0	5.46	4.10	3.27	2.87	4.16	2.93	2.36	2.03
PW	Harbor seal	0.64	0.21	0	0	<0.01	<0.01	<0.01	0	4.80	3.37	2.83	2.44	3.60	2.58	1.95	1.64

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-20. Scenario B4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	3.22	2.41	1.68	1.33	0.03	0	0	0	5.31	3.97	3.22	2.68	5.32	3.98	3.22	2.68
LF	Humpback whale	3.09	2.01	1.55	1.36	0	0	0	0	5.31	3.92	3.14	2.78	5.31	3.94	3.13	2.78
LF	Common minke whale (migrating)	2.23	1.51	1.13	0.89	0.02	0	0	0	5.14	3.86	2.89	2.64	11.28	9.14	7.89	7.38
LF	North Atlantic right whale [c]	2.65	1.88	1.39	1.07	0	0	0	0	5.02	3.78	3.03	2.66	5.05	3.79	3.09	2.66
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	5.01	3.71	2.97	2.56	2.69	1.79	1.33	1.09
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	5.09	3.77	3.01	2.51	2.64	1.83	1.27	1.16
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0	4.74	3.47	2.64	2.29	2.38	1.60	1.25	1.07
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	4.89	3.67	2.99	2.49	2.62	1.76	1.31	1.12
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	5.10	3.76	3.04	2.63	2.74	1.89	1.42	1.14
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	5.04	3.77	3.05	2.65	2.75	1.89	1.41	1.11
MF	Common dolphin	0	0	0	0	<0.01	0	0	0	5.14	3.80	3.08	2.67	2.74	1.92	1.39	1.21
HF	Harbor porpoise (sensitive)	0	0	0	0	0.57	0.24	0.14	0	4.83	3.49	2.91	2.47	12.29	10.22	8.74	8.27
PW	Gray seal	0.92	0.44	0.23	0.23	0	0	0	0	5.38	4.06	3.28	2.90	4.13	2.92	2.35	1.90
PW	Harbor seal	0.50	0.22	0	0	0	0	0	0	4.66	3.40	2.90	2.50	3.54	2.50	1.98	1.69

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-21. Scenario B4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	3.89	2.58	1.92	1.39	0.03	0	0	0	6.80	4.87	3.69	3.22	6.78	4.87	3.66	3.18
LF	Humpback whale	3.65	2.25	1.78	1.51	0	0	0	0	6.84	4.80	3.72	3.16	6.81	4.74	3.71	3.15
LF	Common minke whale (migrating)	2.67	1.66	1.17	0.99	0.02	0	0	0	6.57	4.70	3.58	2.95	17.53	13.46	11.29	10.29
LF	North Atlantic right whale [c]	3.09	2.02	1.50	1.40	0	0	0	0	6.51	4.55	3.50	3.11	6.53	4.55	3.45	3.04
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	6.38	4.53	3.43	3.01	3.01	1.89	1.38	1.09
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	6.53	4.62	3.50	3.06	3.06	1.92	1.32	1.19
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0	6.15	4.35	3.18	2.75	2.67	1.73	1.30	1.16
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0	6.46	4.49	3.49	3.01	3.05	1.91	1.41	1.15
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0	6.61	4.65	3.58	3.06	3.05	2.00	1.48	1.20
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0	6.56	4.64	3.53	3.07	3.12	1.99	1.43	1.13
MF	Common dolphin	0	0	0	0	<0.01	0	0	0	6.55	4.63	3.55	3.12	3.14	2.00	1.50	1.26
HF	Harbor porpoise (sensitive)	0	0	0	0	0.46	0.19	0.07	0	5.81	4.20	3.28	2.91	33.83	20.54	15.81	14.04
PW	Gray seal	1.00	0.44	0.23	0.23	0	0	0	0	6.93	4.88	3.75	3.29	5.16	3.37	2.39	2.14
PW	Harbor seal	0.59	0.22	0	0	0	0	0	0	6.34	4.16	3.25	2.94	4.34	3.11	2.32	1.84

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-22. Scenario B6, Monopile foundation (4.25 m diameter, 3500 kJ hammer, four per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	PTS $L_{E,w,24h}$ 0 dB	PTS $L_{E,w,24h}$ 6 dB	PTS $L_{E,w,24h}$ 10 dB	PTS $L_{E,w,24h}$ 12 dB	PTS L_{PK} 0 dB	PTS L_{PK} 6 dB	PTS L_{PK} 10 dB	PTS L_{PK} 12 dB	Behavior L_p [a] 0 dB	Behavior L_p [a] 6 dB	Behavior L_p [a] 10 dB	Behavior L_p [a] 12 dB	Behavior $L_{p,w}$ [b] 0 dB	Behavior $L_{p,w}$ [b] 6 dB	Behavior $L_{p,w}$ [b] 10 dB	Behavior $L_{p,w}$ [b] 12 dB
LF	Fin whale [c]	7.20	4.28	2.89	2.31	0.03	<0.01	<0.01	<0.01	7.22	4.51	3.25	2.63	7.31	4.63	3.28	2.65
LF	Humpback whale	6.89	3.76	2.57	2.07	0.05	<0.01	<0.01	<0.01	7.20	4.43	3.06	2.58	7.29	4.51	3.13	2.62
LF	Common minke whale (migrating)	4.18	2.26	1.60	1.29	<0.01	0	0	0	6.62	4.03	2.91	2.36	31.50	19.83	14.65	12.86
LF	North Atlantic right whale [c]	4.94	2.93	1.96	1.63	0.03	0	0	0	6.66	3.93	2.77	2.47	6.76	4.01	2.78	2.50
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0	32.48	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0	6.30	3.88	2.77	2.30	3.41	1.82	1.29	1.06
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0	6.55	4.07	2.83	2.38	3.47	1.86	1.26	1.07
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0	5.51	3.23	2.34	1.87	2.78	1.57	1.13	0.93
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0	6.33	3.87	2.76	2.24	3.36	1.79	1.22	1.00
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0	6.48	4.06	2.80	2.39	3.44	1.84	1.26	1.00
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	106.44	105.02	0	0
MF	Blainville’s beaked whale	0	0	0	0	0	0	0	0	0	0	0	0	103.29	101.91	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso’s dolphin	0	0	0	0	<0.01	0	0	0	6.70	4.13	2.97	2.37	3.59	1.79	1.22	1.05
MF	Common dolphin	0	0	0	0	<0.01	0	0	0	6.43	3.96	2.80	2.41	3.37	1.84	1.29	1.08
HF	Harbor porpoise (sensitive)	0.04	0	0	0	0.44	0.22	0.05	0.02	6.12	3.42	2.45	2.14	91.62	83.51	47.18	38.19
PW	Gray seal	2.04	1.33	0.90	0.74	<0.01	<0.01	<0.01	<0.01	7.69	5.00	3.64	3.04	6.42	3.80	2.69	2.08
PW	Harbor seal	1.00	0.49	0.21	0.14	0.03	<0.01	<0.01	<0.01	6.09	3.32	2.56	1.89	5.20	2.70	1.69	1.43

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.
[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA.

H.3.2. Vibratory Pile Setting Followed by Impact Pile Driving

Table H-23. PTS: Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	3.57	2.54	1.95	1.52	0.04	0.01	0.01	0
LF	Humpback whale	3.34	2.19	1.70	1.51	0.05	0.05	0	0
LF	Common minke whale (migrating)	2.48	1.72	1.17	0.99	0.02	0.02	0	0
LF	North Atlantic right whale [c]	2.93	1.95	1.47	1.33	<0.01	<0.01	<0.01	<0.01
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.64	0.23	0.16	0
PW	Gray seal	1.10	0.60	0.23	0.23	0	0	0	0
PW	Harbor seal	0.63	0.22	0.01	0.01	<0.01	<0.01	<0.01	<0.01

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-24. Behavior: Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	5.72	4.31	3.41	3.08	5.72	4.31	3.43	3.09	12.97	10.93	9.62	8.89
LF	Humpback whale	5.67	4.23	3.39	3.07	5.71	4.26	3.40	3.06	12.99	10.98	9.72	9.02
LF	Common minke whale (migrating)	5.54	4.11	3.39	2.89	11.76	9.68	8.28	7.76	12.90	10.85	9.50	8.92
LF	North Atlantic right whale [c]	5.44	4.17	3.28	2.87	5.47	4.21	3.33	2.93	12.41	10.53	9.25	8.50
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	5.40	4.09	3.26	2.83	2.94	1.97	1.44	1.29	12.45	10.59	9.29	8.66
MF	Atlantic white sided dolphin	5.40	4.11	3.27	2.81	2.97	2.09	1.50	1.28	12.68	10.55	9.40	8.69
MF	Common bottlenose dolphin	5.10	3.77	3.08	2.69	2.70	1.79	1.39	1.18	12.05	10.10	8.75	8.25
MF	Long-finned pilot whale	5.43	3.98	3.21	2.90	2.99	2.09	1.44	1.27	12.54	10.48	9.21	8.59
MF	Short-finned pilot whale	5.46	4.17	3.33	2.95	2.99	2.04	1.51	1.23	12.88	10.81	9.48	8.79
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	5.40	4.13	3.25	2.88	3.00	2.07	1.52	1.34	12.61	10.60	9.41	8.78
MF	Common dolphin	5.47	4.05	3.41	2.99	3.01	2.09	1.52	1.33	12.77	10.74	9.60	8.82
HF	Harbor porpoise (sensitive)	5.02	3.68	3.08	2.69	12.84	10.70	9.21	8.62	11.59	9.68	8.61	8.05
PW	Gray seal	5.72	4.30	3.49	3.02	4.33	3.13	2.46	2.13	12.96	10.83	9.61	9.12
PW	Harbor seal	5.27	3.55	3.16	2.85	3.95	2.97	2.19	1.98	11.83	9.89	8.86	8.21

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-25. PTS: Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	4.25	2.94	2.24	1.81	0.04	0.01	0.01	0
LF	Humpback whale	4.03	2.62	1.85	1.54	0.05	0	0	0
LF	Common minke whale (migrating)	2.91	1.89	1.23	1.11	0.02	0.02	0	0
LF	North Atlantic right whale [c]	3.45	2.26	1.64	1.42	<0.01	<0.01	<0.01	<0.01
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0
MF	Short-finned pilot whale	0	0	0	0	<0.01	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.60	0.26	0.16	0
PW	Gray seal	1.10	0.60	0.23	0.23	0	0	0	0
PW	Harbor seal	0.64	0.26	0.01	0.01	<0.01	<0.01	<0.01	<0.01

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-26. Behavior: Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	7.27	5.17	4.00	3.47	7.22	5.18	4.00	3.42	22.50	16.84	14.10	12.71
LF	Humpback whale	7.33	5.22	3.93	3.44	7.28	5.18	3.98	3.40	22.35	16.82	14.15	12.93
LF	Common minke whale (migrating)	7.14	5.06	3.90	3.41	18.85	14.42	12.03	10.93	22.59	16.64	14.01	12.78
LF	North Atlantic right whale [c]	7.13	4.93	3.87	3.33	7.14	5.00	3.87	3.32	21.43	16.05	13.47	12.35
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	6.97	4.95	3.85	3.29	3.30	2.11	1.52	1.37	21.56	16.23	13.68	12.35
MF	Atlantic white sided dolphin	7.14	4.96	3.84	3.37	3.37	2.15	1.54	1.34	21.77	16.63	13.76	12.53
MF	Common bottlenose dolphin	6.61	4.69	3.62	3.18	3.17	1.87	1.45	1.25	20.60	15.70	12.93	11.87
MF	Long-finned pilot whale	7.09	4.91	3.79	3.34	3.39	2.13	1.46	1.36	21.80	16.33	13.78	12.55
MF	Short-finned pilot whale	7.10	4.99	3.86	3.40	3.36	2.20	1.56	1.38	22.26	16.54	13.94	12.73
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	7.01	5.01	3.90	3.39	3.39	2.22	1.53	1.41	21.76	16.71	13.91	12.55
MF	Common dolphin	7.06	5.06	3.88	3.44	3.43	2.20	1.61	1.40	21.89	16.62	13.79	12.65
HF	Harbor porpoise (sensitive)	6.74	4.64	3.53	3.13	38.13	22.45	17.27	15.25	19.94	15.14	12.86	11.77
PW	Gray seal	7.37	5.26	4.06	3.64	5.53	3.73	2.62	2.32	22.33	16.71	14.31	12.86
PW	Harbor seal	6.76	4.55	3.44	3.21	5.15	3.35	2.41	2.14	19.70	15.09	12.73	11.76

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), ***w*** in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, ***24h*** in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-27. PTS: Scenario BV2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	3.41	2.47	1.82	1.37	0.02	0.02	0	0
LF	Humpback whale	3.19	2.10	1.65	1.51	0	0	0	0
LF	Common minke whale (migrating)	2.42	1.64	1.17	0.99	0.02	0	0	0
LF	North Atlantic right whale [c]	2.80	1.95	1.49	1.25	0	0	0	0
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.62	0.24	0.13	0
PW	Gray seal	1.00	0.44	0.23	0.23	0	0	0	0
PW	Harbor seal	0.60	0.38	0	0	0	0	0	0

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-28. Behavior: Scenario BV2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	5.66	4.19	3.36	2.98	5.67	4.19	3.34	3.00	13.37	11.24	10.00	9.25
LF	Humpback whale	5.60	4.17	3.40	2.98	5.63	4.17	3.37	3.00	13.52	11.44	9.98	9.36
LF	Common minke whale (migrating)	5.52	4.10	3.26	2.81	11.71	9.56	8.19	7.72	13.30	11.26	9.77	9.13
LF	North Atlantic right whale [c]	5.33	3.96	3.21	2.83	5.35	4.00	3.19	2.85	12.77	10.93	9.50	8.91
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	5.33	4.00	3.20	2.80	2.95	1.99	1.42	1.22	12.93	10.87	9.61	8.87
MF	Atlantic white sided dolphin	5.37	4.03	3.27	2.80	2.92	1.99	1.36	1.24	13.10	10.93	9.73	9.15
MF	Common bottlenose dolphin	5.04	3.79	3.02	2.55	2.58	1.78	1.33	1.21	12.23	10.19	9.04	8.53
MF	Long-finned pilot whale	5.27	3.94	3.13	2.80	2.96	1.98	1.44	1.19	12.87	10.85	9.51	8.89
MF	Short-finned pilot whale	5.40	4.07	3.22	2.92	2.99	2.01	1.49	1.23	13.29	11.21	9.75	9.14
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	5.36	4.06	3.23	2.86	2.96	2.05	1.44	1.31	13.03	10.95	9.62	8.97
MF	Common dolphin	5.48	4.07	3.36	2.87	2.97	2.05	1.50	1.32	13.21	11.17	9.89	9.11
HF	Harbor porpoise (sensitive)	5.00	3.60	3.00	2.61	12.68	10.54	9.13	8.64	11.92	10.02	8.72	8.28
PW	Gray seal	5.63	4.18	3.48	2.99	4.29	3.01	2.39	2.11	13.41	11.40	9.92	9.39
PW	Harbor seal	5.12	3.58	3.14	2.68	3.92	2.71	2.13	1.85	12.17	10.33	9.35	8.51

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.
[a] NOAA (2005), [b] Wood et al. (2012), [c] Listed as Endangered under the ESA

Table H-29. PTS: Scenario BV2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	4.10	2.75	1.94	1.52	0.02	0.02	0	0
LF	Humpback whale	3.84	2.57	1.83	1.56	0	0	0	0
LF	Common minke whale (migrating)	2.89	1.85	1.26	1.05	0.02	0	0	0
LF	North Atlantic right whale [c]	3.25	2.24	1.53	1.41	0	0	0	0
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	<0.01	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.62	0.28	0.13	0
PW	Gray seal	1.10	0.54	0.23	0.23	0	0	0	0
PW	Harbor seal	0.60	0.38	0	0	0	0	0	0

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-30. Behavior: Scenario BV2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	7.15	5.04	3.92	3.46	7.15	5.05	3.92	3.46	23.59	17.79	14.55	13.27
LF	Humpback whale	7.24	5.10	3.90	3.41	7.21	5.11	3.91	3.41	23.34	17.74	14.62	13.55
LF	Common minke whale (migrating)	6.94	5.01	3.89	3.38	18.79	14.42	12.01	10.92	23.60	17.70	14.45	13.43
LF	North Atlantic right whale [c]	7.03	4.88	3.70	3.28	7.02	4.90	3.70	3.32	22.45	16.68	13.89	12.77
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	6.95	4.88	3.71	3.26	3.30	2.05	1.48	1.33	22.79	17.26	14.15	12.92
MF	Atlantic white sided dolphin	6.95	4.89	3.77	3.36	3.39	2.07	1.45	1.33	23.00	17.54	14.27	13.13
MF	Common bottlenose dolphin	6.56	4.66	3.62	3.02	3.05	1.85	1.36	1.22	21.66	16.42	13.47	12.22
MF	Long-finned pilot whale	6.98	4.80	3.71	3.25	3.29	2.08	1.45	1.28	23.01	17.20	14.26	13.04
MF	Short-finned pilot whale	6.96	4.86	3.78	3.26	3.30	2.10	1.55	1.26	23.24	17.46	14.56	13.26
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	6.97	4.92	3.81	3.36	3.39	2.07	1.46	1.41	23.06	17.63	14.36	13.12
MF	Common dolphin	6.97	4.89	3.83	3.40	3.40	2.12	1.55	1.36	23.16	17.45	14.42	13.20
HF	Harbor porpoise (sensitive)	6.47	4.53	3.50	3.07	37.27	22.23	17.13	15.02	21.40	15.96	13.31	12.31
PW	Gray seal	7.25	5.17	3.96	3.49	5.41	3.65	2.58	2.20	23.25	17.72	14.72	13.46
PW	Harbor seal	6.66	4.46	3.45	3.28	4.89	3.38	2.40	1.96	20.70	15.94	13.33	12.09

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-31. PTS: Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	3.51	2.39	1.81	1.31	0.04	0.01	0	0
LF	Humpback whale	3.16	2.14	1.54	1.48	0.05	0	0	0
LF	Common minke whale (migrating)	2.40	1.54	1.12	0.91	0.02	0	0	0
LF	North Atlantic right whale [c]	2.76	1.81	1.41	1.23	<0.01	<0.01	<0.01	<0.01
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.56	0.23	0.16	0
PW	Gray seal	1.10	0.44	0.23	0.23	0	0	0	0
PW	Harbor seal	0.61	0.18	0.01	0.01	<0.01	<0.01	<0.01	0

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-32. Behavior: Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	5.46	4.06	3.26	2.79	5.44	4.03	3.25	2.77	12.97	10.93	9.62	8.89
LF	Humpback whale	5.48	4.00	3.18	2.83	5.48	3.99	3.19	2.85	12.99	10.98	9.72	9.02
LF	Common minke whale (migrating)	5.22	3.91	3.11	2.68	11.33	9.41	8.05	7.44	12.90	10.85	9.50	8.92
LF	North Atlantic right whale [c]	5.15	3.91	3.15	2.69	5.20	3.89	3.15	2.70	12.41	10.53	9.25	8.50
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	5.14	3.89	3.06	2.64	2.74	1.88	1.41	1.13	12.45	10.59	9.29	8.66
MF	Atlantic white sided dolphin	5.19	3.87	3.06	2.61	2.66	1.85	1.35	1.19	12.68	10.55	9.40	8.69
MF	Common bottlenose dolphin	4.91	3.69	2.88	2.44	2.46	1.74	1.30	1.13	12.05	10.10	8.75	8.25
MF	Long-finned pilot whale	5.12	3.80	3.05	2.61	2.69	1.84	1.42	1.15	12.54	10.48	9.21	8.59
MF	Short-finned pilot whale	5.27	3.95	3.08	2.71	2.83	1.95	1.46	1.17	12.88	10.81	9.48	8.79
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	5.18	3.90	3.04	2.68	2.82	1.93	1.43	1.16	12.61	10.60	9.41	8.78
MF	Common dolphin	5.27	3.89	3.16	2.73	2.76	1.95	1.45	1.25	12.77	10.74	9.60	8.82
HF	Harbor porpoise (sensitive)	4.82	3.56	2.85	2.56	12.48	10.43	8.85	8.29	11.59	9.68	8.61	8.05
PW	Gray seal	5.48	4.11	3.35	2.93	4.17	2.94	2.33	1.94	12.96	10.83	9.61	9.12
PW	Harbor seal	4.98	3.45	3.03	2.45	3.64	2.51	2.06	1.81	11.83	9.89	8.86	8.21

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-33. PTS: Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	4.11	2.74	2.07	1.55	0.04	0.01	0	0
LF	Humpback whale	3.73	2.29	1.72	1.51	0.05	0	0	0
LF	Common minke whale (migrating)	2.81	1.75	1.17	0.99	0.02	0	0	0
LF	North Atlantic right whale [c]	3.32	1.97	1.46	1.33	<0.01	<0.01	<0.01	<0.01
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.52	0.23	0.07	0
PW	Gray seal	1.10	0.55	0.23	0.23	0	0	0	0
PW	Harbor seal	0.61	0.18	0.01	0.01	<0.01	<0.01	<0.01	0

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-34. Behavior: Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	6.92	4.87	3.74	3.26	6.90	4.86	3.71	3.26	22.50	16.84	14.10	12.71
LF	Humpback whale	6.94	4.90	3.77	3.18	6.93	4.93	3.75	3.19	22.35	16.82	14.15	12.93
LF	Common minke whale (migrating)	6.81	4.83	3.71	3.17	17.78	13.81	11.43	10.43	22.59	16.64	14.01	12.78
LF	North Atlantic right whale [c]	6.72	4.60	3.68	3.15	6.75	4.63	3.69	3.15	21.43	16.05	13.47	12.35
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	6.58	4.69	3.60	3.09	3.14	1.96	1.44	1.16	21.56	16.23	13.68	12.35
MF	Atlantic white sided dolphin	6.64	4.74	3.61	3.09	3.10	2.02	1.44	1.20	21.77	16.63	13.76	12.53
MF	Common bottlenose dolphin	6.33	4.26	3.35	2.95	2.94	1.80	1.40	1.16	20.60	15.70	12.93	11.87
MF	Long-finned pilot whale	6.64	4.70	3.57	3.09	3.09	1.93	1.44	1.09	21.80	16.33	13.78	12.55
MF	Short-finned pilot whale	6.75	4.79	3.65	3.10	3.13	2.07	1.51	1.21	22.26	16.54	13.94	12.73
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	6.69	4.74	3.61	3.12	3.12	2.02	1.46	1.18	21.76	16.71	13.91	12.55
MF	Common dolphin	6.76	4.75	3.66	3.17	3.18	2.07	1.52	1.26	21.89	16.62	13.79	12.65
HF	Harbor porpoise (sensitive)	6.25	4.33	3.40	2.94	34.92	20.93	16.20	14.42	19.94	15.14	12.86	11.77
PW	Gray seal	7.04	4.94	3.84	3.35	5.26	3.41	2.47	2.13	22.33	16.71	14.31	12.86
PW	Harbor seal	6.37	4.41	3.37	3.05	4.57	3.16	2.23	1.92	19.70	15.09	12.73	11.76

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-35. PTS: Scenario BV4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	3.23	2.41	1.51	1.33	0.02	0.02	0	0
LF	Humpback whale	3.06	2.02	1.56	1.36	0	0	0	0
LF	Common minke whale (migrating)	2.23	1.51	1.13	0.89	0.02	0	0	0
LF	North Atlantic right whale [c]	2.61	1.88	1.40	1.07	0	0	0	0
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.58	0.24	0.14	0
PW	Gray seal	0.93	0.44	0.23	0.23	0	0	0	0
PW	Harbor seal	0.50	0.22	0	0	0	0	0	0

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-36. Behavior: Scenario BV4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	5.36	3.96	3.19	2.72	5.36	3.98	3.22	2.72	13.37	11.24	10.00	9.25
LF	Humpback whale	5.40	3.92	3.19	2.83	5.35	3.92	3.19	2.83	13.52	11.44	9.98	9.36
LF	Common minke whale (migrating)	5.19	3.90	2.93	2.64	11.38	9.20	7.98	7.39	13.30	11.26	9.77	9.13
LF	North Atlantic right whale [c]	5.14	3.83	3.12	2.66	5.16	3.82	3.13	2.62	12.77	10.93	9.50	8.91
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	5.05	3.77	3.03	2.59	2.70	1.80	1.34	1.12	12.93	10.87	9.61	8.87
MF	Atlantic white sided dolphin	5.15	3.80	3.06	2.63	2.72	1.87	1.33	1.16	13.10	10.93	9.73	9.15
MF	Common bottlenose dolphin	4.85	3.67	2.78	2.33	2.40	1.62	1.28	1.13	12.23	10.19	9.04	8.53
MF	Long-finned pilot whale	5.01	3.75	3.04	2.52	2.64	1.84	1.31	1.15	12.87	10.85	9.51	8.89
MF	Short-finned pilot whale	5.19	3.87	3.08	2.70	2.75	1.95	1.45	1.17	13.29	11.21	9.75	9.14
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	5.08	3.81	3.05	2.69	2.77	1.90	1.41	1.16	13.03	10.95	9.62	8.97
MF	Common dolphin	5.25	3.85	3.14	2.68	2.74	1.92	1.40	1.22	13.21	11.17	9.89	9.11
HF	Harbor porpoise (sensitive)	4.77	3.51	2.90	2.52	12.45	10.31	8.84	8.40	11.92	10.02	8.72	8.28
PW	Gray seal	5.39	4.07	3.29	2.92	4.14	2.94	2.35	1.90	13.41	11.40	9.92	9.39
PW	Harbor seal	4.79	3.46	2.96	2.53	3.58	2.54	1.98	1.76	12.17	10.33	9.35	8.51

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-37. PTS: Scenario BV4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	3.81	2.62	1.88	1.40	0.02	0.02	0	0
LF	Humpback whale	3.54	2.24	1.71	1.51	0	0	0	0
LF	Common minke whale (migrating)	2.67	1.68	1.17	0.99	0.02	0	0	0
LF	North Atlantic right whale [c]	3.06	1.96	1.49	1.41	0	0	0	0
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	0	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	0	0	0	0
MF	Long-finned pilot whale	0	0	0	0	0	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	<0.01	<0.01	0	0
MF	Common dolphin	0	0	0	0	<0.01	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.46	0.22	0.07	0
PW	Gray seal	1.00	0.44	0.23	0.23	0	0	0	0
PW	Harbor seal	0.59	0.22	0	0	0	0	0	0

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-38. Behavior: Scenario BV4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	6.85	4.88	3.72	3.22	6.82	4.88	3.69	3.15	23.59	17.79	14.55	13.27
LF	Humpback whale	6.94	4.82	3.74	3.19	6.92	4.73	3.73	3.19	23.34	17.74	14.62	13.55
LF	Common minke whale (migrating)	6.72	4.76	3.62	3.09	17.79	13.76	11.39	10.41	23.60	17.70	14.45	13.43
LF	North Atlantic right whale [c]	6.62	4.61	3.51	3.15	6.62	4.60	3.45	3.12	22.45	16.68	13.89	12.77
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	6.46	4.60	3.46	3.06	3.06	1.93	1.41	1.12	22.79	17.26	14.15	12.92
MF	Atlantic white sided dolphin	6.59	4.67	3.53	3.08	3.08	1.99	1.36	1.18	23.00	17.54	14.27	13.13
MF	Common bottlenose dolphin	6.37	4.40	3.28	2.83	2.82	1.74	1.34	1.18	21.66	16.42	13.47	12.22
MF	Long-finned pilot whale	6.55	4.56	3.54	3.07	3.07	1.96	1.41	1.15	23.01	17.20	14.26	13.04
MF	Short-finned pilot whale	6.67	4.68	3.60	3.10	3.10	2.01	1.49	1.20	23.24	17.46	14.56	13.26
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville’s beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso’s dolphin	6.62	4.67	3.59	3.07	3.11	2.04	1.44	1.18	23.06	17.63	14.36	13.12
MF	Common dolphin	6.68	4.69	3.59	3.17	3.17	2.06	1.50	1.27	23.16	17.45	14.42	13.20
HF	Harbor porpoise (sensitive)	6.06	4.24	3.36	2.90	34.15	20.87	16.07	14.26	21.40	15.96	13.31	12.31
PW	Gray seal	6.93	4.89	3.75	3.33	5.17	3.39	2.39	2.14	23.25	17.72	14.72	13.46
PW	Harbor seal	6.34	4.27	3.41	2.98	4.48	3.12	2.36	1.85	20.70	15.94	13.33	12.09

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), ***w*** in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, ***24h*** in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

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

Table H-39. PTS: Scenario BV6, Jacket foundation (4.25 m diameter, 3500 kJ, four per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	$L_{E,w,24h}$ 0 dB	$L_{E,w,24h}$ 6 dB	$L_{E,w,24h}$ 10 dB	$L_{E,w,24h}$ 12 dB	L_{pk} 0 dB	L_{pk} 6 dB	L_{pk} 10 dB	L_{pk} 12 dB
LF	Fin whale [c]	4.16	2.73	2.02	1.80	0.04	<0.01	<0.01	<0.01
LF	Humpback whale	3.67	2.31	1.79	1.38	0.04	0	0	0
LF	Common minke whale (migrating)	2.45	1.65	1.15	0.88	<0.01	0	0	0
LF	North Atlantic right whale [c]	3.02	2.02	1.49	1.25	0.03	0	0	0
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	0	0	0	0	<0.01	0	0	0
MF	Atlantic white sided dolphin	0	0	0	0	<0.01	0	0	0
MF	Common bottlenose dolphin	0	0	0	0	<0.01	0	0	0
MF	Long-finned pilot whale	0	0	0	0	<0.01	0	0	0
MF	Short-finned pilot whale	0	0	0	0	0	0	0	0
MF	Goose-beaked whale	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0
MF	Risso's dolphin	0	0	0	0	0	0	0	0
MF	Common dolphin	0	0	0	0	0	0	0	0
HF	Harbor porpoise (sensitive)	0	0	0	0	0.33	0.19	0.03	0.02
PW	Gray seal	1.76	0.94	0.61	0.54	<0.01	0	0	0
PW	Harbor seal	0.70	0.27	0.15	0	0.01	0	0	0

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-40. Behavior: Scenario BV6, Jacket foundation (4.25 m diameter, 3500 kJ, four per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to marine mammal threshold criteria with sound attenuation.

Hearing group	Species	Impact piling L_p [a] 0 dB	Impact piling L_p [a] 6 dB	Impact piling L_p [a] 10 dB	Impact piling L_p [a] 12 dB	Impact piling $L_{p,w}$ [b] 0 dB	Impact piling $L_{p,w}$ [b] 6 dB	Impact piling $L_{p,w}$ [b] 10 dB	Impact piling $L_{p,w}$ [b] 12 dB	Vibratory piling L_p [a] 0 dB	Vibratory piling L_p [a] 6 dB	Vibratory piling L_p [a] 10 dB	Vibratory piling L_p [a] 12 dB
LF	Fin whale [c]	5.42	3.66	2.68	2.25	5.45	3.71	2.70	2.27	14.66	12.68	11.33	10.72
LF	Humpback whale	5.19	3.45	2.58	2.17	5.30	3.59	2.59	2.17	14.76	12.70	11.39	10.78
LF	Common minke whale (migrating)	4.76	3.22	2.37	2.01	12.34	9.83	8.23	7.43	14.53	12.49	11.15	10.54
LF	North Atlantic right whale [c]	4.81	3.34	2.52	2.01	4.89	3.40	2.54	2.07	14.10	12.12	10.83	10.28
LF	Sei whale [c] (migrating)	0	0	0	0	0	0	0	0	0	0	0	0
MF	Sperm whale [c]	0	0	0	0	0	0	0	0	0	0	0	0
MF	Atlantic spotted dolphin	4.55	3.21	2.43	2.02	2.76	1.65	1.18	0.98	14.37	12.44	11.18	10.47
MF	Atlantic white sided dolphin	4.75	3.21	2.48	2.06	2.79	1.70	1.18	0.95	14.32	12.46	11.19	10.57
MF	Common bottlenose dolphin	4.02	2.77	2.02	1.60	2.36	1.45	1.07	0.84	13.60	11.71	10.48	9.85
MF	Long-finned pilot whale	4.48	3.09	2.31	2.00	2.63	1.65	1.13	0.97	14.34	12.24	10.95	10.26
MF	Short-finned pilot whale	4.75	3.36	2.45	2.09	2.80	1.67	1.19	0.91	14.51	12.49	11.19	10.54
MF	Goose-beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Blainville's beaked whale	0	0	0	0	0	0	0	0	0	0	0	0
MF	Striped dolphin	0	0	0	0	0	0	0	0	0	0	0	0
MF	Risso's dolphin	4.73	3.14	2.43	2.00	2.79	1.70	1.09	0.91	14.28	12.31	10.97	10.42
MF	Common dolphin	4.75	3.26	2.51	2.08	2.84	1.69	1.20	1.00	14.41	12.54	11.28	10.63
HF	Harbor porpoise (sensitive)	4.13	2.72	2.12	1.79	14.96	12.60	11.07	10.23	13.16	11.32	10.08	9.52
PW	Gray seal	5.71	3.96	3.01	2.40	4.75	3.10	2.24	1.74	14.66	12.81	11.28	10.57
PW	Harbor seal	4.33	2.97	2.31	1.66	3.49	2.38	1.64	1.27	13.02	11.22	10.17	9.68

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{p,w}$ and $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

H.4. Exposure Ranges – Sea Turtles

This section contains sea turtle exposure ranges for each of the modeled foundation types and seasons assuming 0, 6, 10, and 12 dB broadband attenuation.

H.4.1. Impact Pile Driving

Table H-41. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.84	0.50	0.21	0.21	0	0	0	0	1.97	1.25	0.74	0.72
Leatherback turtle [a]	1.70	0.96	0.64	0.35	0	0	0	0	2.48	1.63	1.13	0.96
Loggerhead turtle	1.35	0.84	0.37	0	0	0	0	0	2.31	1.37	1.00	0.93
Green turtle	1.09	0.44	0.16	0.17	0	0	0	0	2.29	1.41	1.04	0.94

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-42. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.96	0.52	0.21	0.21	0	0	0	0	2.18	1.26	0.86	0.71
Leatherback turtle [a]	1.84	1.06	0.68	0.35	0	0	0	0	2.71	1.70	1.18	0.96
Loggerhead turtle	1.34	0.93	0.37	0	0	0	0	0	2.73	1.49	1.00	0.96
Green turtle	1.11	0.44	0.25	0.17	0	0	0	0	2.52	1.67	1.09	0.94

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-43. Scenario B1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, two per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.95	0.47	0.28	0.17	0	0	0	0	2.02	1.27	0.88	0.76
Leatherback turtle [a]	1.75	1.00	0.63	0.42	0	0	0	0	2.61	1.60	1.17	1.00
Loggerhead turtle	1.29	0.70	0.40	0.33	0	0	0	0	2.32	1.52	1.02	0.92
Green turtle	1.08	0.55	0.21	0.23	0	0	0	0	2.20	1.46	1.04	0.94

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-44. Scenario B2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.87	0.29	0.21	0.15	0	0	0	0	1.69	1.27	0.81	0.57
Leatherback turtle [a]	1.49	0.93	0.55	0.35	0	0	0	0	2.47	1.59	1.13	0.95
Loggerhead turtle	1.00	0.35	0.13	0	0	0	0	0	2.24	1.42	0.98	0.96
Green turtle	1.08	0.27	0.17	0.17	0	0	0	0	2.25	1.34	1.05	0.72

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-45. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.85	0.21	0.20	0.15	0	0	0	0	1.61	1.20	0.70	0.54
Leatherback turtle [a]	1.57	0.93	0.55	0.35	0	0	0	0	2.36	1.57	1.10	0.94
Loggerhead turtle	0.97	0.47	0.42	0	0	0	0	0	2.14	1.36	0.98	0.92
Green turtle	0.96	0.27	0.16	0.02	0	0	0	0	2.21	1.40	0.99	0.72

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-46. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.84	0.29	0.20	0.15	0	0	0	0	1.97	1.26	0.74	0.54
Leatherback turtle [a]	1.70	0.94	0.55	0.35	0	0	0	0	2.60	1.63	1.13	0.94
Loggerhead turtle	1.35	0.61	0.40	0	0	0	0	0	2.34	1.37	0.98	0.92
Green turtle	1.05	0.27	0.16	0.02	0	0	0	0	2.35	1.41	0.98	0.72

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-47. Scenario B3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, two per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	1.01	0.44	0.17	0.17	0	0	0	0	1.88	1.20	0.89	0.62
Leatherback turtle [a]	1.59	0.94	0.53	0.22	0	0	0	0	2.35	1.56	1.07	0.94
Loggerhead turtle	1.25	0.53	0.41	0.06	0	0	0	0	2.16	1.32	0.96	0.89
Green turtle	1.01	0.54	0.21	0.13	0	0	0	0	2.03	1.36	1.00	0.89

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-48. Scenario B4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.76	0.21	0.21	0	0	0	0	0	1.60	1.20	0.82	0.46
Leatherback turtle [a]	1.44	0.77	0.35	0.35	0	0	0	0	2.27	1.52	1.09	0.86
Loggerhead turtle	0.97	0.34	0	0	0	0	0	0	2.07	1.35	0.97	0.78
Green turtle	0.84	0.27	0.17	0.02	0	0	0	0	2.04	1.34	0.88	0.72

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-49. Scenario B4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.87	0.29	0.20	0	0	0	0	0	1.68	1.26	0.81	0.54
Leatherback turtle [a]	1.55	0.83	0.35	0.35	0	0	0	0	2.52	1.59	1.09	0.86
Loggerhead turtle	1.00	0.33	0	0	0	0	0	0	2.34	1.42	0.98	0.78
Green turtle	1.08	0.27	0.17	0.02	0	0	0	0	2.33	1.34	0.88	0.72

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-50. Scenario B6, Jacket foundation (4.25 m diameter, 3500 kJ hammer, one per day, summer): Impact only exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24}$ 0 dB	Injury $L_{E,w,24}$ 6 dB	Injury $L_{E,w,24}$ 10 dB	Injury $L_{E,w,24}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	1.22	0.51	0.29	0.20	0	0	0	0	1.46	0.74	0.48	0.39
Leatherback turtle [a]	2.97	1.80	1.08	1.01	0	0	0	0	2.27	1.30	0.91	0.59
Loggerhead turtle	1.52	0.68	0.42	0.36	<0.01	0	0	0	1.67	0.92	0.57	0.42
Green turtle	1.36	0.67	0.29	0.24	0	0	0	0	1.68	0.85	0.52	0.45

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

H.4.2. Vibratory Pile Setting Followed by Impact Pile Driving

Table H-51. Scenario BV1, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.86	0.44	0.21	0.15	0	0	0	0	1.85	1.29	0.74	0.76
Leatherback turtle [a]	1.68	0.94	0.64	0.35	0	0	0	0	2.47	1.62	1.13	0.94
Loggerhead turtle	1.32	0.84	0.22	0	0	0	0	0	2.36	1.39	0.98	0.94
Green turtle	0.90	0.35	0.17	0.16	0	0	0	0	2.27	1.41	0.94	0.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-52. Scenario BV1, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	1.02	0.52	0.21	0.14	0	0	0	0	2.16	1.48	0.88	0.75
Leatherback turtle [a]	1.85	1.09	0.68	0.35	0	0	0	0	2.70	1.69	1.16	0.98
Loggerhead turtle	1.33	0.93	0.22	0	0	0	0	0	2.72	1.49	0.98	0.97
Green turtle	1.15	0.46	0.24	0.16	0	0	0	0	2.54	1.57	0.94	0.82

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-53. Scenario BV2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.87	0.29	0.21	0.15	0	0	0	0	1.55	1.27	0.90	0.58
Leatherback turtle [a]	1.49	0.90	0.55	0.35	0	0	0	0	2.48	1.60	1.13	0.95
Loggerhead turtle	1.02	0.47	0.39	0	0	0	0	0	2.26	1.43	0.99	0.93
Green turtle	1.08	0.28	0.17	0.17	0	0	0	0	2.27	1.36	1.06	0.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-54. Scenario BV2, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 8000 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.88	0.39	0.21	0.15	0	0	0	0	2.15	1.26	0.91	0.57
Leatherback turtle [a]	1.63	0.93	0.55	0.35	0	0	0	0	2.69	1.69	1.13	0.98
Loggerhead turtle	1.29	0.61	0.38	0	0	0	0	0	2.59	1.51	1.01	0.93
Green turtle	1.10	0.28	0.17	0.17	0	0	0	0	2.49	1.38	1.09	0.78

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-55. Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.87	0.21	0.20	0.15	0	0	0	0	1.75	1.22	0.75	0.53
Leatherback turtle [a]	1.56	0.94	0.56	0.35	0	0	0	0	2.46	1.54	1.13	0.94
Loggerhead turtle	0.98	0.52	0.17	0	0	0	0	0	2.07	1.36	0.98	0.92
Green turtle	0.85	0.35	0.17	0.11	0	0	0	0	2.13	1.41	0.87	0.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-56. Scenario BV3, Monopile foundation (12.5 m diameter, DTD, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.85	0.29	0.20	0.15	0	0	0	0	1.94	1.30	0.74	0.55
Leatherback turtle [a]	1.68	0.94	0.64	0.35	0	0	0	0	2.52	1.62	1.13	0.94
Loggerhead turtle	1.31	0.72	0.16	0	0	0	0	0	2.49	1.39	0.98	0.92
Green turtle	0.85	0.35	0.17	0.11	0	0	0	0	2.28	1.41	0.90	0.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-57. Scenario BV4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, summer): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.76	0.21	0.21	0	0	0	0	0	1.45	1.21	0.91	0.41
Leatherback turtle [a]	1.44	0.75	0.35	0	0	0	0	0	2.28	1.52	1.09	0.87
Loggerhead turtle	0.97	0.35	0	0	0	0	0	0	2.08	1.35	0.99	0.78
Green turtle	0.88	0.25	0.17	0.02	0	0	0	0	2.09	1.36	0.88	0.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa^2·s), L_p—root mean square sound pressure level (dB re 1 µPa^2), *w* in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-58. Scenario BV4, Monopile foundation (12.5 m diameter, 5500 kJ hammer scaled to 6600 kJ, one per day, winter): Vibratory pile setting (TR-CV640, 30 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.87	0.29	0.21	0	0	0	0	0	1.78	1.27	0.90	0.55
Leatherback turtle [a]	1.56	0.83	0.35	0.35	0	0	0	0	2.52	1.60	1.09	0.87
Loggerhead turtle	1.02	0.48	0	0	0	0	0	0	2.34	1.43	0.99	0.78
Green turtle	0.95	0.25	0.17	0.02	0	0	0	0	2.34	1.36	0.88	0.73

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), ***w*** in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

Table H-59. Scenario BV6, Jacket foundation (4.25 m diameter, 3500 kJ hammer, four per day, summer): Vibratory pile setting (TR-CV640, 60 minutes) followed by impact pile driving exposure ranges ($ER_{95\%}$) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury $L_{E,w,24h}$ 0 dB	Injury $L_{E,w,24h}$ 6 dB	Injury $L_{E,w,24h}$ 10 dB	Injury $L_{E,w,24h}$ 12 dB	Injury L_{pk} 0 dB	Injury L_{pk} 6 dB	Injury L_{pk} 10 dB	Injury L_{pk} 12 dB	Behavior L_p 0 dB	Behavior L_p 6 dB	Behavior L_p 10 dB	Behavior L_p 12 dB
Kemp's ridley turtle [a]	0.78	0.42	0.16	0.06	0	0	0	0	1.18	0.65	0.42	0.23
Leatherback turtle [a]	2.51	1.54	1.03	0.77	0	0	0	0	1.99	1.03	0.59	0.34
Loggerhead turtle	1.16	0.63	0.42	0.15	0	0	0	0	1.54	0.72	0.42	0.36
Green turtle	0.89	0.48	0.19	0.09	0	0	0	0	1.42	0.80	0.50	0.34

L_{pk}—peak sound pressure level (dB re 1 µPa), L_E—sound exposure level (dB re 1 µPa²·s), L_p—root mean square sound pressure level (dB re 1 µPa²), ***w*** in $L_{E,w,24h}$ indicates the use of a frequency-weighting function, *24h* in $L_{E,w,24h}$ indicates that a 24h period was used to calculate cumulative SEL.

[a] Listed as Endangered under the ESA.

H.5. Animal Densities

To calculate exposures, animal densities were calculated within buffered polygons around the Lease Area perimeter for the following buffer ranges: 1, 5, 10, 15, 20, 30, 40, and 50 km. The following section contains mean animal density values for those ranges.

H.5.1. Marine Mammals

Table H-60. Mean monthly marine mammal density estimates for all species in a 1 km perimeter around the Lease Area [a].

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.181	0.194	0.177	0.127	0.257	0.345	0.304	0.244	0.099	0.035	0.058	0.109	0.177	0.181
Humpback whale	0.077	0.059	0.070	0.103	0.196	0.201	0.048	0.035	0.079	0.118	0.110	0.071	0.097	0.107
Common minke whale (migrating)	0.076	0.068	0.072	0.901	1.773	1.314	0.353	0.202	0.146	0.164	0.029	0.059	0.430	0.505
North Atlantic right whale [b]	0.123	0.156	0.157	0.122	0.038	0.008	0.004	0.004	0.006	0.012	0.020	0.055	0.059	0.018
Sei whale [b] (migrating)	0.022	0.013	0.031	0.080	0.088	0.016	0.003	0.002	0.007	0.019	0.038	0.026	0.029	0.025
Sperm whale [b]	0.014	0.003	0.003	0.003	0.005	0.006	0.010	0.027	0.013	<0.001	0.007	0.007	0.008	0.009
Atlantic spotted dolphin	0.003	<0.001	0.002	0.007	0.024	0.044	0.051	0.112	0.409	0.633	0.275	0.023	0.132	0.196
Atlantic white sided dolphin	1.243	0.756	0.538	0.999	2.136	2.287	0.223	0.092	0.479	1.367	1.174	1.557	1.071	1.164
Common bottlenose dolphin	0.893	0.272	0.168	0.402	1.379	2.288	2.133	1.453	1.442	1.749	1.981	2.088	1.354	1.814
Long-finned pilot whale [c]	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Short-finned pilot whale [c]	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Risso's dolphin	0.095	0.013	0.007	0.040	0.078	0.031	0.028	0.015	0.017	0.021	0.099	0.303	0.062	0.074
Common dolphin	10.402	3.579	2.084	3.222	5.298	5.270	3.195	4.438	4.805	8.156	9.934	14.541	6.243	6.954
Harbor porpoise (sensitive)	7.239	7.545	7.606	8.900	3.360	0.632	0.905	0.483	0.385	0.381	0.775	3.878	3.507	1.350
Gray seal	4.954	5.371	4.401	3.928	6.286	0.434	0.028	0.019	0.057	0.331	1.162	4.305	2.606	1.578
Harbor seal	9.616	10.426	8.543	7.625	12.202	0.843	0.053	0.036	0.110	0.643	2.255	8.357	5.059	3.062

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

Table H-61. Mean monthly marine mammal density estimates [a] for all species in a 5 km perimeter around the Lease Area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.182	0.199	0.172	0.134	0.259	0.327	0.289	0.219	0.098	0.037	0.055	0.113	0.174	0.175
Humpback whale	0.078	0.059	0.070	0.103	0.189	0.191	0.045	0.033	0.075	0.114	0.107	0.074	0.095	0.104
Common minke whale (migrating)	0.081	0.071	0.076	0.919	1.779	1.279	0.340	0.194	0.140	0.162	0.031	0.063	0.428	0.498
North Atlantic right whale [b]	0.120	0.150	0.152	0.117	0.036	0.008	0.004	0.003	0.006	0.011	0.019	0.054	0.057	0.018
Sei whale [b] (migrating)	0.023	0.013	0.031	0.081	0.086	0.015	0.003	0.002	0.007	0.018	0.039	0.029	0.029	0.025
Sperm whale [b]	0.013	0.002	0.002	0.003	0.004	0.007	0.011	0.029	0.013	<0.001	0.007	0.007	0.008	0.010
Atlantic spotted dolphin	0.003	<0.001	0.002	0.007	0.029	0.048	0.052	0.115	0.401	0.621	0.276	0.024	0.132	0.196
Atlantic white sided dolphin	1.158	0.717	0.522	0.988	2.093	2.183	0.210	0.087	0.465	1.337	1.138	1.491	1.032	1.125
Common bottlenose dolphin	0.889	0.272	0.170	0.411	1.403	2.308	2.146	1.494	1.457	1.759	1.989	2.082	1.365	1.830
Long-finned pilot whale [c]	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103
Short-finned pilot whale [c]	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Risso's dolphin	0.093	0.013	0.007	0.041	0.077	0.031	0.028	0.015	0.016	0.021	0.097	0.296	0.061	0.073
Common dolphin	9.965	3.482	2.020	3.182	5.148	5.114	3.034	4.173	4.417	7.543	9.687	14.073	5.986	6.649
Harbor porpoise (sensitive)	7.080	7.461	7.505	8.823	3.295	0.593	0.850	0.450	0.344	0.349	0.714	3.901	3.447	1.312
Gray seal	5.079	5.463	4.425	3.947	6.603	0.481	0.031	0.021	0.060	0.338	1.198	4.357	2.667	1.636
Harbor seal	9.860	10.604	8.589	7.661	12.818	0.934	0.060	0.040	0.117	0.656	2.326	8.458	5.177	3.176

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

Table H-62. Mean monthly marine mammal density estimates [a] for all species in a 10 km perimeter around the Lease Area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.187	0.200	0.176	0.140	0.261	0.324	0.296	0.222	0.111	0.038	0.055	0.117	0.177	0.178
Humpback whale	0.078	0.058	0.070	0.107	0.189	0.191	0.046	0.033	0.075	0.115	0.108	0.075	0.095	0.104
Common minke whale (migrating)	0.084	0.074	0.080	0.934	1.793	1.267	0.336	0.194	0.147	0.168	0.032	0.066	0.431	0.500
North Atlantic right whale [b]	0.118	0.147	0.149	0.115	0.036	0.008	0.004	0.003	0.006	0.011	0.019	0.054	0.056	0.017
Sei whale [b] (migrating)	0.023	0.014	0.032	0.083	0.084	0.015	0.003	0.002	0.007	0.018	0.039	0.031	0.029	0.025
Sperm whale [b]	0.013	0.003	0.003	0.003	0.004	0.008	0.013	0.027	0.015	<0.001	0.007	0.007	0.009	0.010
Atlantic spotted dolphin	0.003	<0.001	0.002	0.008	0.034	0.056	0.055	0.120	0.407	0.653	0.278	0.025	0.137	0.204
Atlantic white sided dolphin	1.126	0.704	0.524	1.005	2.064	2.141	0.204	0.082	0.451	1.311	1.112	1.452	1.015	1.102
Common bottlenose dolphin	0.922	0.289	0.182	0.426	1.438	2.355	2.190	1.550	1.505	1.801	2.030	2.120	1.401	1.874
Long-finned pilot whale [c]	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Short-finned pilot whale [c]	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Risso's dolphin	0.097	0.014	0.007	0.042	0.078	0.032	0.028	0.015	0.017	0.022	0.098	0.290	0.062	0.073
Common dolphin	10.206	3.695	2.112	3.265	5.290	5.302	3.062	4.247	4.650	8.054	9.837	14.324	6.170	6.846
Harbor porpoise (sensitive)	6.965	7.376	7.415	8.716	3.215	0.585	0.847	0.445	0.338	0.357	0.707	3.877	3.404	1.296
Gray seal	5.099	5.418	4.406	3.939	6.477	0.528	0.035	0.023	0.065	0.344	1.221	4.399	2.663	1.636
Harbor seal	9.899	10.517	8.553	7.647	12.574	1.025	0.068	0.045	0.125	0.668	2.369	8.539	5.169	3.177

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

Table H-63. Mean monthly marine mammal density estimates [a] for all species in a 15 km perimeter around the Lease Area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.193	0.197	0.180	0.146	0.264	0.323	0.310	0.229	0.138	0.041	0.055	0.122	0.183	0.185
Humpback whale	0.076	0.058	0.070	0.110	0.189	0.193	0.046	0.034	0.075	0.115	0.110	0.076	0.096	0.105
Common minke whale (migrating)	0.087	0.079	0.085	0.949	1.806	1.252	0.333	0.195	0.164	0.186	0.034	0.069	0.437	0.505
North Atlantic right whale [b]	0.114	0.143	0.144	0.114	0.035	0.007	0.004	0.003	0.006	0.011	0.018	0.052	0.054	0.017
Sei whale [b] (migrating)	0.024	0.014	0.033	0.084	0.083	0.016	0.003	0.002	0.007	0.018	0.040	0.033	0.030	0.025
Sperm whale [b]	0.013	0.003	0.003	0.003	0.005	0.010	0.014	0.023	0.015	0.001	0.007	0.007	0.009	0.010
Atlantic spotted dolphin	0.003	<0.001	0.002	0.010	0.043	0.068	0.059	0.126	0.427	0.722	0.285	0.028	0.148	0.220
Atlantic white sided dolphin	1.110	0.702	0.535	1.032	2.046	2.137	0.200	0.077	0.438	1.282	1.094	1.414	1.006	1.086
Common bottlenose dolphin	0.995	0.326	0.205	0.455	1.501	2.449	2.273	1.643	1.594	1.893	2.118	2.200	1.471	1.959
Long-finned pilot whale [c]	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
Short-finned pilot whale [c]	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Risso's dolphin	0.105	0.017	0.008	0.045	0.083	0.035	0.031	0.016	0.020	0.025	0.101	0.282	0.064	0.074
Common dolphin	10.778	4.145	2.310	3.439	5.602	5.721	3.190	4.506	5.341	9.607	10.241	14.939	6.652	7.394
Harbor porpoise (sensitive)	6.809	7.233	7.283	8.571	3.118	0.586	0.854	0.447	0.344	0.383	0.722	3.813	3.347	1.283
Gray seal	5.083	5.321	4.356	3.887	6.213	0.602	0.043	0.028	0.072	0.357	1.247	4.433	2.637	1.624
Harbor seal	9.866	10.329	8.456	7.545	12.061	1.169	0.083	0.054	0.139	0.694	2.420	8.605	5.118	3.153

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

Table H-64. Mean monthly marine mammal density estimates [a] for all species in a 20 km perimeter around the Lease Area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.194	0.191	0.179	0.148	0.261	0.313	0.315	0.227	0.162	0.043	0.054	0.124	0.184	0.187
Humpback whale	0.076	0.058	0.070	0.111	0.185	0.191	0.045	0.033	0.073	0.112	0.108	0.079	0.095	0.103
Common minke whale (migrating)	0.087	0.080	0.086	0.956	1.799	1.217	0.323	0.193	0.176	0.201	0.034	0.069	0.435	0.501
North Atlantic right whale [b]	0.110	0.139	0.139	0.112	0.034	0.007	0.004	0.003	0.005	0.010	0.018	0.051	0.053	0.017
Sei whale [b] (migrating)	0.024	0.014	0.034	0.085	0.082	0.016	0.003	0.002	0.007	0.018	0.040	0.036	0.030	0.026
Sperm whale [b]	0.013	0.003	0.003	0.004	0.005	0.012	0.015	0.022	0.014	0.002	0.008	0.008	0.009	0.011
Atlantic spotted dolphin	0.004	0.001	0.003	0.010	0.049	0.078	0.061	0.131	0.441	0.771	0.287	0.030	0.156	0.231
Atlantic white sided dolphin	1.087	0.694	0.545	1.060	2.027	2.132	0.195	0.073	0.427	1.249	1.079	1.374	0.995	1.069
Common bottlenose dolphin	1.055	0.359	0.226	0.487	1.574	2.558	2.362	1.733	1.685	1.997	2.214	2.274	1.544	2.050
Long-finned pilot whale [c]	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Short-finned pilot whale [c]	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Risso's dolphin	0.113	0.019	0.009	0.048	0.088	0.039	0.034	0.017	0.023	0.029	0.105	0.274	0.067	0.076
Common dolphin	11.453	4.704	2.561	3.687	6.024	6.252	3.389	4.854	6.143	11.422	10.845	15.727	7.255	8.082
Harbor porpoise (sensitive)	6.638	7.045	7.126	8.396	3.013	0.580	0.838	0.440	0.340	0.396	0.725	3.763	3.275	1.262
Gray seal	5.091	5.211	4.283	3.830	6.034	0.748	0.058	0.036	0.085	0.389	1.299	4.477	2.628	1.641
Harbor seal	9.883	10.115	8.315	7.435	11.713	1.451	0.113	0.070	0.164	0.755	2.521	8.691	5.102	3.185

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

Table H-65. Mean monthly marine mammal density estimates [a] for all species in a 30 km perimeter around the Lease Area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.191	0.185	0.179	0.152	0.251	0.299	0.334	0.228	0.200	0.051	0.052	0.125	0.187	0.193
Humpback whale	0.075	0.057	0.071	0.112	0.178	0.191	0.044	0.031	0.070	0.107	0.105	0.083	0.094	0.101
Common minke whale (migrating)	0.082	0.079	0.086	0.947	1.720	1.129	0.301	0.188	0.194	0.226	0.033	0.066	0.421	0.482
North Atlantic right whale [b]	0.102	0.131	0.131	0.108	0.034	0.007	0.004	0.003	0.005	0.010	0.017	0.048	0.050	0.016
Sei whale [b] (migrating)	0.024	0.015	0.036	0.086	0.082	0.017	0.003	0.002	0.007	0.018	0.040	0.038	0.031	0.026
Sperm whale [b]	0.013	0.005	0.003	0.004	0.005	0.012	0.015	0.022	0.015	0.005	0.009	0.010	0.010	0.012
Atlantic spotted dolphin	0.005	0.001	0.003	0.012	0.061	0.098	0.067	0.140	0.474	0.870	0.291	0.035	0.172	0.255
Atlantic white sided dolphin	1.075	0.700	0.579	1.135	2.022	2.200	0.187	0.066	0.414	1.200	1.047	1.310	0.995	1.056
Common bottlenose dolphin	1.203	0.442	0.279	0.585	1.824	2.954	2.700	2.041	2.007	2.373	2.559	2.504	1.789	2.370
Long-finned pilot whale [c]	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
Short-finned pilot whale [c]	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Risso's dolphin	0.138	0.028	0.013	0.060	0.109	0.051	0.043	0.023	0.034	0.041	0.120	0.274	0.078	0.087
Common dolphin	13.309	6.144	3.203	4.332	7.165	7.709	3.971	5.824	7.920	15.150	12.415	17.728	8.739	9.735
Harbor porpoise (sensitive)	6.165	6.518	6.722	7.929	2.795	0.572	0.806	0.438	0.347	0.433	0.751	3.510	3.082	1.206
Gray seal	4.867	4.818	4.033	3.724	5.621	1.106	0.100	0.057	0.114	0.482	1.370	4.376	2.556	1.653
Harbor seal	9.449	9.352	7.830	7.229	10.911	2.146	0.195	0.110	0.222	0.936	2.660	8.495	4.961	3.209

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

Table H-66. Mean monthly marine mammal density estimates [a] for all species in a 40 km perimeter around the Lease Area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.188	0.182	0.180	0.153	0.241	0.284	0.338	0.225	0.220	0.059	0.051	0.124	0.187	0.193
Humpback whale	0.074	0.057	0.073	0.117	0.176	0.196	0.044	0.031	0.070	0.107	0.106	0.085	0.095	0.102
Common minke whale (migrating)	0.080	0.078	0.085	0.919	1.606	1.037	0.279	0.179	0.196	0.231	0.033	0.064	0.399	0.453
North Atlantic right whale [b]	0.097	0.126	0.125	0.105	0.033	0.007	0.003	0.003	0.005	0.010	0.016	0.045	0.048	0.015
Sei whale [b] (migrating)	0.023	0.015	0.036	0.084	0.081	0.018	0.003	0.002	0.007	0.017	0.039	0.038	0.030	0.026
Sperm whale [b]	0.013	0.005	0.004	0.004	0.006	0.012	0.015	0.024	0.014	0.005	0.009	0.011	0.010	0.012
Atlantic spotted dolphin	0.005	0.002	0.003	0.013	0.068	0.117	0.072	0.146	0.496	0.921	0.291	0.040	0.181	0.269
Atlantic white sided dolphin	1.050	0.697	0.598	1.166	1.974	2.225	0.178	0.060	0.400	1.142	1.000	1.233	0.977	1.026
Common bottlenose dolphin	1.302	0.506	0.319	0.671	2.037	3.307	3.070	2.400	2.365	2.786	2.881	2.670	2.026	2.690
Long-finned pilot whale [c]	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144
Short-finned pilot whale [c]	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Risso's dolphin	0.149	0.035	0.015	0.062	0.113	0.057	0.050	0.027	0.044	0.049	0.124	0.259	0.082	0.090
Common dolphin	13.885	6.824	3.500	4.544	7.517	8.351	4.169	6.190	8.451	16.216	12.840	18.052	9.212	10.223
Harbor porpoise (sensitive)	5.686	6.005	6.310	7.453	2.606	0.567	0.771	0.444	0.349	0.456	0.768	3.213	2.886	1.147
Gray seal	4.634	4.497	3.840	3.700	5.324	1.706	0.163	0.087	0.166	0.702	1.438	4.225	2.540	1.726
Harbor seal	8.995	8.729	7.454	7.182	10.334	3.311	0.316	0.170	0.323	1.362	2.791	8.202	4.931	3.351

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

Table H-67. Mean monthly marine mammal density estimates [a] for all species in a 50 km perimeter around the Lease Area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Fin whale [b]	0.190	0.187	0.190	0.162	0.244	0.279	0.347	0.234	0.249	0.068	0.051	0.123	0.194	0.200
Humpback whale	0.073	0.058	0.076	0.129	0.185	0.218	0.048	0.033	0.074	0.111	0.111	0.084	0.100	0.108
Common minke whale (migrating)	0.080	0.080	0.087	0.906	1.534	0.984	0.264	0.173	0.199	0.242	0.034	0.064	0.387	0.437
North Atlantic right whale [b]	0.092	0.122	0.122	0.106	0.035	0.007	0.003	0.003	0.005	0.010	0.016	0.042	0.047	0.015
Sei whale [b] (migrating)	0.023	0.016	0.037	0.085	0.085	0.020	0.004	0.002	0.007	0.017	0.039	0.037	0.031	0.026
Sperm whale [b]	0.013	0.006	0.004	0.005	0.006	0.012	0.017	0.028	0.015	0.006	0.009	0.012	0.011	0.013
Atlantic spotted dolphin	0.008	0.002	0.003	0.014	0.081	0.156	0.084	0.165	0.579	1.055	0.321	0.053	0.210	0.312
Atlantic white sided dolphin	1.072	0.729	0.647	1.236	2.017	2.378	0.182	0.058	0.408	1.137	0.995	1.207	1.005	1.048
Common bottlenose dolphin	1.413	0.579	0.353	0.729	2.148	3.483	3.243	2.585	2.550	3.017	3.084	2.793	2.165	2.863
Long-finned pilot whale [c]	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161
Short-finned pilot whale [c]	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Goose-beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Striped dolphin	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Risso's dolphin	0.168	0.046	0.018	0.066	0.122	0.068	0.063	0.037	0.063	0.062	0.133	0.257	0.092	0.101
Common dolphin	15.321	8.032	4.074	5.016	8.312	9.669	4.693	7.055	9.483	18.138	13.978	19.322	10.258	11.331
Harbor porpoise (sensitive)	5.366	5.685	6.070	7.194	2.508	0.589	0.765	0.467	0.364	0.495	0.813	2.998	2.776	1.125
Gray seal	4.440	4.261	3.714	3.665	5.018	1.846	0.176	0.095	0.187	0.830	1.451	4.060	2.479	1.708
Harbor seal	8.619	8.271	7.210	7.115	9.742	3.583	0.342	0.184	0.362	1.611	2.816	7.881	4.811	3.315

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).
[b] Listed as Endangered under the ESA.
[c] Density adjusted by relative abundance.

H.5.2. Sea Turtles

Table H-68. Sea turtle density estimates for all modeled species in a 1 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.009	0.011	0.011	0.007	0.006	0.001	0	0.004	0.006
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.009	0.044	0.086	0.167	0.235	0.234	0.043	0.004	0.068	0.103
Loggerhead sea turtle	0.009	0.007	0.004	0.005	0.030	0.093	0.085	0.075	0.085	0.104	0.064	0.020	0.048	0.070
Green sea turtle	0	0	0	0	0	0.229	0.249	0.227	0.354	0.159	0.013	0	0.103	0.154

[a] Density estimates are from DiMatteo et al. (2024).

Table H-69. Sea turtle density estimates for all modeled species in a 5 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.011	0.012	0.012	0.008	0.008	0.001	0	0.004	0.006
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.009	0.043	0.084	0.165	0.235	0.232	0.040	0.003	0.068	0.101
Loggerhead sea turtle	0.009	0.006	0.004	0.005	0.029	0.091	0.083	0.072	0.080	0.098	0.059	0.018	0.046	0.066
Green sea turtle	0	0	0	0	0	0.208	0.232	0.214	0.334	0.153	0.012	0	0.096	0.144

[a] Density estimates are from DiMatteo et al. (2024).

Table H-70. Sea turtle density estimates for all modeled species in a 10 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.011	0.012	0.013	0.008	0.008	0.001	0	0.004	0.007
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.008	0.042	0.083	0.162	0.231	0.227	0.040	0.003	0.066	0.100
Loggerhead sea turtle	0.009	0.006	0.004	0.005	0.029	0.093	0.084	0.074	0.084	0.102	0.061	0.019	0.047	0.068
Green sea turtle	0	0	0	0	0	0.207	0.233	0.215	0.335	0.151	0.012	0	0.096	0.144

[a] Density estimates are from DiMatteo et al. (2024).

Table H-71. Sea turtle density estimates for all modeled species in a 15 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.011	0.013	0.013	0.008	0.008	0.001	0	0.005	0.007
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.008	0.042	0.081	0.158	0.226	0.220	0.039	0.003	0.065	0.097
Loggerhead sea turtle	0.009	0.006	0.004	0.005	0.029	0.093	0.084	0.073	0.083	0.101	0.060	0.019	0.047	0.068
Green sea turtle	0	0	0	0	0	0.197	0.224	0.208	0.324	0.148	0.012	0	0.093	0.139

[a] Density estimates are from DiMatteo et al. (2024).

Table H-72. Sea turtle density estimates for all modeled species in a 20 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.011	0.012	0.012	0.008	0.008	0.001	0	0.004	0.007
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.008	0.041	0.082	0.157	0.221	0.213	0.040	0.004	0.064	0.096
Loggerhead sea turtle	0.009	0.007	0.005	0.006	0.031	0.098	0.087	0.078	0.091	0.111	0.067	0.022	0.051	0.073
Green sea turtle	0	0	0	0	0	0.201	0.233	0.216	0.332	0.148	0.013	0	0.095	0.143

[a] Density estimates are from DiMatteo et al. (2024).

Table H-73. Sea turtle density estimates for all modeled species in a 30 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.011	0.012	0.012	0.008	0.008	0.001	0	0.004	0.007
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.008	0.039	0.078	0.148	0.207	0.199	0.038	0.004	0.060	0.090
Loggerhead sea turtle	0.010	0.008	0.006	0.006	0.032	0.101	0.087	0.079	0.094	0.116	0.070	0.024	0.053	0.075
Green sea turtle	0	0	0	0	0	0.186	0.216	0.202	0.315	0.142	0.013	0	0.089	0.134

[a] Density estimates are from DiMatteo et al. (2024).

Table H-74. Sea turtle density estimates for all modeled species in a 40 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.010	0.011	0.012	0.007	0.007	0.001	0	0.004	0.006
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.007	0.036	0.072	0.135	0.186	0.177	0.035	0.004	0.054	0.081
Loggerhead sea turtle	0.010	0.009	0.006	0.006	0.033	0.106	0.089	0.081	0.099	0.124	0.076	0.028	0.056	0.080
Green sea turtle	0	0	0	0	0	0.181	0.214	0.203	0.310	0.139	0.014	0	0.088	0.133

[a] Density estimates are from DiMatteo et al. (2024).

Table H-75. Sea turtle density estimates for all modeled species in a 50 km perimeter around the Lease Area [a].

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	May to December mean
Kemp's ridley sea turtle	0	0	0	0	0	0.010	0.011	0.012	0.007	0.007	0.001	0	0.004	0.006
Leatherback sea turtle	<0.001	<0.001	<0.001	<0.001	0.007	0.035	0.070	0.131	0.176	0.166	0.033	0.004	0.052	0.078
Loggerhead sea turtle	0.012	0.009	0.007	0.007	0.037	0.115	0.094	0.087	0.107	0.137	0.084	0.033	0.061	0.087
Green sea turtle	0	0	0	0	0	0.186	0.222	0.211	0.317	0.143	0.015	0	0.091	0.137

[a] Density estimates are from DiMatteo et al. (2024).

H.6. 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 displaying the highest density month for that species. If density surfaces were unavailable for a particular species, a surrogate may have been used. Please refer to Sections 3.1 and 3.2 for a detailed description of density sources and calculations.

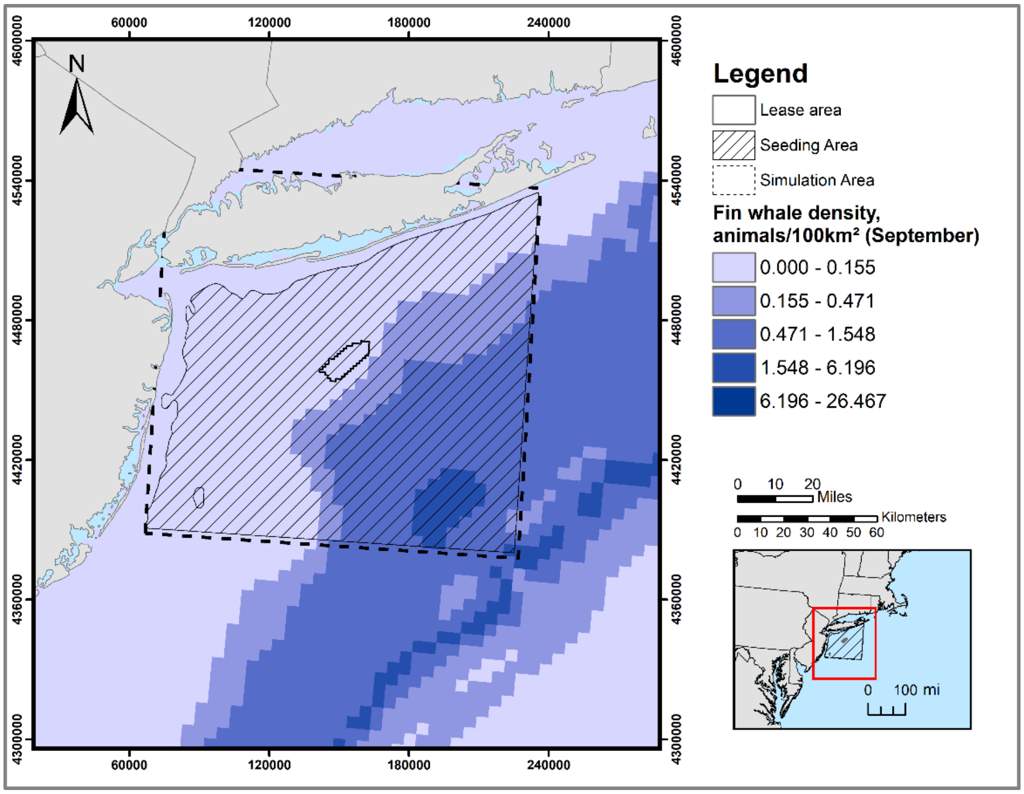


Figure H-1. Fin whale: Map of animat seeding area range.

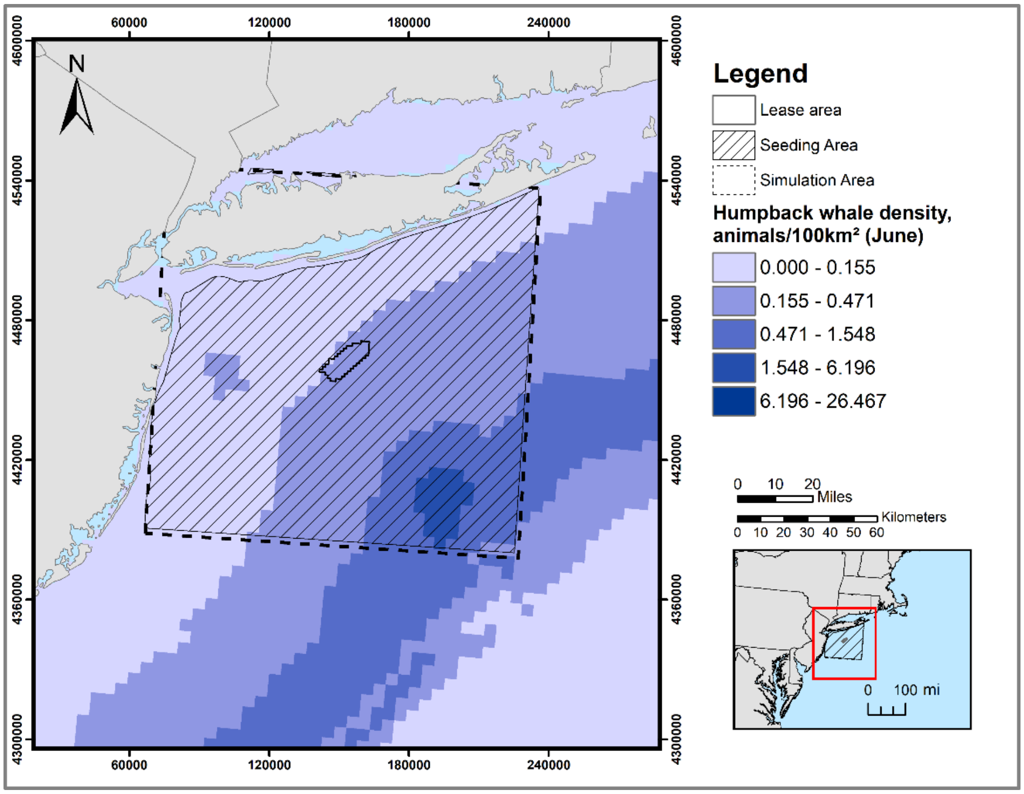


Figure H-2. Humpback whale: Map of animat seeding area range.

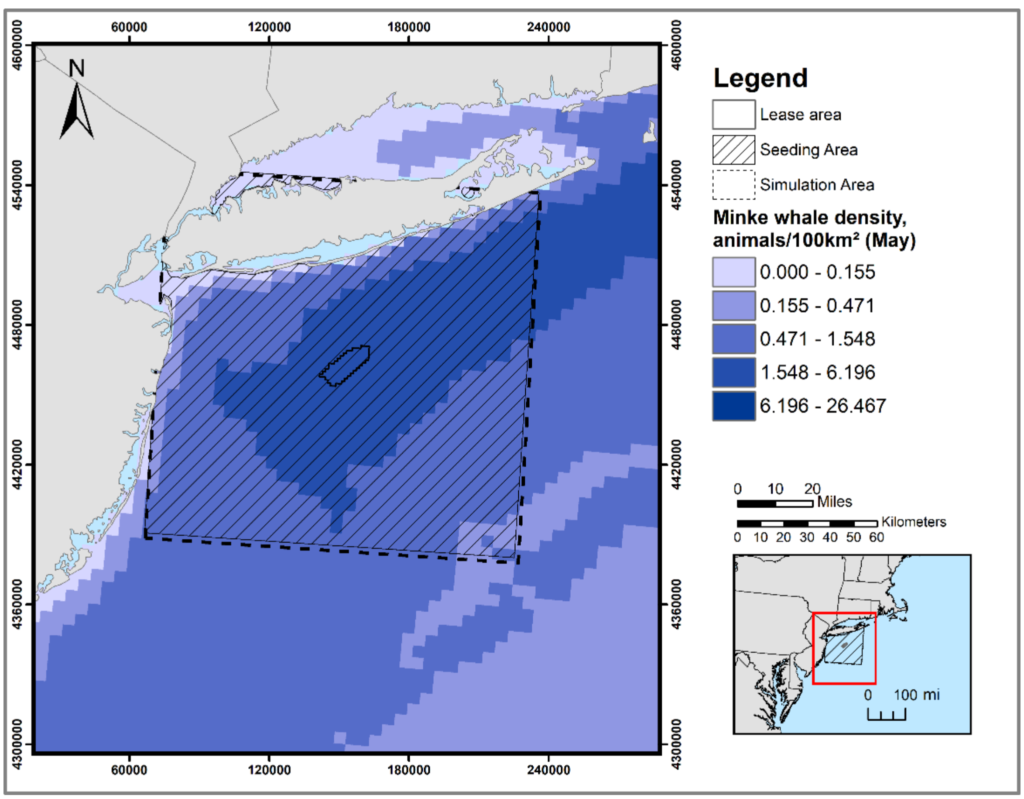


Figure H-3. Common minke whale: Map of animat seeding area range.

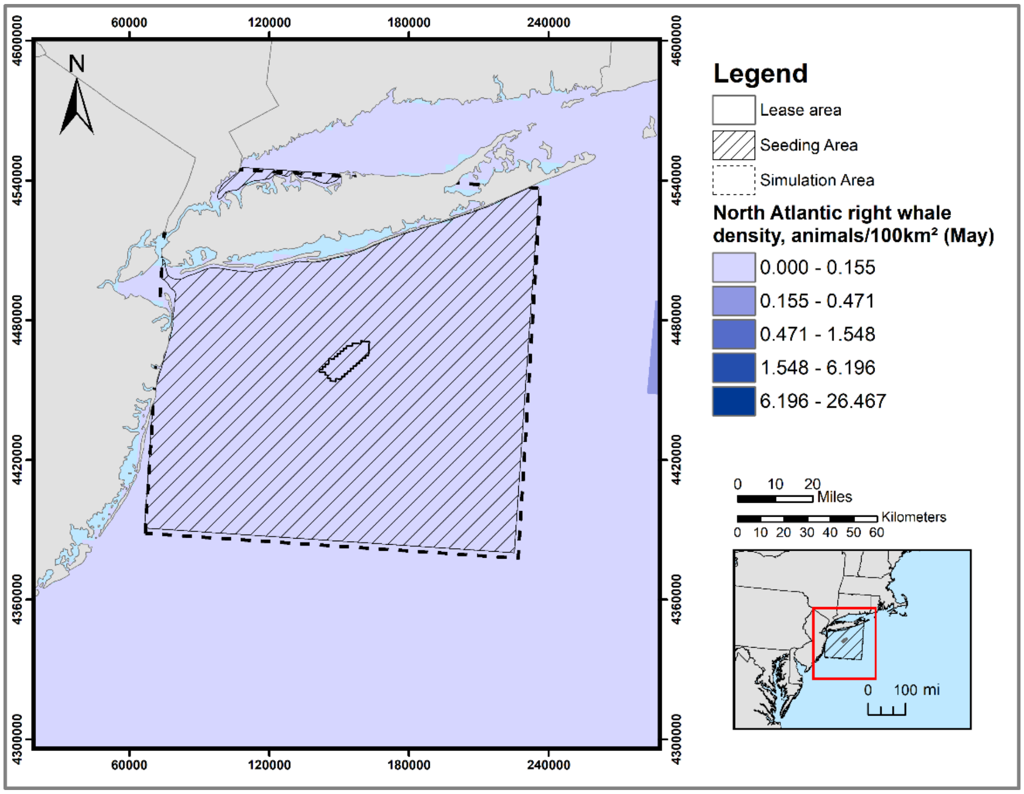


Figure H-4. North Atlantic right whale: Map of animat seeding area range.

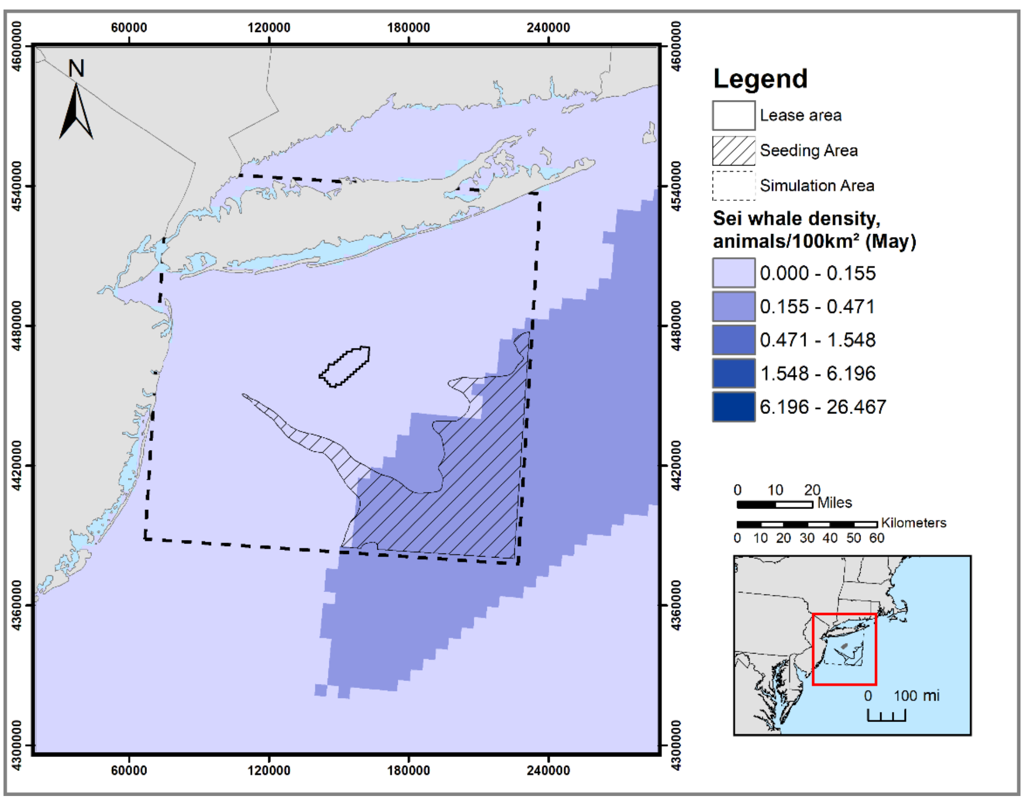


Figure H-5. Sei whale: Map of animat seeding area range.

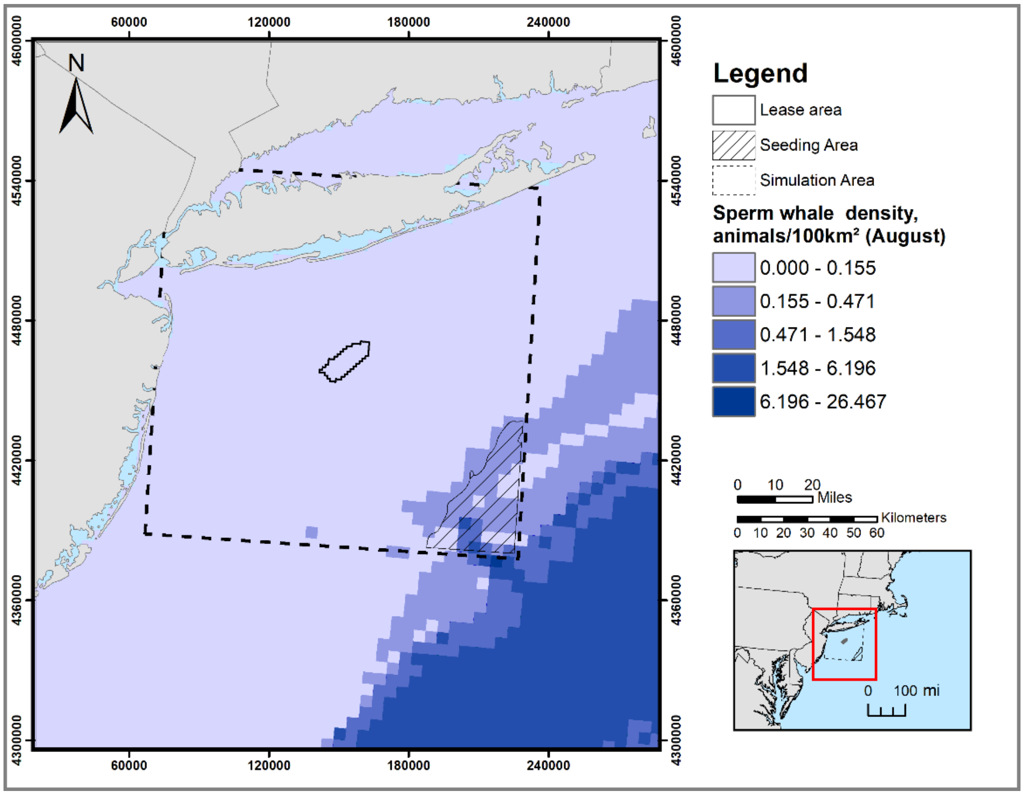


Figure H-6. Sperm whale: Map of animat seeding area range.

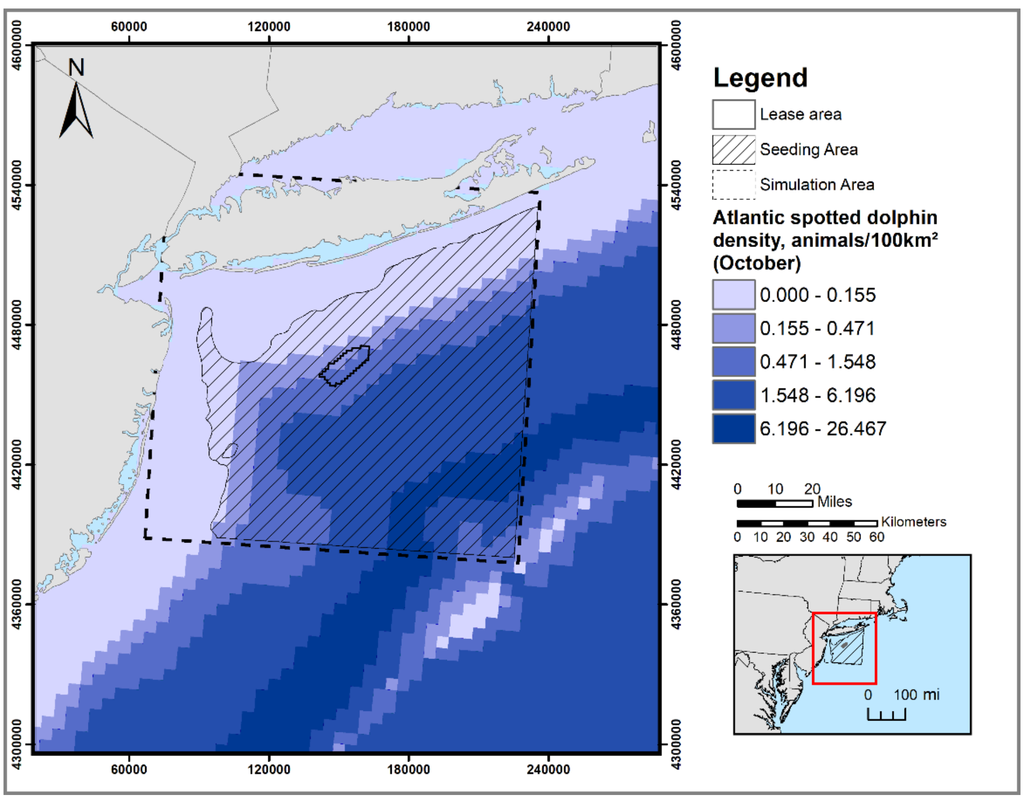


Figure H-7. Atlantic spotted dolphin: Map of animat seeding area range.

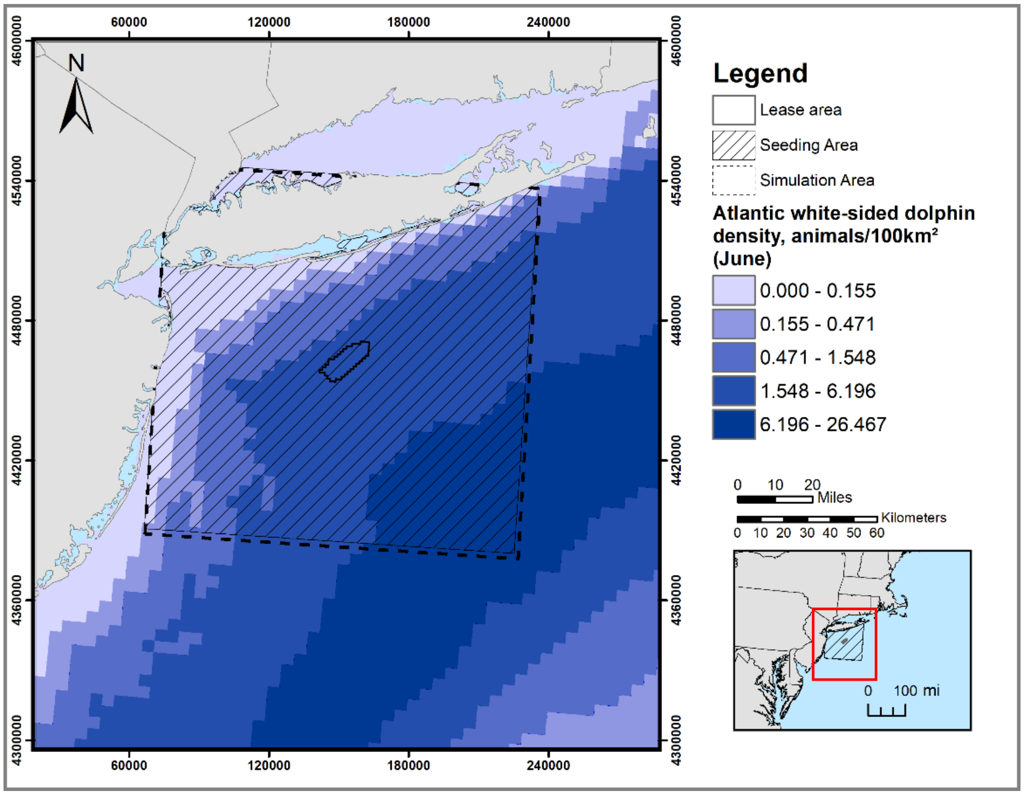


Figure H-8. Atlantic white-sided dolphin: Map of animat seeding area range.

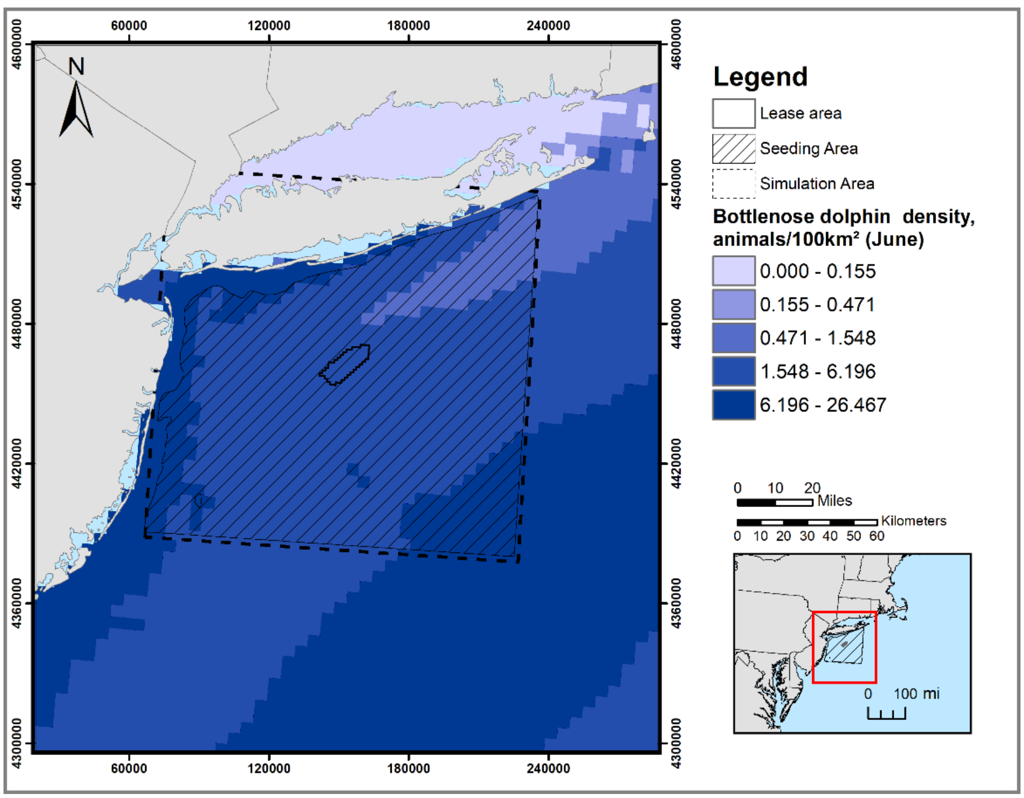


Figure H-9. Bottlenose dolphin: Map of animat seeding area range.

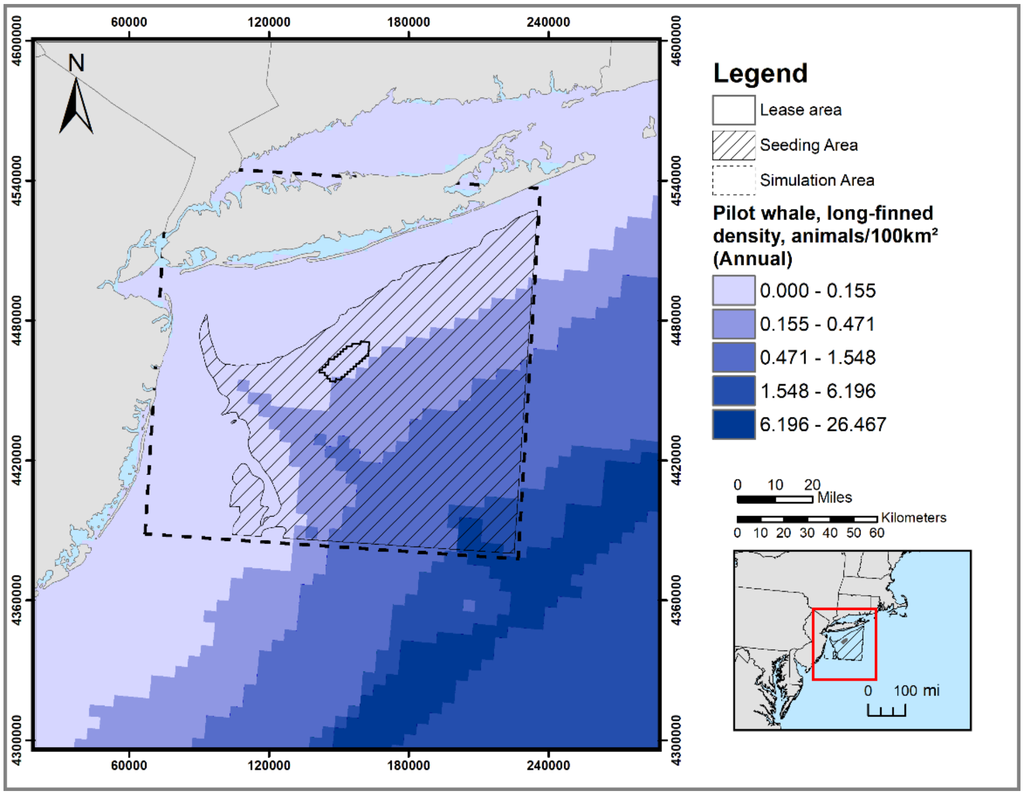


Figure H-10. Long-finned pilot whale: Map of animat seeding area range.

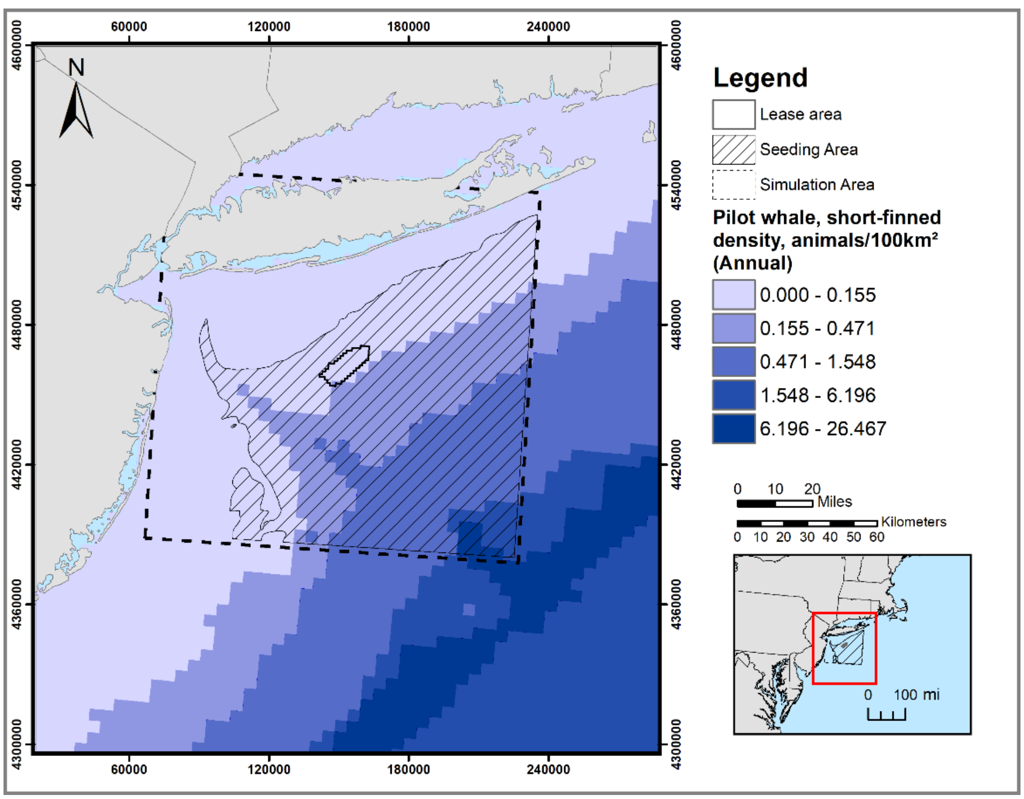


Figure H-11. Short-finned pilot whale: Map of animat seeding area range.

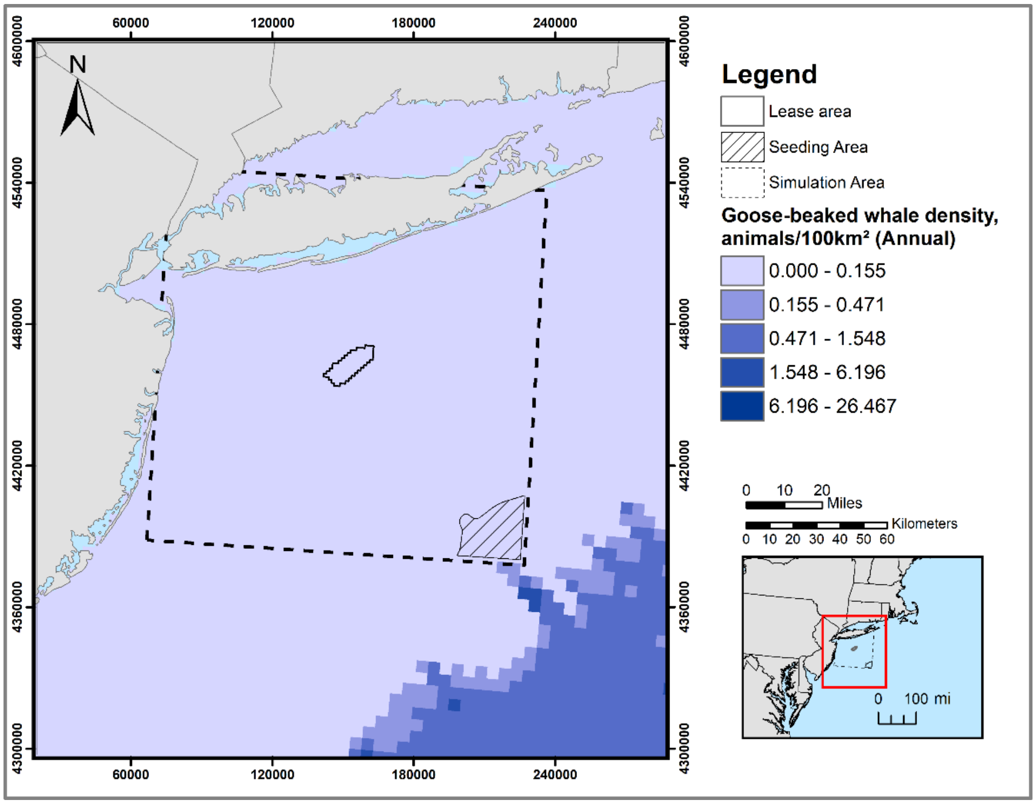


Figure H-12. Goose-beaked whale: Map of animat seeding area range.

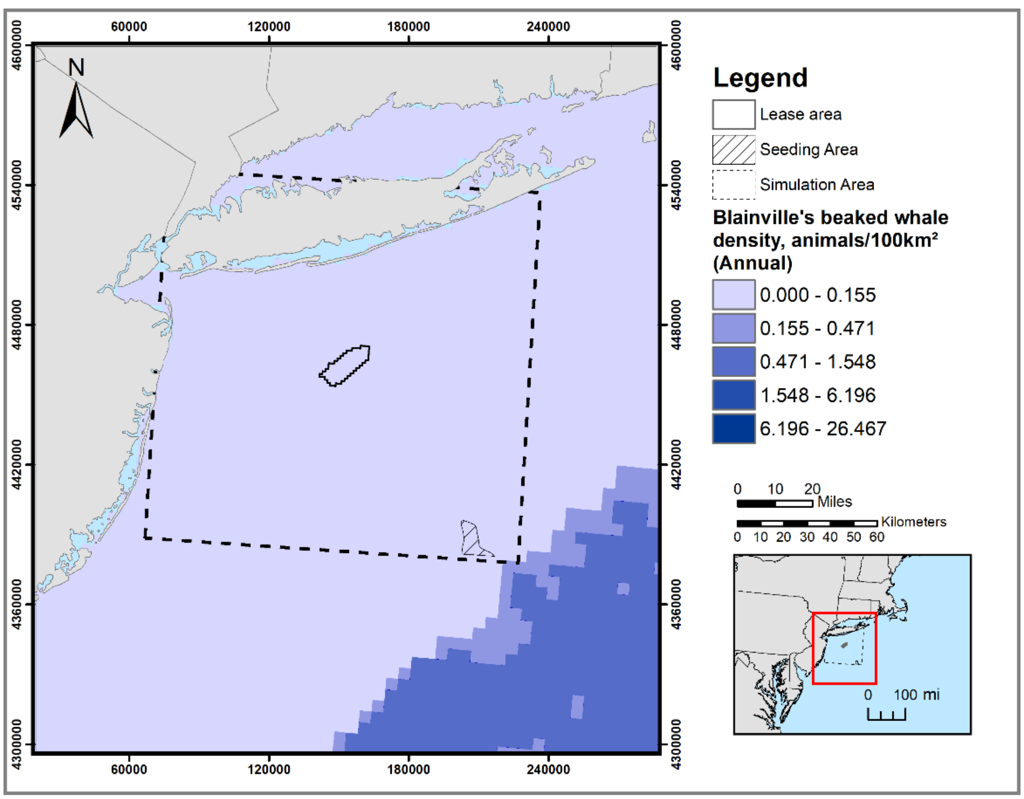


Figure H-13. Blainville's beaked whale: Map of animat seeding area range.

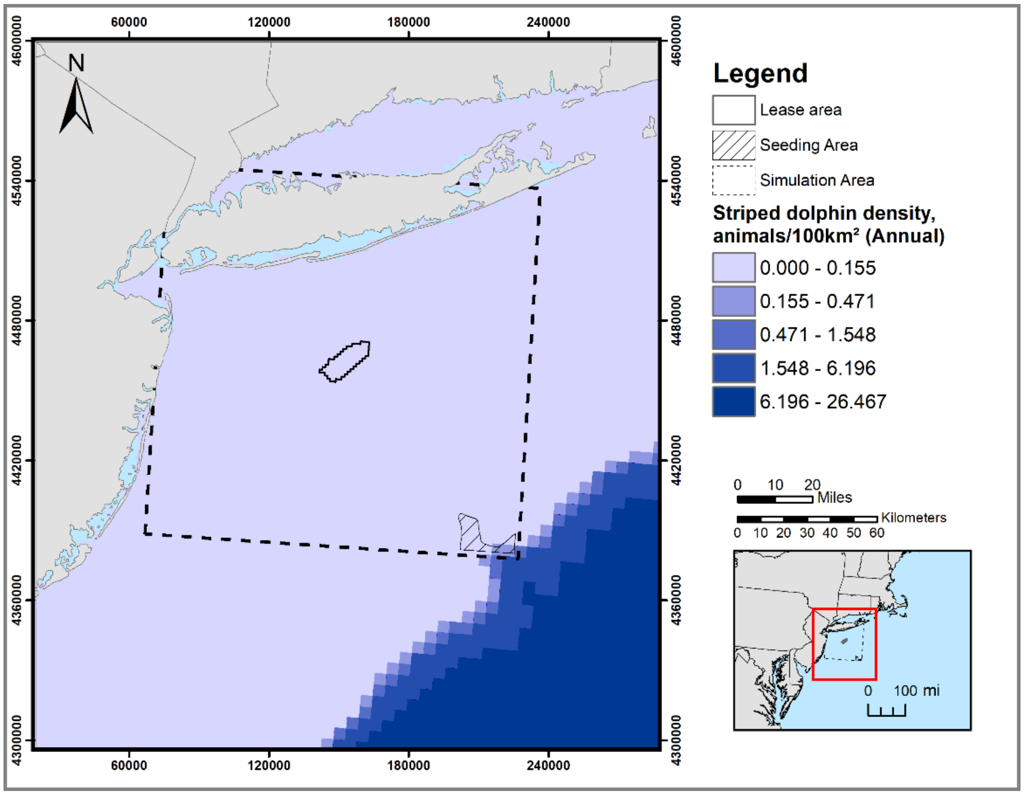


Figure H-14. Striped dolphin: Map of animat seeding area range.

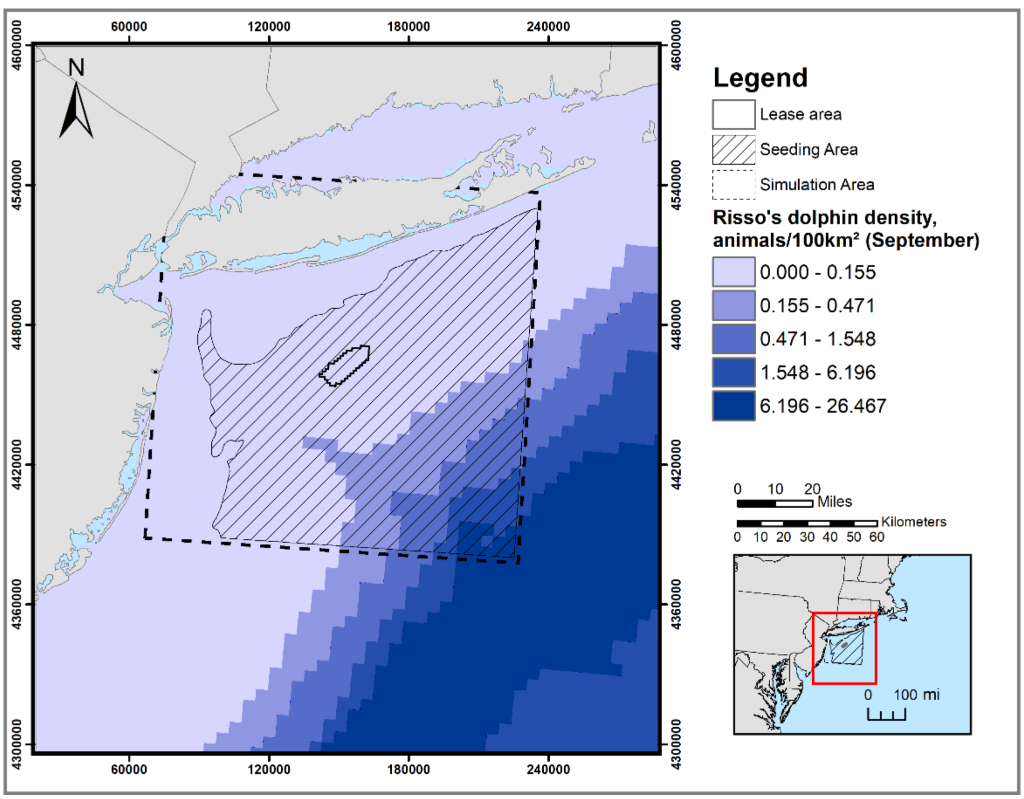


Figure H-15. Risso's dolphin: Map of animat seeding area range.

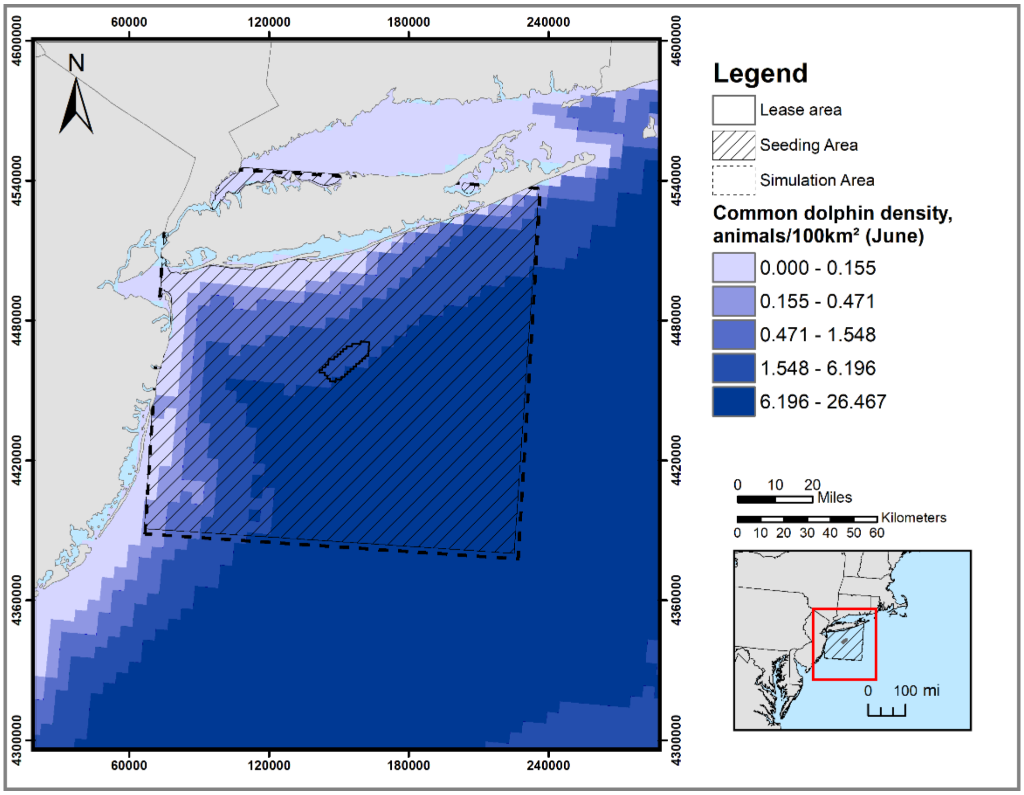


Figure H-16. Common dolphin: Map of animat seeding area range.

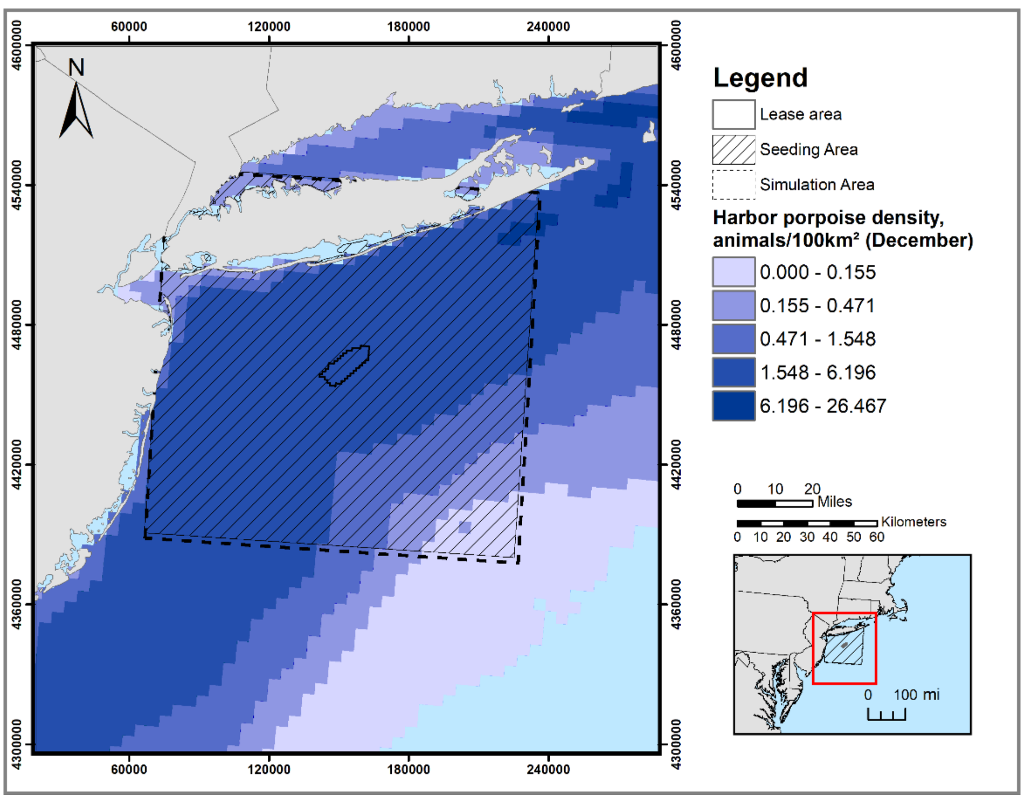


Figure H-17. Harbor porpoise: Map of animat seeding area range.

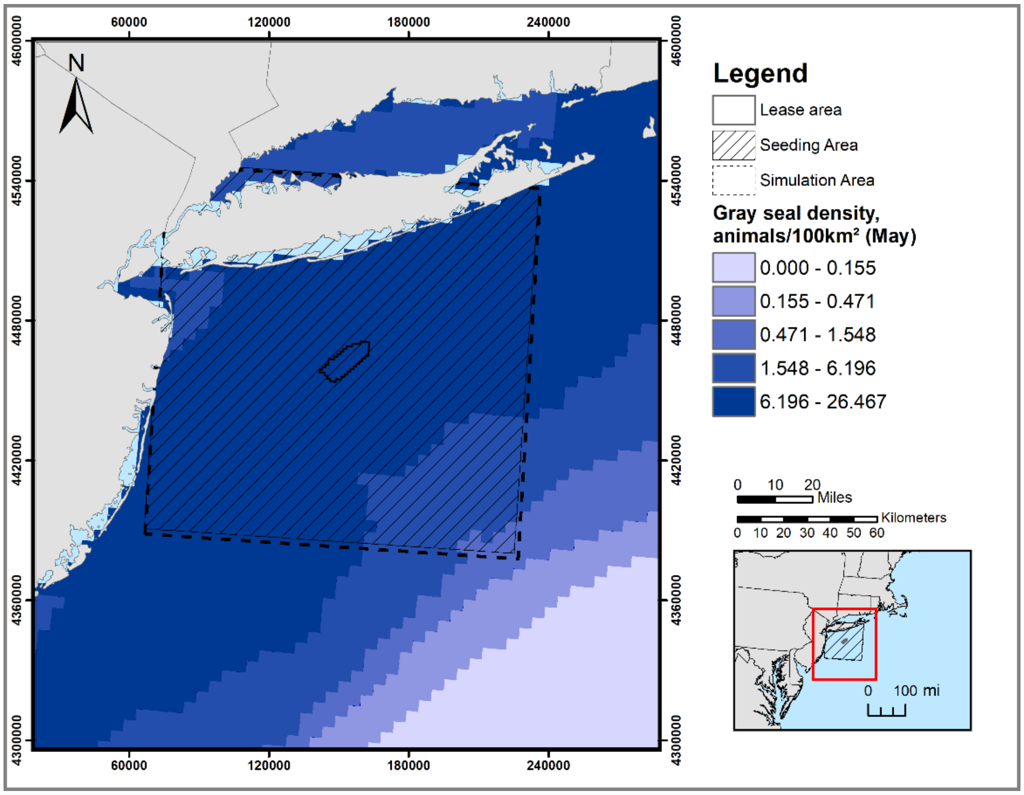


Figure H-18. Gray seal: Map of animat seeding area range.

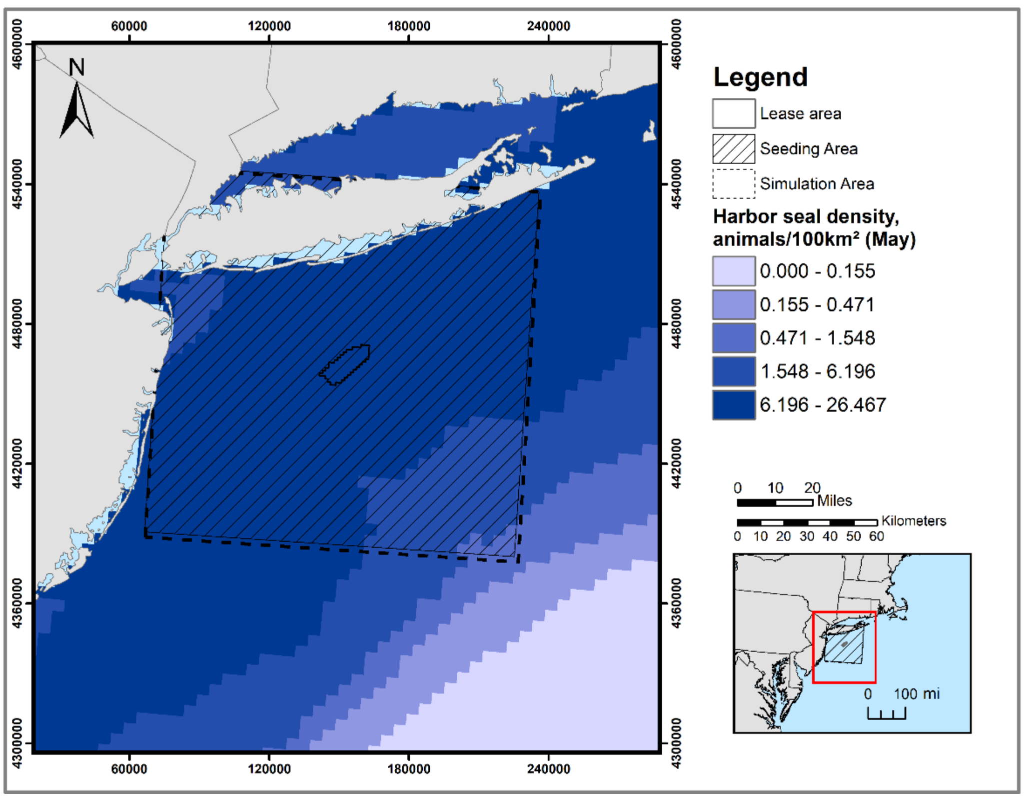


Figure H-19. Harbor seal: Map of animat seeding area range.

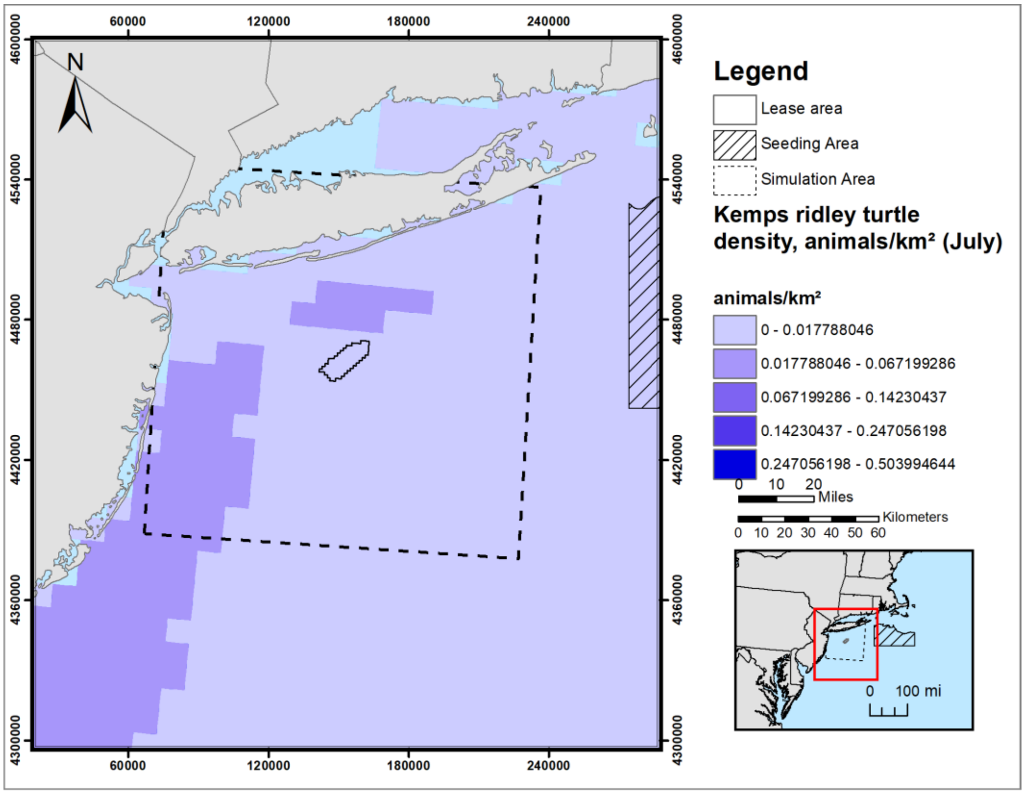


Figure H-20. Kemp's ridley turtle: Map of animat seeding area range.

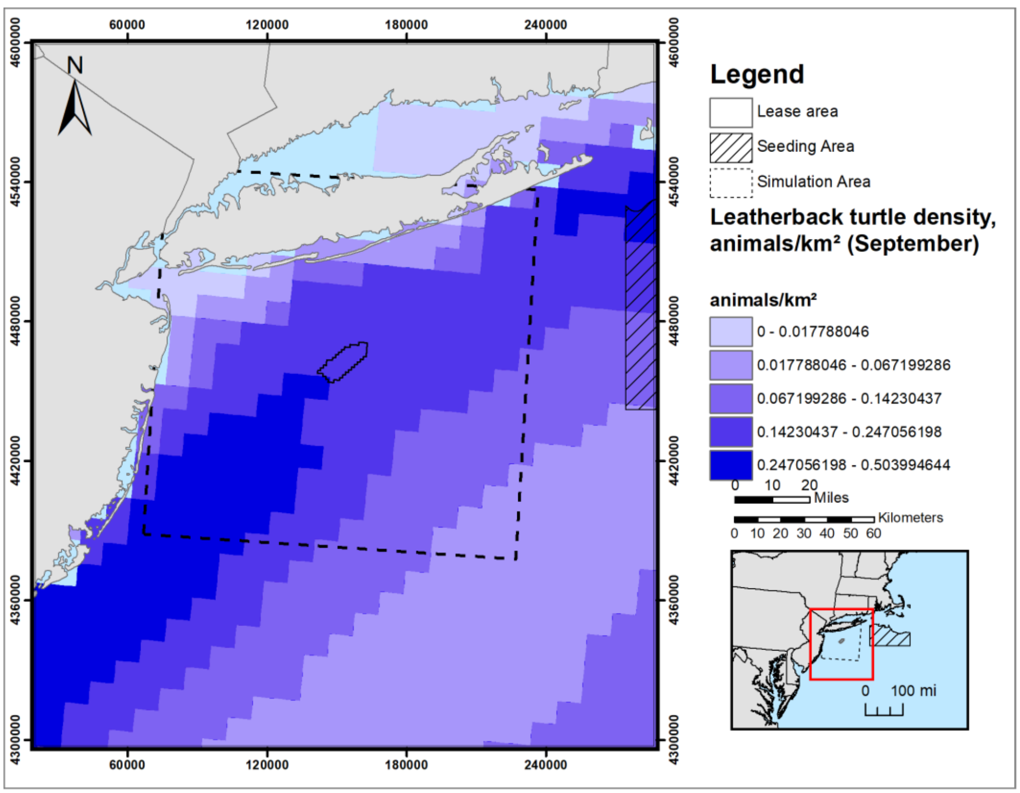


Figure H-21. Leatherback turtle: Map of animat seeding area range.

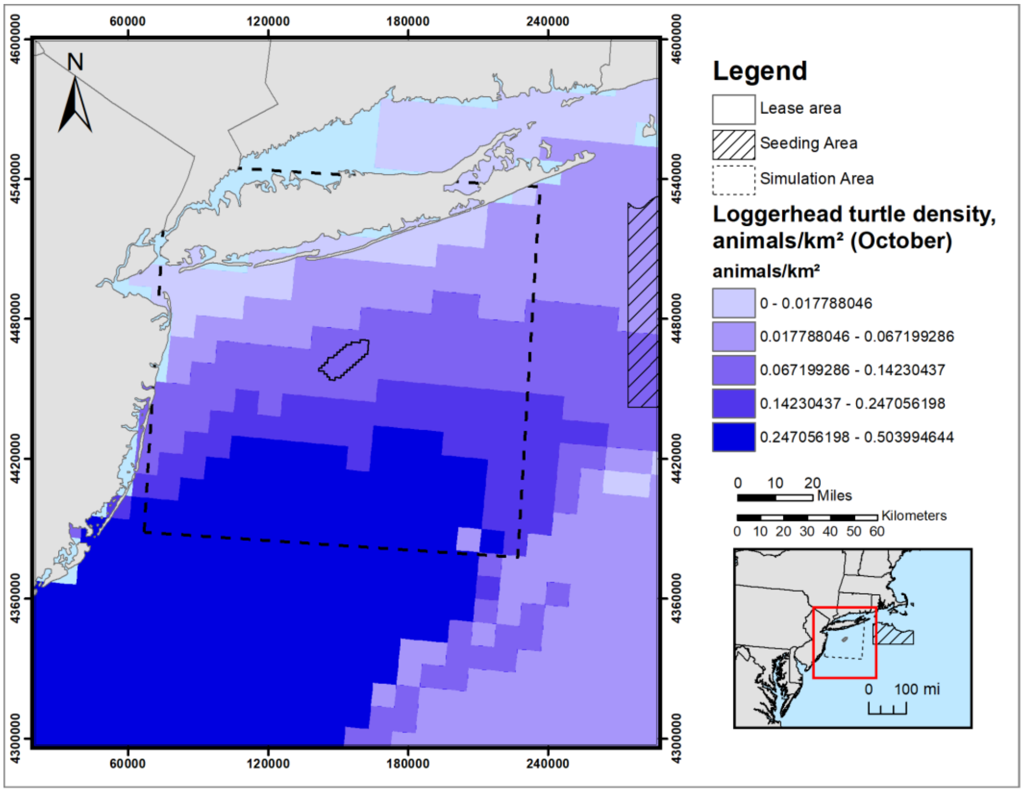


Figure H-22. Loggerhead turtle: Map of animat seeding area range.

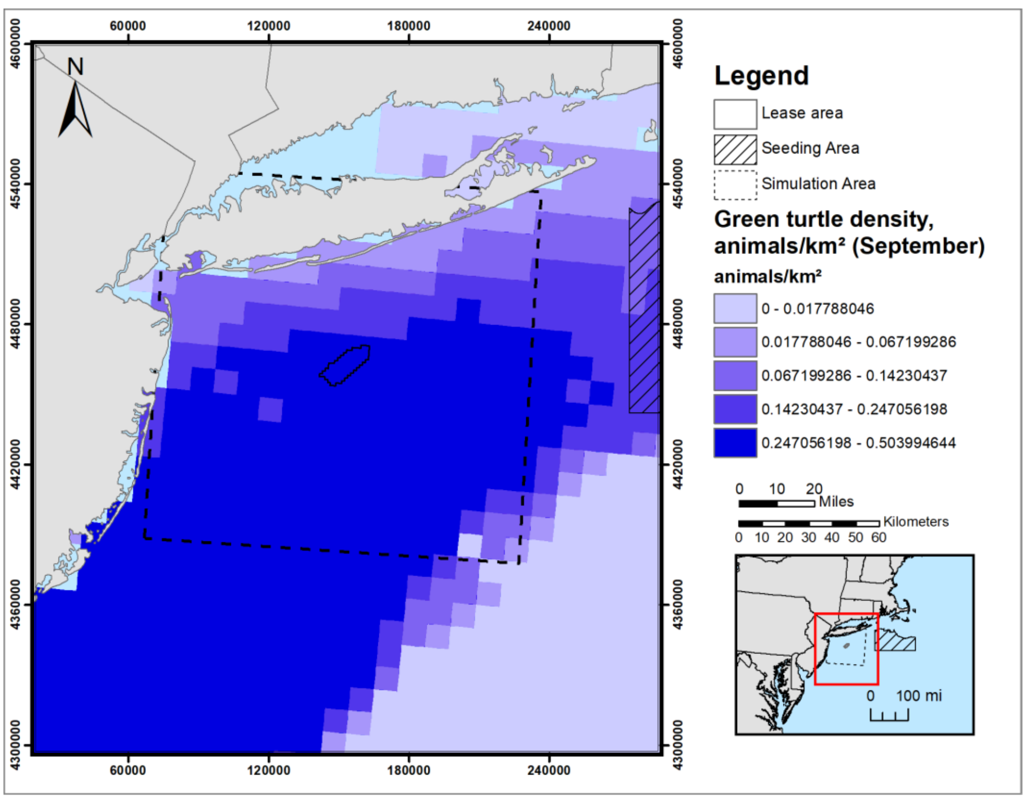


Figure H-23. Green turtle: Map of animat seeding area range.

Supplement I. Drilling Memo: Acoustic Ranges and Exposure Estimates for Drilling Activities During Pile Installation for Vineyard Mid-Atlantic

DATE: 11 November 2024

Version: 4.0

FROM: Emma C.R. Ozanich, Kaylyn N. Terry, Bailey W. Jenkins

TO: Maria Hartnett (Epsilon)

I.1. Introduction

During the construction phase of Vineyard Mid-Atlantic in Lease Area OCS-A 0544, there may be instances when hard sediment layers or sub-surface boulders are encountered during pile driving. Drilling may be needed to pass through these barriers. Vineyard Mid-Atlantic estimates that some foundations could potentially require up to 6 hours (h) of drilling per day in addition to pile driving operations. Drilling may occur in the months of May to November.

Drilling activities produce non-impulsive sounds that may cause hearing damage or behavioral responses in marine mammals, sea turtles, and fish. Distances to potential injury and behavioral disruption of marine animals are computed here by propagating measured drilling source levels in the construction area and then comparing the resulting sound fields to regulatory thresholds. Marine mammal and sea turtles that could be exposed above regulatory thresholds were estimated by multiplying the ensonified areas by seasonal animal density. Exposure estimates were not calculated for fish, but acoustic ranges to fish impact criteria thresholds were calculated by determining the isopleth at which thresholds could be exceeded.

I.2. Methods

I.2.1. Modeled Locations

Sound fields from drilling activities were modeled at two representative locations (L01 and L02) in the Lease Area as depicted in Figure I-1, with coordinates provided in Table I-1. The selected modeling locations, which were also used to model impact and vibratory piling installation (Kanu et al. 2024), represent the variations in water depth and geoacoustic strata in the Lease Area.

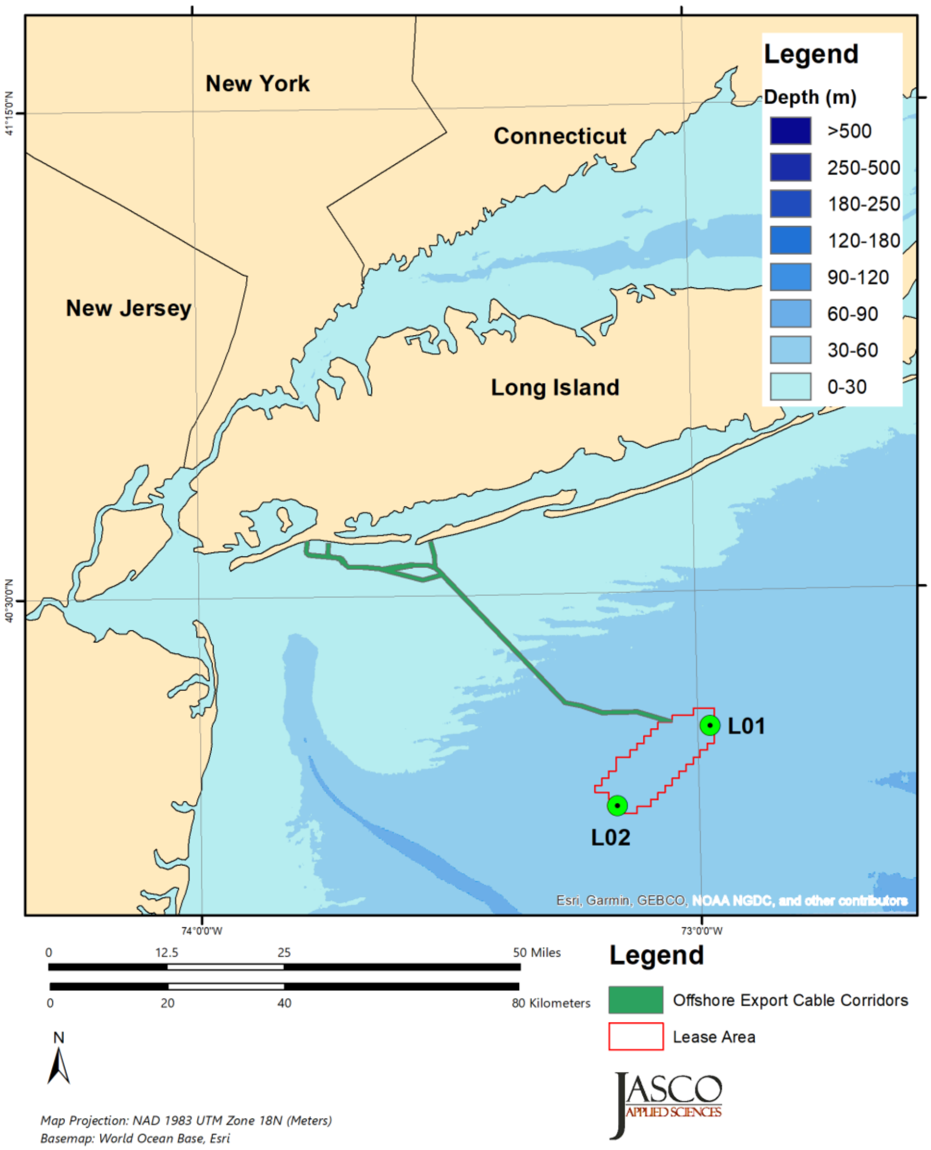


Figure I-1. Vineyard Mid-Atlantic Lease Area OCS-A 0544 acoustic modeling locations (L01 and L02, green dots) for drilling activities.

Table I-1. Acoustic modeling locations and water depth for the foundations.

Modeling location	Latitude	Longitude	Depth (m)
L01	40.2928	-72.9744	45.27
L02	40.1719	-73.1644	43.97

I.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 the 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's) 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 h. NMFS (2023) also provided guidance on using weighting functions to adjust the received sound levels according to the hearing sensitivity of marine mammals. Acoustic criteria and weighting function application are divided into functional hearing groups (low-, mid-, and high-frequency cetaceans and phocid pinnipeds) to which species are assigned based on their respective hearing frequency ranges. Table I-2 shows hearing group frequency ranges that are used to define the auditory weighting function, and Table I-3 shows the hearing group thresholds.

After numerous studies on marine mammal behavioral response to sound exposure, there is still no consensus in the scientific community regarding the appropriate metric for assessing behavioral reactions. NMFS currently uses a behavioral response threshold of 120 dB re 1 μPa^2 for continuous sounds for all marine mammal species (NMFS 2023).

Distances to SEL thresholds for fish published in the scientific literature are also provided (Popper et al. 2014). As there is limited research available for non-impulsive fish injury thresholds, criteria adapted from impulsive sources were used for this analysis (Table I-3).

Injury, impairment, and behavioral thresholds for sea turtles were developed for use by the US Navy (Finneran et al. 2017) based on exposure studies (e.g., McCauley et al. 2000). Dual criteria (PK and SEL) have been suggested by NMFS 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 a sound pressure level (SPL) of 175 dB re 1 μPa^2 (McCauley et al. 2000, Finneran et al. 2017).

Marine mammals, sea turtles, and fish were considered static receivers. Acoustic distances where sound levels could exceed injury regulatory thresholds for marine mammals (NMFS 2023), sea turtles (Finneran et al. 2017), and fish (FHWG 2008) were determined using a maximum-over-depth approach.

Table I-2. Marine mammal hearing groups and frequency ranges (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 (PW)	50 Hz to 86 kHz

[a] The generalized hearing range is for all species within a group. Individual hearing will vary.

Table I-3. Summary of permanent threshold shift onset acoustic thresholds for marine animals exposed to continuous sound sources.

Faunal group	Frequency-weighted $L_{E,24h}$ (dB re 1 µPa²·s)
Low-frequency (LF) cetaceans	199
Mid-frequency (MF) cetaceans	198
High-frequency (HF) cetaceans	173
Phocid pinnipeds in water (PW)	201
Fish ≥2 g	187 [a]
Fish <2 g	183 [a]
Fish without swim bladder	216 [b]
Fish with swim bladder	203 [b]
Sea turtles	220 [c]

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014).
[c] Finneran et al. (2017).

I.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). Austin et al. (2018) measured SPL for three mobile drilling units at 1000 m distance 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. Figure I-2 shows the resulting average decidecade band source levels for the 10–32,000 Hz band used in this study.

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 Vineyard Mid-Atlantic Lease 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 1,630 m/s constant sound speed and a 1.45 g/cm^3 density, overlying more consolidated sediments with a 2,384 m/s sound speed and a 2.32 g/cm^3 density.

The geoacoustic properties profiles for the seafloor at Vineyard Mid-Atlantic were defined during acoustic modeling of construction activities for Vineyard Mid-Atlantic and were adopted for this project (Kanu et al. 2024). Two profiles, L01 and L02, were defined. Based on samples from nearby study sites, the surficial sediment in the Lease Area is expected to be predominantly composed of sand. The Vineyard Mid-Atlantic geotechnical studies provide lithology of extracted cores through at least the top 50 m of seabed sediments across the project area. Surficial sediments here are primarily silty sand to dense sand. The core samples provided density, grain size, and porosity of the sediment at various depths below seafloor. Geoacoustic profile L01 (Table I-5) was used for acoustic modeling at Location L01 and geoacoustic profile L02 (Table I-6) at Location L02.

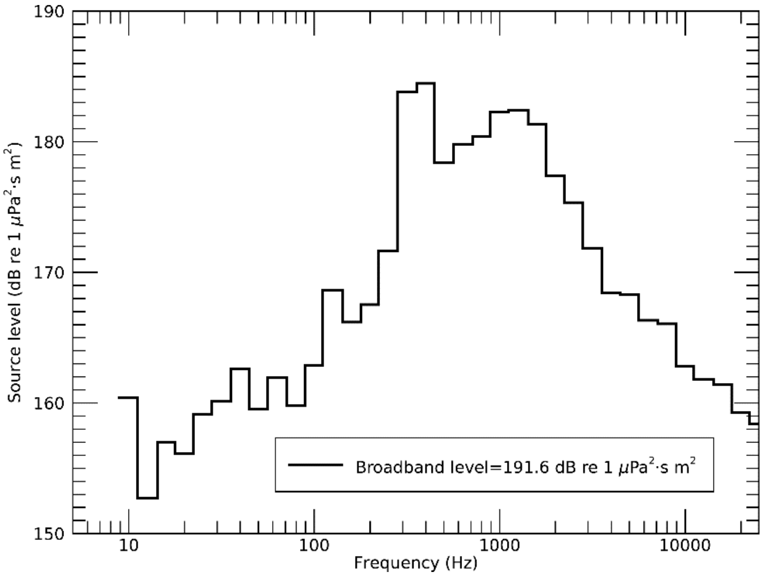


Figure I-2. Decidecade band source levels averaged across three drilling platforms for drilling and excavation of mudline cellars (Austin et al. 2018).

JASCO's Marine Operations Noise Model (MONM) was used to predict SEL and SPL sound fields for frequencies up to and including1.6 kHz. MONM uses a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993). It is based on a version of the US Naval Research Laboratory's Range-dependent Acoustic Model (RAM) that has been modified to account for a solid seabed (Zhang and Tindle 1995). For frequencies from 2 to 32 kHz, the Bellhop ray tracing model (Porter and Liu 1994) was used to predict sound fields at the same representative locations. Bellhop used up to 7,200 geometric beams, increasing the number of beams with frequency. Two modeling locations were selected using representative foundation locations considering the influence of bathymetry, seabed geoacoustics, and water sound speed. The drill was represented as a point source, and modeling was conducted for three source depths at both locations: near the surface (4 m), mid-water (22 m), and above the sea bottom at each location (50 m at L01, 39 m at L02). The longest acoustic range to threshold across the three source depths is presented in this report. 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. 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* × 2-D). Composite broadband received SEL were computed by summing the received decidecade band levels across frequency and taking the maximum-over-depth. Table I-4 lists the modeling assumptions in this study, and Tables I-5 and I-6 list the seabed geoacoustic properties (consistent with the piling study (Kanu et al. 2024)) for locations L01 and L02, respectively.

Table I-4. Assumptions used in underwater acoustic modeling of drilling activities.

Parameter	Description	Reference (if applicable)
Drill	6 m drill bit, mudline cellar excavation	Austin et al. (2018)
Bathymetry	1 arc-second resolution	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) (Mean Lower Low Water (MLLW) datum).
Geoacoustics	Elastic seabed properties based on client-supplied description of seabed layering	See Tables I-5 and I-6

[a] Sound speed was converted to mean summer (June to September) profiles.

Table I-5. Location L01: Geoacoustic properties used for acoustic 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 speed (m/s)	Compressional wave attenuation (dB/λ)
0.00–11.34	Fine sand	2.00–2.01	1,694.87–1,709.57	0.82–0.82
11.34–28.74	Sandy silt	1.84–1.86	1,613.35–1,635.53	1.19–1.09
28.74–39.70	Silty sand	1.86–1.88	1,632.57–1,646.32	1.11–1.04
39.70–48.50	Very fine sand	1.96–1.98	1,701.09–1,712.00	0.84–0.83
48.50–50.00	Very fine sand	1.98–1.98	1,712.00–1,713.85	0.84–0.83
50.00–64.00	Silty sand	1.89–1.91	1,659.08–1,676.19	0.99–0.90
64.00–500.00	Fine sand	2.08–2.55	1,775.36–2,193.75	0.80–0.63
>500.00	Sand	2.55	2,193.75	0.63

Table I-6. Location L02: Geoacoustic properties used for acoustic 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 speed (m/s)	Compressional wave attenuation (dB/λ)
0.00–19.07	Fine sand	2.00–2.03	1,694.87–1,719.47	0.82–0.81
19.07–21.63	Sand-silt-clay	1.70–1.67	1,553.68–1,556.95	0.47–0.49
21.63–32.00	Fine sand	2.03–2.04	1,722.74–1,735.85	0.81–0.81
32.00–62.10	Fine sand	2.04–2.08	1,735.85–1,773.06	0.81–0.80
62.10–84.08	Sandy silt	1.91–1.93	1,676.84–1,703.21	0.90–0.85
84.08–91.00	Fine sand	2.11–2.12	1,799.42–1,807.60	0.80–0.79
91.00–500.00	Fine sand	2.12–2.55	1,807.60–2,193.75	0.79–0.63
>500.00	Fine sand	2.55	2,193.75	0.63

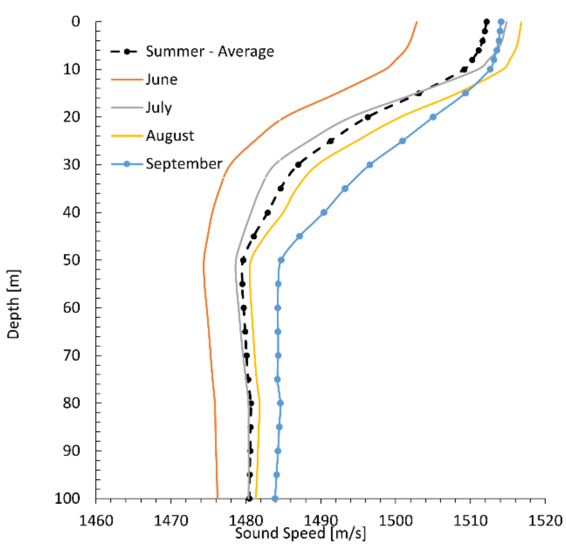


Figure I-3. Sound speed profiles up to 100 m for the summer months of June through September for Vineyard Mid-Atlantic. Modelling was conducted using the average profile for summer.

I.2.4. Exposure Estimates for Marine Mammals and Sea Turtles

Exposures were calculated for one day of drilling assuming 6 h of drilling per day. Drilling was modeled at both locations (L01 and L02). Exposures were estimated using the maximum monthly animal densities for summer months, from May to November, which are expected to result in the most conservative exposure estimates.

I.2.4.1. 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, 2023, 2024). 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 estimated using the East Coast sea turtle density models developed by the US Naval Undersea Warfare Center (NUWC; DiMatteo et al. 2023). The data are long-term monthly average estimates of density expressed as the number of individuals per square kilometer.

To calculate marine mammal densities for the potential drilling impact area, it was assumed that the drilling would occur in two areas of interest: L01 and L02. The density perimeters were determined using the longest 95th percentile acoustic range to threshold ($R_{95\%}$) for injury and behavior, for both locations, rounded up to the nearest 5 km, and then applied around the entire lease area (see Tables I-8 and I-10); 0.149 km for injury (5 km) and 44.8 km (50 km) for behavior). Monthly densities were calculated for each area of interest and for each species as the average of the densities from all MGEL/Duke model grid cells that overlap partially or completely with each area of interest. Cells entirely on land were not included, but cells that overlap only partially with land were included. To obtain the most conservative exposure estimates, the maximum monthly density for each species in summer was used for calculating exposures.

There are two cases in this study for which the MGEL/Duke models report densities for species guilds: pilot whales and seals. When calculating exposures for individual pilot whale and seal species, the guild densities provided by Roberts et al. (2016, 2023, 2024) 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 were downloaded from the Ocean Biodiversity Information System (OBIS) data repository (available at https://obis.org/). The best data available for pilot whales came from the Mystic Aquarium data set of marine mammal strandings in the region, due to their overlap with the project area. The proportions of 0.93 for long-finned and 0.07 for short-finned pilot whales were used (Smith 2014). For the two seal species, 2022–2023 protected species observer (PSO) sighting data from the 0544 Lease Area was insufficient, so proportions of seals were determined from OBIS data as cited in the Final Rule for the adjacent Empire Wind project: 0.34 for gray seals and 0.66 for harbor seals (DoC and NOAA 2024).

Table I-8 shows the maximum animal densities calculated over summer (May to November). Figures I-4 and I-5 show the data cells included in the density average for distances to injury and behavior thresholds, respectively.

Table I-7. Maximum monthly density (animals per 100 km^2), estimated during summer (May to November) for distances to injury and behavior thresholds.

Species	Summer Injury	Summer Behavior
Fin whale	0.327	0.323
Humpback whale	0.191	0.193
Minke whale	1.279	1.252
North Atlantic right whale	0.008	0.007
Sei whale	0.015	0.016
Sperm whale	0.007	0.010
Atlantic spotted dolphin	0.048	0.068
Atlantic white-sided dolphin	2.183	2.137
Bottlenose dolphin	2.308	2.449
Pilot whale, long-finned	0.103	0.105
Pilot whale, short-finned	0.008	0.008
Cuvier's beaked whale	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001
Striped dolphin	0.001	0.001
Risso’s dolphin	0.031	0.035
Common dolphin	5.114	5.721
Harbor porpoise	0.593	0.586
Gray seal	0.481	0.602
Harbor seal	0.934	1.169
Kemps ridley turtle	0.011	0.011
Leatherback turtle	0.043	0.042
Loggerhead turtle	0.091	0.093
Green turtle	0.208	0.197

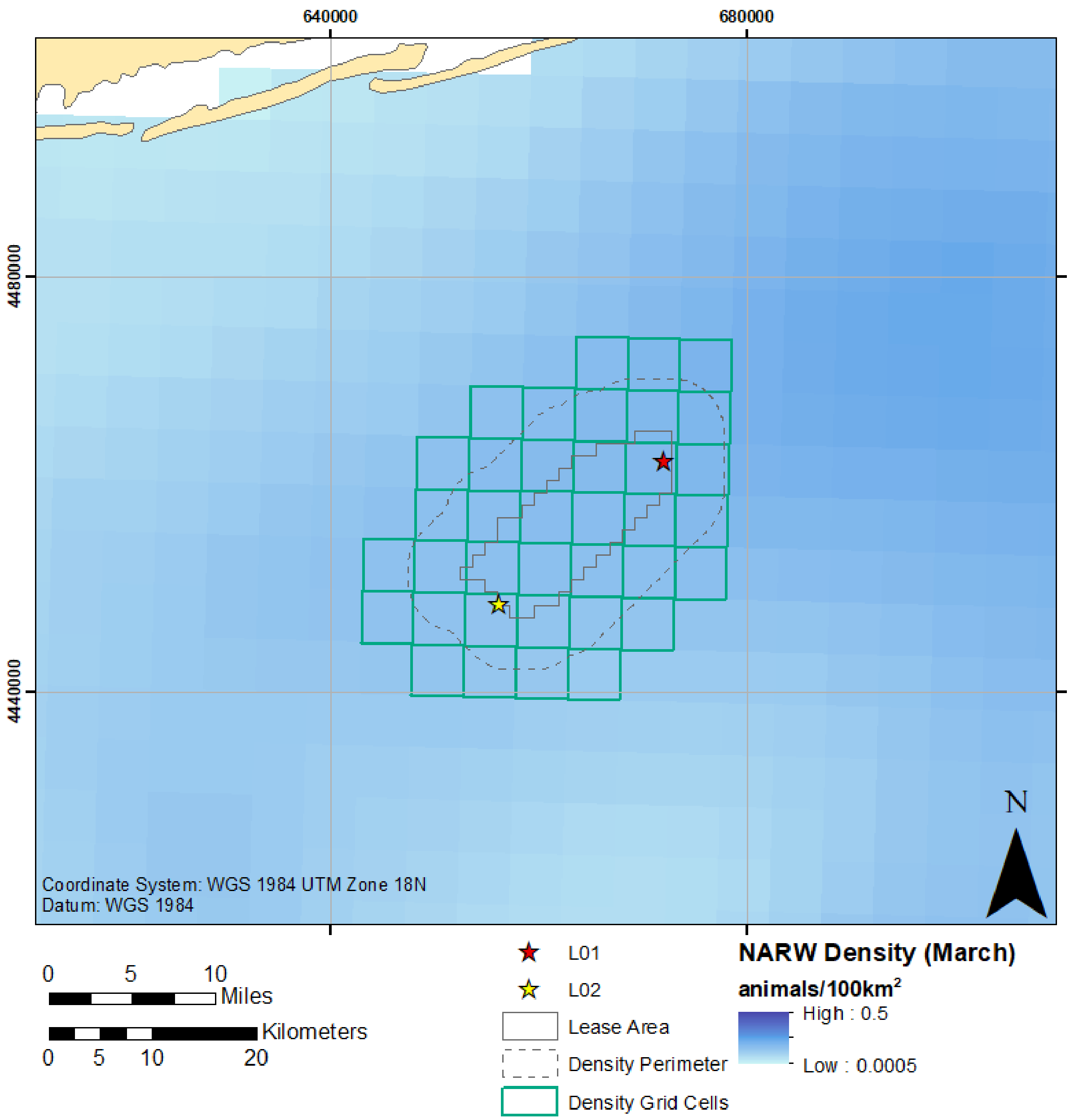


Figure I-4. 5 km density perimeter: Marine mammal (e.g., NARW) density showing highlighted grid cells used to calculate seasonal species density estimate perimeter around Lease Area OCS-A 0544 (Roberts et al. 2016, 2023, 2024).

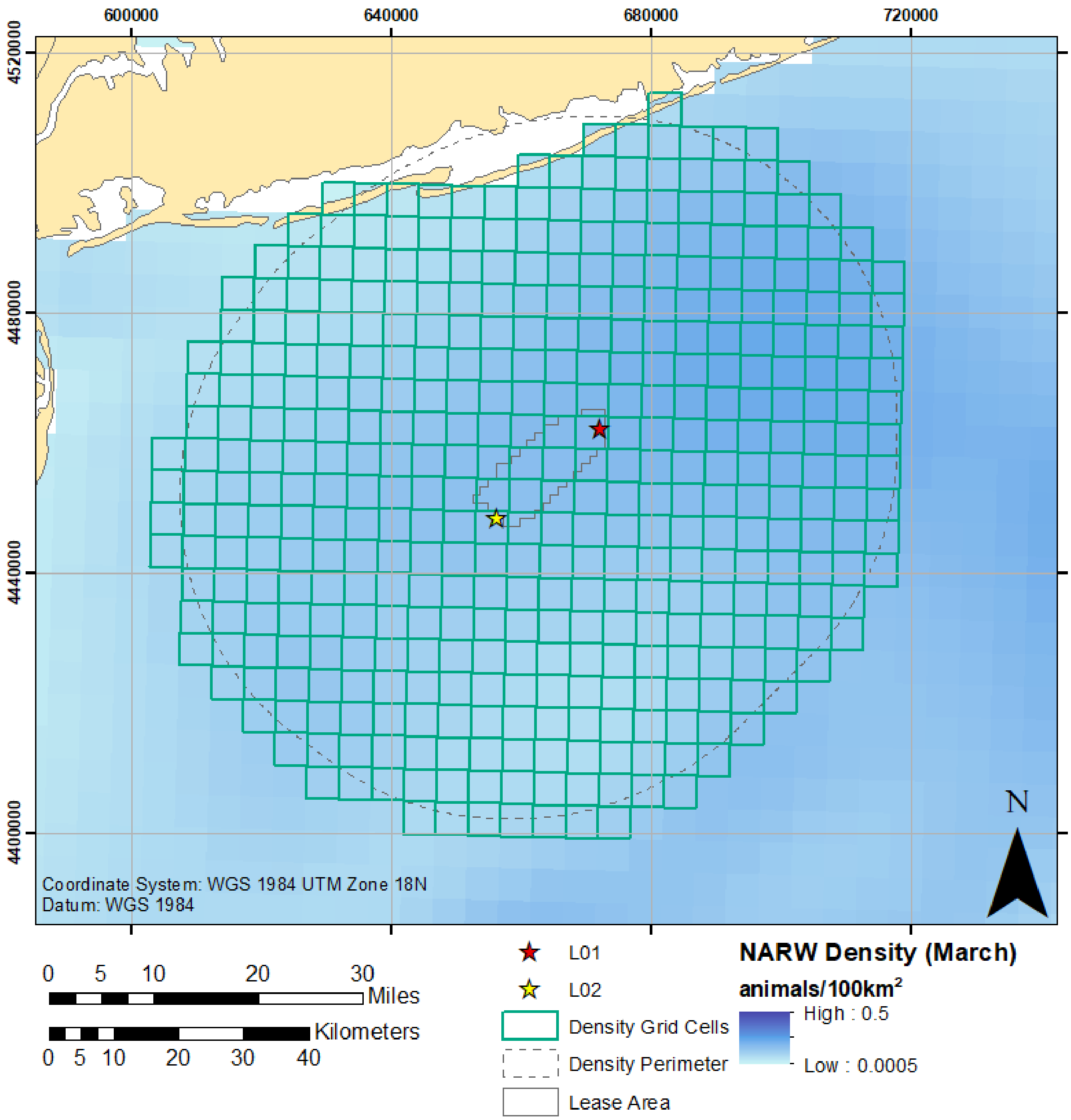


Figure I-5. 50 km density perimeter: Marine mammal (e.g., NARW) density showing highlighted grid cells used to calculate seasonal species density estimate around Lease Area OCS-A 0544 (Roberts et al. 2016, 2023, 2024).

I.3. Results

I.3.1. Acoustic Ranges

Assuming 6 h of drilling will occur during a 24 h period, the frequency-weighted distances to potential injury for the marine mammal hearing groups, fish, and sea turtles are shown in Table I-8 for L01 and Table I-9 for L02. The maximum distance to any SEL threshold was 2.35 km for summer, occurring at L02 for fish <2 g according to the Fisheries Hydroacoustic Working Group (FHWG 2008) guidelines. All acoustic ranges to marine mammal PTS thresholds were <153 m. The acoustic ranges to the SPL 120 dB re 1 μPa^2 behavior threshold (NMFS 2023) without frequency weighting are shown in Table I-10 for L01 and Table I-11 for L02. The maximum unweighted behavioral acoustic range at L01 was found to extend to 12.80 km in summer. At L02, the maximum range was 12.50 km in summer. Excluding 5% of the farthest points ($R_{95\%}$), the behavioral threshold range at L01 was 11.6 km in summer. At L02, the $R_{95\%}$ range was 11.40 km in summer. At both locations, the behavioral threshold ranges were approximately equidistant in all directions (Figure I-7).

Table I-8. Site L01: Distances to PTS onset thresholds for marine mammal hearing groups, fish, and sea turtle for continuous sounds generated by drilling during piling. The distances represent the longest modeled distance for a source near the surface, mid-water, and above the sea bottom.

Hearing group	Frequency-weighted $L_{E,24h}$ (dB re 1 μPa^2·s)	Summer R_{max} (m)	Summer $R_{95\%}$ (m)	Summer Area (km^2)
Low-frequency (LF) cetaceans	199 [a]	153	149	0.0735
Mid-frequency (MF) cetaceans	198 [a]	<10	nc	nc
High-frequency (HF) cetaceans	173 [a]	133	122	0.0507
Phocid pinnipeds in water (PW)	201 [a]	36	36	0.0045
Fish ≥2 g	187 [b]	1,330	1,270	4.88
Fish <2 g	183 [b]	2,060	1,920	12.1
Fish without swim bladder	216 [c]	14	14	<0.010
Fish with swim bladder	203 [c]	71	70	0.015
Sea turtles	220 [d]	<10	nc	nc

nc = 'not computed,' which indicates that the computed ranges were less than the modeling resolution.
[a] NMFS (2023).
[b] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[c] Popper et al. (2014).
[d] Finneran et al. (2017).

Table I-9. Site L02: Distances to PTS onset thresholds for marine mammal hearing groups, fish, and sea turtle for continuous sounds generated by drilling during piling. The distances represent the longest modeled distance for a source near the surface, mid-water, and above the sea bottom.

Hearing group	Frequency-weighted $L_{E,24h}$ (dB re 1 µPa²·s)	Summer R_{max} (m)	Summer $R_{95\%}$ (m)	Summer Area (km²)
Low-frequency (LF) cetaceans	199 [a]	153	149	0.0735
Mid-frequency (MF) cetaceans	198 [a]	<10	nc	nc
High-frequency (HF) cetaceans	173 [a]	130	122	0.0499
Phocid pinnipeds in water (PW)	201 [a]	36	36	0.0045
Fish ≥2 g	187 [b]	1,290	1,220	4.90
Fish <2 g	183 [b]	2,350	1,890	11.8
Fish without swim bladder	216 [c]	14	14	<0.010
Fish with swim bladder	203 [c]	73	72	0.018
Sea turtles	220 [d]	<10	nc	nc

nc = ‘not computed,’ which indicates that the computed ranges were less than the modeling resolution.
[a] NMFS (2023).
[b] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[c] Popper et al. (2014).
[d] Finneran et al. (2017).

Table I-10. Site L01: Distances to behavioral thresholds for marine mammals, fish, and sea turtles for continuous sounds generated by drilling during piling. The distances represent the longest modeled distance for a source near the surface, mid-water, and above the sea bottom.

Hearing group	Unweighted L_P (dB re 1 µPa²)	Summer R_{max} (m)	Summer $R_{95\%}$ (m)	Summer Area (km²)
Marine mammals	120 [a]	12,800	11,600	440
Fish	150 [a]	639	620	0.754
Sea turtles	175 [a]	<10	nc	nc

nc = ‘not computed,’ which indicates that the computed ranges were less than the modeling resolution.
[a] NMFS (2023).

Table I-11. Site L02: Distances to behavioral thresholds for marine mammal, fish, and sea turtles for continuous sounds generated by drilling during piling. The distances represent the longest modeled distance for a source near the surface, mid-water, and above the sea bottom.

Hearing group	Unweighted L_P (dB re 1 µPa²)	Summer R_{max} (m)	Summer $R_{95\%}$ (m)	Summer Area (km²)
Marine mammals	120 [a]	12,500	11,400	431
Fish	150 [a]	612	592	0.715
Sea turtles	175 [a]	<10	nc	nc

nc = ‘not computed,’ which indicates that the computed ranges were less than the modeling resolution.
[a] NMFS (2023).

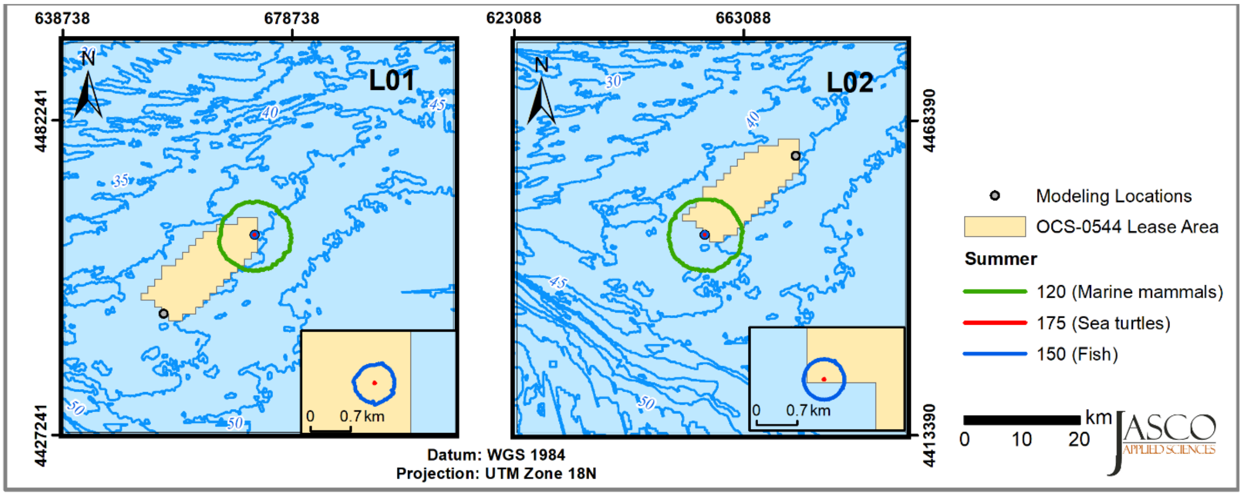


Figure I-6. Near-surface source (4 m depth): Modeled sound pressure level (SPL) at 120 dB re 1 µPa^2 (marine mammal behavioral threshold) at locations (left) L01 and (right) L02 for summer.

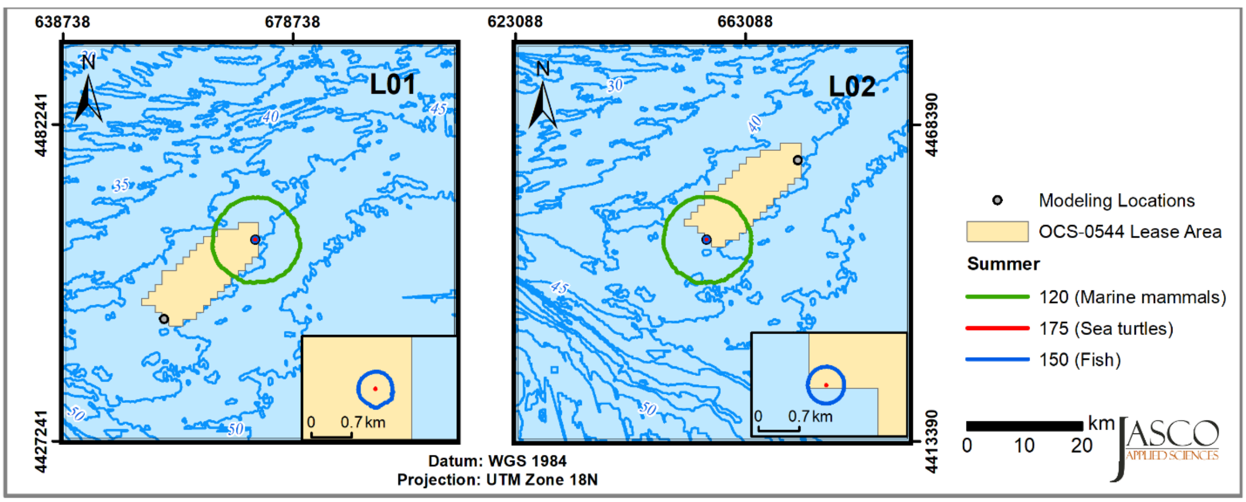


Figure I-7. Mid-water source (22 m depth): Modeled sound pressure level (SPL) at 120 dB re 1 µPa^2 (marine mammal behavioral threshold) depth at locations (left) L01 and (right) L02 for summer.

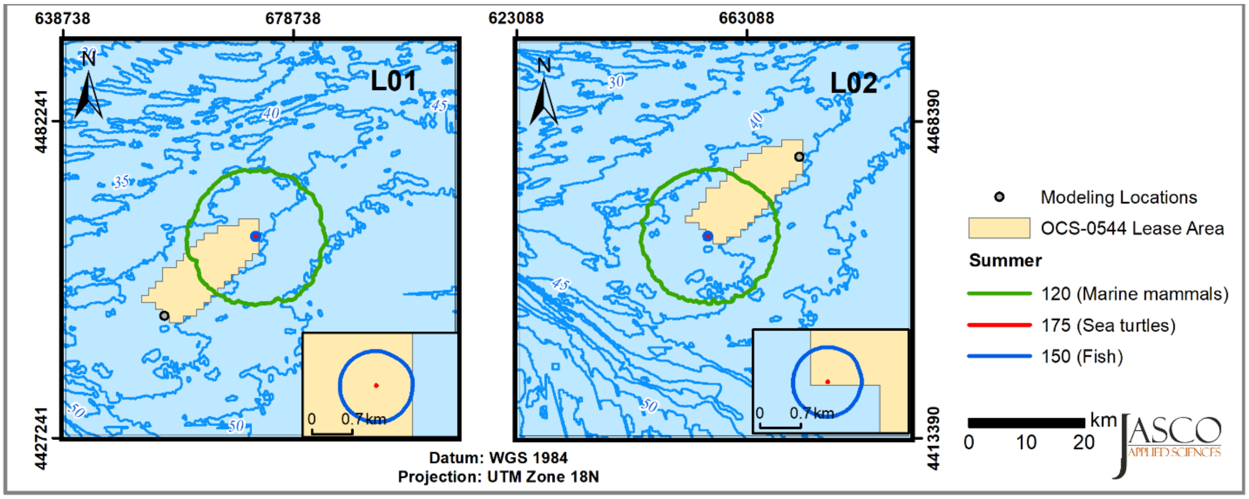


Figure I-8. Near-bottom source (40 m, 39 m depth): Modeled sound pressure level (SPL) at 120 dB re 1 μPa^2 (marine mammal behavioral threshold) at locations (left) L01 and (right) L02 for summer.

I.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-h 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:

$$\text{exposures} = \text{ZOI} \times \text{density}, \quad (0\text{-}1)$$

where density is from Table I-7.

Exposure estimates were calculated for the summer months for drilling at locations L01 and L02. The number of exposures to marine mammal and sea turtle injury and behavioral thresholds are provided in Table I-12 for L01 and Table I-13 for L02. Injury exposures are low, with less than 0.01 for all species at both locations.

The number of behavioral exposures were generally higher at L01, with the highest number of exposures of 53.07 for harbor seals during the summer months. At L02, the highest number of exposures was 51.98 for harbor seals in the summer months. Behavioral exposures at both locations are less than 0.01 for all species of turtles.

Table I-12. Location L01*:* Maximum predicted injury and behavior exposures resulting from one day of drilling activity during summer months.

Species	Summer PTS/Injury	Summer Behavior
Fin whale	<0.01	1.42
Humpback whale	<0.01	0.85
Minke whale	<0.01	7.95
North Atlantic right whale	<0.01	0.16
Sei whale	<0.01	0.37
Sperm whale	<0.01	0.10
Atlantic spotted dolphin	<0.01	3.18
Atlantic white-sided dolphin	<0.01	9.40
Bottlenose dolphin	<0.01	10.77
Pilot whale, long-finned	<0.01	0.46
Pilot whale, short-finned	<0.01	0.03
Cuvier's beaked whale	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01
Striped dolphin	<0.01	<0.01
Risso's dolphin	<0.01	0.45
Common dolphin	<0.01	45.06
Harbor porpoise	<0.01	13.72
Gray seal	<0.01	27.34
Harbor seal	<0.01	53.07
Kemps ridley turtle	<0.01	<0.01
Leatherback turtle	<0.01	<0.01
Loggerhead turtle	<0.01	<0.01
Green turtle	<0.01	<0.01

Table I-13. Location L02*:* Maximum predicted injury and behavior exposures resulting from one day of drilling activity during summer months.

Species	Summer PTS/Injury	Summer Behavior
Fin whale	<0.01	1.39
Humpback whale	<0.01	0.83
Minke whale	<0.01	7.78
North Atlantic right whale	<0.01	0.15
Sei whale	<0.01	0.36
Sperm whale	<0.01	0.10
Atlantic spotted dolphin	<0.01	3.11
Atlantic white-sided dolphin	<0.01	9.21
Bottlenose dolphin	<0.01	10.55
Pilot whale, long-finned	<0.01	0.45
Pilot whale, short-finned	<0.01	0.03
Cuvier's beaked whale	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01
Striped dolphin	<0.01	<0.01
Risso’s dolphin	<0.01	0.44
Common dolphin	<0.01	44.14
Harbor porpoise	<0.01	13.44
Gray seal	<0.01	26.78
Harbor seal	<0.01	51.98
Kemps ridley turtle	<0.01	<0.01
Leatherback turtle	<0.01	<0.01
Loggerhead turtle	<0.01	<0.01
Green turtle	<0.01	<0.01

I.4. Summary

PTS injury is unlikely to occur from the proposed drilling activities because the $R_{95\%}$ acoustic ranges were <150 m at both locations for all marine mammal species and hearing groups. Injury is not expected to occur for sea turtles because the ranges to threshold were less than the modeling resolution at both locations. These distances may be considered conservative because in real life, animals will be moving through the area during the 6 h of drilling per day. Furthermore, animals, especially high-frequency species, are unlikely to approach the construction area during installation, which would further reduce the likelihood of injury. At L01, the longest $R_{95\%}$ acoustic range to the SPL 120 dB re 1 µPa^2 behavioral threshold was 11.6 km (Figure I-7). At L02, the longest distance to the marine mammal behavioral threshold was 11.4 km (Figure I-7).

Per-day injury exposures for both locations are less than 0.01 for all species. Behavioral exposures for marine mammals were generally higher at L01 than at L02. During summer, harbor seals were predicted to have the highest number of exposures with 53.07 at L01 and 51.98 at L02. Mitigation was not included in this exposure estimate. The use of monitoring and mitigation practices during drilling operation, such as noise abatement system (NAS) operation, may lead to further reduction in effective exposure ranges and total marine mammal exposures.

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Supplement J. Preliminary Underwater Acoustic Modeling of Detonations of Unexploded Ordnance (UXO Removal) for Vineyard Mid-Atlantic Construction

Date: 11 November 2024

Version: 4.0

From: Mikhail M. Zykov and Bailey W. Jenkins

To: Maria Hartnett (Epsilon)

J.1. Introduction

Vineyard Mid-Atlantic may encounter unexploded ordinances (UXOs) on the seabed in Lease Area OCS-A 0544 (Lease Area) and along the offshore export cable corridors (OECCs). At present, Vineyard Mid-Atlantic is conservatively estimating three UXO detonations in the OECC and two within the Lease Area. The Proponent will prioritize avoidance of UXO, wherever possible, by micro-siting structures and cables around the object. Where avoidance is not possible, UXOs will be relocated or otherwise disposed of (e.g., via deflagration [burning without detonating], detonation, or dismantling the UXO to extract explosive components). It is conservatively assessed that some may need to be removed by explosive detonation. Underwater explosive detonations generate sound waves with high pressure levels that could disturb and/or injure marine fauna. If the removal-by-explosive methods is used, mitigation measures will be required to avoid injurious exposures of animals, and behavioral exposures may need to be accounted for. The study described in this report has modeled acoustic source and sound propagation to estimate the ranges to injury and behavioral thresholds, also referred to as acoustic ranges, for several species and for a selection of charge masses spanning the expected UXO types that may be encountered. The purpose of the modeled acoustic ranges and calculated exposure estimates provided in this report is to predict the number of marine fauna that may be affected by underwater sound during UXO detonation associated with the construction of Vineyard Mid-Atlantic.

Most UXO assessment work in the US has been performed by or for the US Navy, who has worked closely with National Marine Fisheries Service (NMFS) to choose and define appropriate criteria for effects based on best available science. We have evaluated effects thresholds based on three key sound pressure metrics considered by the Navy and NMFS as indicators of injury and behavioral disturbance: unweighted peak compressional pressure level (abbreviated here as PK), frequency weighted sound exposure level (SEL), and acoustic impulse (J_p). A fourth metric, sound pressure level (SPL), which is often used for other impulsive sound assessments, has not been evaluated here because it is not presently used by NMFS as an assessment criterion for sounds from explosive detonations. The names and symbols used for the above metrics follow the terminology of International Organization of Standards (ISO) 18405 (ISO 2017), except where tables and equations have been copied from previous regulatory documents.

The thresholds applied here for each of the acoustic metrics have been obtained from three primary sources:

1. *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III), June 2017* (Finneran et al. 2017). This report provides thresholds for gastrointestinal and lung injury, and mortality to marine mammals, sea turtles, and fish due to explosive pressure based on impulse and peak pressure.
2. *Marine Mammal Acoustic Technical Guidance (2018 Revision to Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing)*, Office of Protected Resources, NOAA Technical Memorandum NMFS-OPR-59, April 2018 (NMFS 2018). This technical memorandum incorporates the report by Finneran (2016) that provides auditory weighting functions for SEL calculations and provides thresholds for hearing-related effects.
3. *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. ASA S3/SC1.4 TR-2014* (Popper et al. 2014). This report provides peak pressure thresholds for injury and mortality to fish.

The acoustic metrics and thresholds for effects depend on species and, in some cases, animal size and animal submersion depth. Specialized acoustic models and semiempirical formulae are applied to evaluate the threshold acoustic ranges from explosive charges detonated on the seabed and exposed directly to seawater. The theory underlying these models is provided in the technical discussion sections of this report.

This assessment considers acoustic effects to marine mammals, sea turtles, and fish from two possible charge sizes. Five separate locations are considered: two locations in the Lease Area and three locations within the OECCs. Water depths are site-dependent and range from 2.3 m at the landfall site along the OECC to 47.1 m in the Lease Area. An unmitigated scenario and a mitigated scenario are considered at each site, with mitigation considering a 10 decibel (dB) reduction to PK, SEL, and acoustic impulse, which might be obtained using noise abatement systems (NASs). Supplements J.8 and J.9 provide the results for unmitigated and mitigated UXO detonations, respectively.

The model predictions presented in this report assume the full mass of UXO explosive charges is detonated together with an additional donor charge with a mass equal to 2% of the UXO weight but limited to 10 kg trinitrotoluene (TNT) equivalent. A recent review of UXO explosive removals in the North Sea indicates that in most cases, the UXO charge mass either did not detonate or only partly detonated, with the result being that the pressure waves generated were produced by the donor charge and only a small fraction of the UXO charge (Bellmann 2021). As such, it is likely that the full UXO charge will not detonate in all cases and the results presented herein assume full UXO charge detonation and, therefore, should be considered the most conservative case. This approach has been taken because there remains considerable uncertainty about the fraction of UXO explosive charges that are likely to detonate.

J.2. UXO Charge Sizes

The UXO charges considered here are characterized by their equivalent TNT masses. Two charge mass ‘bins’ were defined, E10 and E12, with respective charge masses set to the maximum charge size from a group of similar weapons in the bin using a categorization defined by the US Navy (Table J-1). The mass of the donor charge, used to detonate the UXO, is assumed to be 2% of the UXO TNT-equivalent charge weight. The maximum donor charge mass is limited to 10 kg (Bellmann 2021). This modeling assumes the full combined mass of the UXO and donor charge are fully detonated.

Table J-1. US Navy ‘bins’ and corresponding maximum Unexploded Ordnance (UXO) charge masses (maximum equivalent mass TNT) modeled for this assessment.

Navy bin	Maximum equivalent mass TNT (kg)	Maximum equivalent mass TNT (lbs)	Maximum equivalent mass TNT including 2% donor charge (kg)	Maximum equivalent mass TNT including 2% donor charge (lbs)
E10	227	500	231.5	510
E12	454	1,000	463.1	1,021

J.3. Modeling Locations and Depths

Sound propagation away from UXO detonations is affected by in-water refraction and acoustic reflections from the sea surface and seabed. Water depth and seabed properties, which are site-dependent, will influence the SEL and SPL at distance from detonations. It is usually infeasible in modeling assessments such as this to examine all possible UXO locations, mainly because it is difficult to present and interpret such large volumes of model results. A common approach is to choose a finite set of test locations with environmental characteristics that span the ocean environment variability over the area of interest. This approach requires enough locations be chosen so that the influence of variability in ocean conditions on acoustic ranges to threshold surrounding a test location is negligible relative to the variability between test locations.

Here, five specific sites (UXO-1 to UXO-5) were modeled to injury and behavioral acoustic thresholds from UXO detonations of two charge sizes (Table J-1). Site UXO-1 is on one of the landfall branches of the OECC at 10 m depth. Sites UXO-2 and UXO-3 are along the OECC, with water depths of 20.0 and 30.0 m, respectively. UXO-4 and UXO-5 are in Lease Area for Vineyard Mid-Atlantic, with water depths of 43.4 and 46.6 m, respectively. Table J-2 summarizes the site depths, and Figure J-3 provides a map of the site locations. The source position was modeled to be 1 m above the seafloor for the purpose of source level calculations and acoustic propagation modeling.

Table J-2. Water depths and modeled source depths at the Unexploded Ordnance (UXO) acoustic model sites.

Model site	Easting (UTM 18N)	Northing (UTM 18N)	Water depth (m)	Source depth (m)
UXO-1	624500	4492700	10.0	9.0
UXO-2	628600	4485600	20.0	19.0
UXO-3	638900	4475000	30.0	29.0
UXO-4	666800	4463900	43.4	42.4
UXO-5	660700	4449000	46.6	45.6

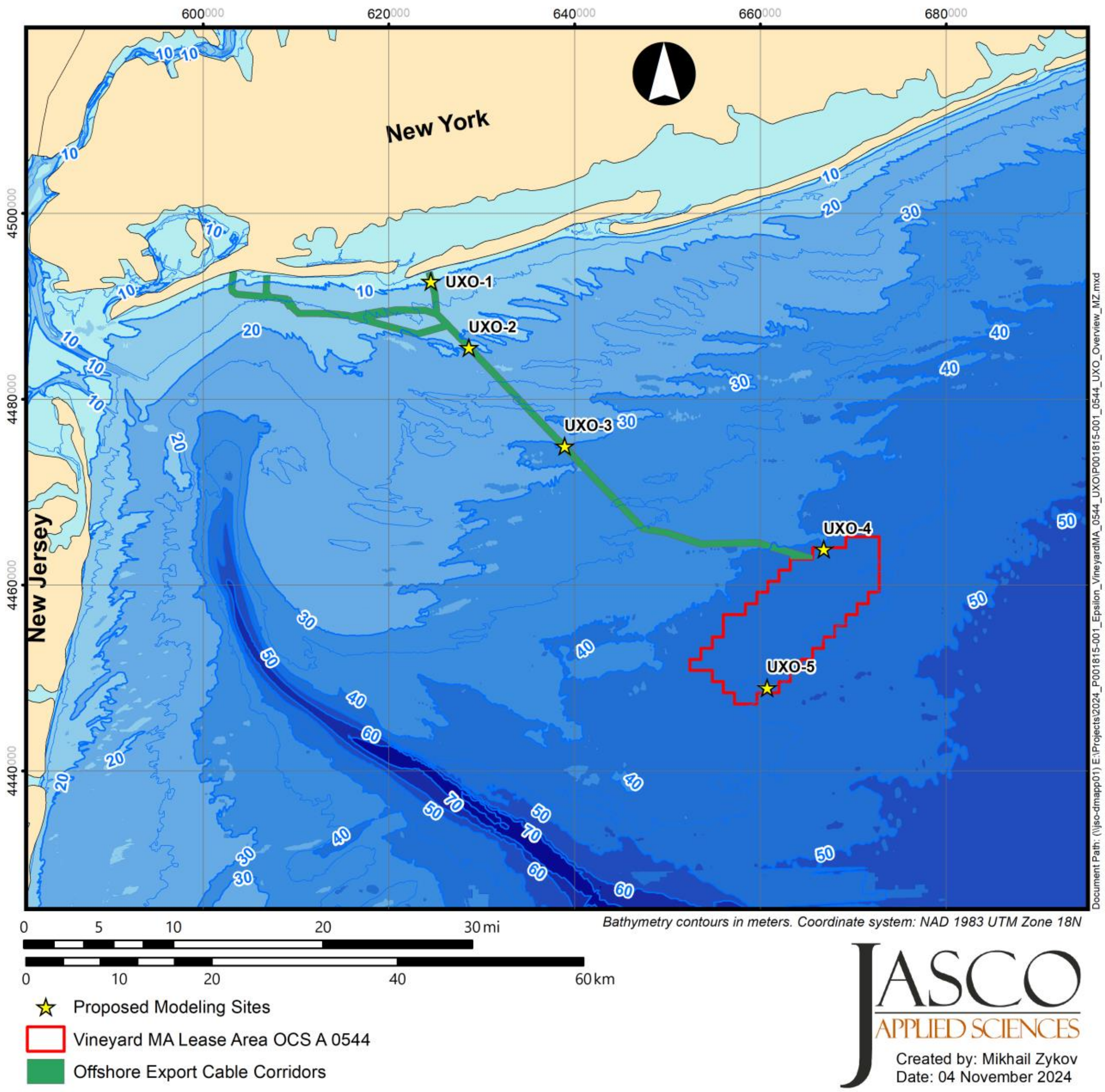

Figure J-1. Overview map showing locations of the five Unexploded Ordnance (UXO) modeling sites.

J.4. Blast Noise Mitigation

Acoustic ranges to marine mammal thresholds were predicted for unmitigated and mitigated scenarios. Although Vineyard Mid-Atlantic anticipates using mitigation technology during UXO detonations, unmitigated results are presented for comparison and completeness. Mitigated results were obtained by reducing the received levels by 10 dB at all sound frequencies. The 10 dB reduction was applied to L_{pk} and decidecade band L_E and $L_{E,\mathrm{w}}$. The corresponding reduction to J_p was applied using a multiplicative factor of $10^{-1/2}$. This amount of acoustic reduction is expected to be achievable by deploying NAS system(s), such as bubble curtains or similar technology, around the detonation site.

There is little published information available on direct measurements of bubble curtain effectiveness for reducing PK, SEL, and impulse produced by underwater explosives detonations. One measurement of a small bubble curtain showed good performance for 1 kilogram (kg) charges, providing approximately 16 dB insertion loss at all frequencies greater than 1 kilohertz (kHz) using small curtains of less than 11.5 m diameter (Schmidtke et al. 2009). The same study evaluated another relatively small bubble curtain (22 m diameter in 20 m water depth) surrounding 300 kg mines. That bubble curtain configuration produced smaller insertion losses of approximately 2 dB at 100 hertz (Hz) to 6 dB at 10 kHz. These values are substantially smaller than the observed insertion loss at corresponding frequencies for modern bubble curtains applied to mitigate sounds from large pile installations. The smaller reductions observed by Schmidtke et al. (2009) were likely due to use of a small bubble curtain for a relatively large detonation charge size, even though the air flow rate per unit curtain length was similar. Modern curtains also apply bubble size optimization to maximize the frequency-dependent acoustic level reductions, but it is unclear whether that was performed for the bubble curtains used in the Schmidtke et al. (2009) study.

A recent review of bubble curtain effectiveness for pile driving noise mitigation by Bellmann et al. (2020) found insertion loss performance of modern bubble curtains increases with sound frequency from about 20 Hz to 1.5 kHz and then decreases slowly with further increases in frequency. They tabulated insertion loss results for a Big Bubble Curtain (BBC) that indicated acoustic level reductions of at least 10 dB at 32 Hz, increasing to approximately 35 dB near 1 kHz. A follow-up report indicates first results for insertion loss of UXO acoustic levels by BBC of 11 dB for broadband L_E and up to 18 dB for L_{pk}, although particulars of the charge sizes and water depths in the study were not provided (Bellmann 2021).

The spectral energy distribution of the pressure waveforms of explosives detonated in water will differ from the spectral distribution of pile driving sounds. Nevertheless, the frequency-dependent insertion losses are expected to be similar if the bubble curtain radius is large enough to avoid nearfield effects of the explosive detonations. The spectra of smaller charges contain relatively more high-frequency energy than the spectra of larger charges after accounting for the higher overall energy of the larger charges. This spectral shape dependence on charge size is discussed in detail in Supplement J.7.2.1. The maximum spectral levels of all charge sizes considered in this report occur at less than 10 Hz, but their spectral roll-off is small so their maximum decidecade L_E band levels occur above a few hundred Hertz. Pile driving spectra have maximum band levels at lower frequencies, which suggests bubble curtain performance for explosive charges should in general produce greater broadband insertion loss than for pile driving. The minimum modern bubble curtain insertion loss effectiveness for the frequency bands dominating explosive detonation L_E in shallow waters is well above 10 dB. Therefore, the choice of 10 dB as a broadband L_E insertion loss is expected to be conservative.

The very rapid onset of the shock pulse, within a few microseconds (μs), and its rapid decay constant of less than 2 ms for the largest charge size considered (454 kg UXO plus 9.1 kg donor charge) suggests the shock pulse peak pressure is dominated by high frequencies that are likely much higher than 500 Hz. The results compiled by Bellmann et al. (2020) indicate the peak pressure insertion loss at those frequencies by modern bubble curtains should be greater than 10 dB. As mentioned above, the first results that applied the use of BBC for UXO produced insertion loss slightly larger than 10 dB.

The Proponent will continue to explore new NAS technologies with the potential to achieve 10 dB or more of broadband mitigation and effectively reduce PK, SEL, and impulse produced by underwater explosives detonations as these technologies become available.

As a final note regarding UXO removal detonation pressures: Bellman (2021) noted that many UXO charges are situated slightly below the seafloor elevation after removal of overlying sedimentation. These charges then lie slightly below the seafloor grade and are then partly shielded by surrounding sediments. The generated pressure waves propagating away in the horizontal direction must pass partly through the sediments, which have higher absorption characteristics than seawater. Bellman (2021) found that propagation losses were higher for these partially buried charges than for charges detonated in seawater. In this study, we assumed no such shielding by sediments.

J.5. Environmental Parameters

J.5.1. Bathymetry

A bathymetry grid for the acoustic propagation model was extracted from NGDC's 1 arc-second US Coastal Relief Model (CRM) created by the National Centers for Environmental Information (NCEI).

J.5.2. Seafloor Geoacoustic Parameters

In shallow water environments, where there is increased interaction with the seafloor, the properties of the substrate have more influence over the sound propagation.

The geoacoustic properties profiles for the seafloor in the area were defined during acoustic modeling of foundation installation activities for Vineyard Mid-Atlantic and were adopted for this modeling task (see Appendix E.1). The surficial sediment within the Lease Area is predominantly composed of silty sand to dense sand. The Vineyard Mid-Atlantic geotechnical studies provide lithology of extracted cores through at least the top 50 m of seabed sediments across the Lease Area. The core samples provided density, grain size, and porosity of the sediment at various depths below seafloor. The geoacoustic profiles for the area has been developed from geotechnical studies of surficial sediments within the project area and from regional studies for deeper sediments (Tang et al. 2002, Lyu et al. 2021). Geoacoustic profile L01 (Table J-3) was used for acoustic modeling at Sites UXO-1 to UXO-4 and geoacoustic profile L02 (Table J-4) at Site UXO-5.

Table J-3. Geoacoustic profile L01: 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 Speed (m/s)	Compressional wave Attenuation (dB/λ)	Shear wave Speed (m/s)	Shear wave Attenuation (dB/λ)
0.00–11.34	Fine sand	2.000–2.014	1,694.87–1,709.57	0.820–0.816	300	5.5
11.34–28.74	Sandy silt	1.839–1.863	1,613.35–1,635.53	1.190–1.091	300	5.5
28.74–39.70	Silty sand	1.864–1.878	1,632.57–1,646.32	1.106–1.044	300	5.5
39.70–48.50	Very fine sand	1.965–1.976	1,701.09–1,712.00	0.835–0.833	300	5.5
48.50–50.00	Very fine sand	1.976–1.978	1,712.00–1,713.85	0.833–0.833	300	5.5
50.00–64.00	Silty sand	1.892–1.910	1,659.08–1,676.19	0.985–0.903	300	5.5
64.00–500.00	Fine sand	2.084–2.547	1,775.36–2,193.75	0.803–0.628	300	5.5
>500.00	Sand	2.547	2,193.75	0.628	300	5.5

Table J-4. Geoacoustic profile L02: 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 Speed (m/s)	Compressional wave Attenuation (dB/λ)	Shear wave Speed (m/s)	Shear wave Attenuation (dB/λ)
0.00–11.34	Fine sand	2.000–2.014	1,694.87–1,709.57	0.820–0.816	300	5.5
11.34–28.74	Sandy silt	1.839–1.863	1,613.35–1,635.53	1.190–1.091	300	5.5
28.74–39.70	Silty sand	1.864–1.878	1,632.57–1,646.32	1.106–1.044	300	5.5
39.70–48.50	Very fine sand	1.965–1.976	1,701.09–1,712.00	0.835–0.833	300	5.5
48.50–50.00	Very fine sand	1.976–1.978	1,712.00–1,713.85	0.833–0.833	300	5.5
50.00–64.00	Silty sand	1.892–1.910	1,659.08–1,676.19	0.985–0.903	300	5.5
64.00–500.00	Fine sand	2.084–2.547	1,775.36–2,193.75	0.803–0.628	300	5.5
>500.00	Sand	2.547	2,193.75	0.628	300	5.5

J.5.3. Ocean Sound Speed Profile

The sound speed profiles were derived using temperature and salinity profiles from the US Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25 ° resolution, with a temporal resolution of one month, based on global historical observations from the US Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6,800 m (where the ocean is that deep), including 55 standard depths between 0 and 2,000 m. The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

During summer (April-November), the most conservative sound speed profile of April (Figure J-2) was used for acoustic propagation modeling in this project instead of the average summer profile. Modeling was also conducted for winter and used December as the most representative winter profile.

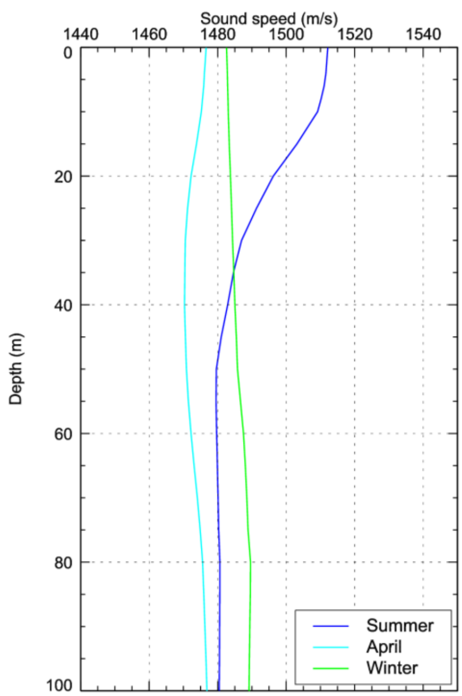

Figure J-2. Sound speed profiles up to 100 m for summer, winter, and April. The April profile was used to represent the most conservative summer month for UXO.

J.6. Acoustic Criteria for Marine Fauna

J.6.1. Marine Mammals and Sea Turtles: Auditory Injury (PTS)

The injury zones surrounding explosives detonations are of key importance for developing mitigation approaches to minimize the number of marine mammal and sea turtle exposures. Two injury mechanisms are assessed for marine mammals: auditory injury and non-auditory injury. We follow the US Navy approach for assessing both types of effects (US Navy 2017). Auditory injury (onset of permanent threshold shift [PTS]) is assessed using a dual criteria of L_{pk} and frequency-weighted SEL ($L_{E,w}$), where the frequency weighting functions are dependent on the species group (NMFS 2018). The Navy follows NMFS's guidelines for assessing PTS and temporary threshold shift (TTS) using metrics L_{pk} and $L_{E,w}$ for marine mammals. These thresholds and additional thresholds for sea turtles are listed in Table J-5. TTS thresholds, also listed in Table J-5, are used for estimating potential behavioral responses to underwater sound (see Supplement J.6.3). The Group column in Table J-5 represents species groups from top to bottom: low-frequency cetaceans (LF), mid-frequency cetaceans (MF), high-frequency cetaceans (HF), phocid pinnipeds in water (PW), and sea turtles (TU).

Table J-5. US Navy (2017) peak frequency-weighted sound exposure level and peak pressure thresholds for onset of permanent threshold shift (PTS) and temporary threshold shift (TTS). See text above for a description of the Animal Group abbreviations.

Animal group	TTS threshold $L_{E,w}$ (dB re µPa²s)	TTS threshold L_{pk} (dB re µPa)	PTS threshold $L_{E,w}$ (dB re µPa²s)	PTS threshold L_{pk} (dB re µPa)
LF	168	213	183	219
MF	170	224	185	230
HF	140	196	155	202
PW	170	212	185	218
TU	189	226	204	232

J.6.2. Marine Mammals and Sea Turtles: Non-Auditory Injury and Mortality

Non-auditory injury and mortality mitigation zones are calculated using metrics representing onset of injury to animal's lungs and gastrointestinal tracts, attributed to compression-related injury of tissues near enclosed air volumes or gas bubbles. The relevant metrics are L_{pk} and J_p of the blast shock pulse. The peak pressure threshold for onset of injury caused by explosive detonations (effect observed in 1% of exposed animals) to the gastrointestinal tract is an L_{pk} of 237 dB re µPa, and this is independent of animal mass. However, that criterion originated from studies on mid-sized terrestrial animals and adult human divers, and it may not be conservative for smaller animals that could be more suspectable to blast injury than larger animals. Our recommendation is to avoid its use for animals with mass less than 50 kg until its validity for smaller animals can be confirmed.

The impulse calculation for lung injury and mortality integrates pressure through the time of the shock pulse, with the integration period limited by the arrival of the surface-reflected path or 20% of the animal's lung oscillation period—whichever is smaller. These integration time limits are applied because the arrival of the phase-inverted surface reflection signal reduces or truncates the positive phase of the shock pulse, and because the excitation of lung compression is reduced if the impulse duration is greater than 20% of the lung's oscillation period. As discussed in Supplement J.7.1.3, the lung oscillation limiting times are straightforward to calculate using the Goertner formulas (Goertner 1982); they depend on animal mass and submersion depth. The surface reflection arrival time is determined by the geometry of the source and receiving animal relative to each other and the sea surface.

The Navy's impulse criteria for onset of lung injury and mortality are based on measurements of blast effects on several species of mammals experimentally exposed to detonation pressures (Yelverton et al. 1973). The Navy has published two sets of equations, reproduced here in Table J-7, for effects thresholds for impulsive sounds that depend on animal mass and submersion depth. The two equations represent thresholds respectively for injury effects (observed in 50% of exposed animals) and onset of injury effects (observed in 1% of the exposed animals). NMFS suggested the more conservative (onset of effects) values be used for assessing impacts if the distances exceed those of other injurious exposure criteria and that is the approach used here.

The impulse thresholds for lung injury and mortality to marine mammals and sea turtles depend on the animal lung volume, which is a function of animal mass and submersion depth. To be conservative, maximum horizontal distances to acoustic thresholds were calculated in 1 m submersion depth increments, from the surface to seabed, at the respective assessment location. The maximum distance over these depths was listed as the representative acoustic range.

The animal masses used for acoustic range calculations were obtained from Finneran et al. (2017; Table C-9) and summarized in Table J-6. The Navy table provides conservative calf/pup and adult masses for all marine mammal species. The adult mass is the smallest mass from the range of adult masses for the respective species. The five animal groups defined in Table J-6 represent and comprise similar-mass species to those that may be encountered at the project sites, including rare species for those areas. For each group, a representative species with the smallest calf and adult masses are used as conservative values for the entire animal group. Sperm whales were grouped with larger baleen whales due to their similar adult masses. The sei whale calf mass was used for this group because it had the smallest mass. The smallest animals of dolphin, *Kogia* species, pinniped, and sea turtle families had very similar mass to harbor seals. Harbor seal calf and adult masses were, therefore, used as the representative species for that animal group for conservatism. Table J-6 lists the defined animal groups and the corresponding calf/pup and adult masses of representative species used for impulse threshold calculations. Tables J-8 and J-9 provide thresholds for onset of lung injury and onset of mortality, for all relevant animal masses at a selection of submersion depths. The actual assessment of effects distances considered all possible submersion depths.

Table J-6. Representative calf/pup and adult mass estimates for the animal groups defined for this assessment. These mass values are based on the smallest expected animals for the species that might be present within project areas. Masses listed here are used for assessing impulse-based acoustic ranges to onset of lung injury and mortality thresholds.

Impulse animal group	Representative species	Calf/pup mass (kg)	Adult mass (kg)
Large baleen whales and sperm whale	Sei whale calf (*Balaenoptera borealis*) Sperm whale adult (*Physeter macrocephalus*)	680	16,000
Pilot and minke whales	Minke whale (*Balaenoptera acutorostrata*)	200	4,000
Beaked whales	Gervais' beaked whale (*Mesoplodon europaeus*)	49	366
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	Harbor seal (*Phoca vitulina*)	8	60
Porpoises	Harbor porpoise (*Phocoena phocoena*)	5	40

Table J-7. US Navy impulse and peak pressure threshold equations for mortality and lung injury in marine mammals and sea turtles due to explosive detonations (US Navy 2017).

Likelihood of observed effects in animals	Effects assessment criterion	Metric	Threshold formula or value for animal mass *M* (kg) at submersion depth *D* (m)
Effects observed in 50% of exposed animals	Mortality – Impulse	J_p	$144\,M^{1/3}\left(1+\frac{D}{10}\right)^{1/6}$ Pa·s
Effects observed in 50% of exposed animals	Injury – Impulse	J_p	$65.8\,M^{1/3}\left(1+\frac{D}{10}\right)^{1/6}$ Pa·s
Effects observed in 50% of exposed animals	Injury – Peak pressure	L_{pk}	243 dB re µPa
Effects observed in 1% of exposed animals	Onset Mortality – Impulse	J_p	$103\,M^{1/3}\left(1+\frac{D}{10}\right)^{1/6}$ Pa·s
Effects observed in 1% of exposed animals	Onset Injury – Impulse	J_p	$47.5\,M^{1/3}\left(1+\frac{D}{10}\right)^{1/6}$ Pa·s
Effects observed in 1% of exposed animals	Onset Injury – Peak pressure	L_{pk}	237 dB re µPa

The top three rows are grayed to indicate they are for information purposes only. The impulse formulae and peak pressure thresholds of the bottom three rows, representing onset of effects in 1% of exposed animals, are used in this assessment as suggested by NOAA as more conservative.

Table J-8. Onset Injury (equation in Table J-7): Example impulse thresholds (units of Pa·s) for all animal masses (kg) in Table J-6, for selected animal submersion depths between 1 and 60 m. The assessment considered all possible submersion depths to find the maximum acoustic ranges.

Submersion depth (m)	5 kg	8 kg	40 kg	49 kg	60 kg	200 kg	366 kg	680 kg	4,000 kg	16,000 kg
1	82.5	96.5	165.0	176.6	188.9	282.2	345.2	766.0	424.3	1,215.9
10	91.1	106.5	182.2	194.9	208.6	311.5	381.1	845.7	468.5	1,342.4
20	97.4	114.0	194.9	208.5	223.1	333.2	407.6	904.5	501.1	1,435.8
30	102.2	119.5	204.4	218.7	234.0	349.5	427.6	948.8	525.6	1,506.2
40	106.1	124.1	212.1	227.0	242.8	362.8	443.7	984.7	545.5	1,563.1
50	109.3	127.9	218.7	234.0	250.3	373.9	457.4	1,015.0	562.3	1,611.2
60	112.2	131.2	224.4	240.1	256.8	383.7	469.3	1,041.4	576.9	1,653.1

Table J-9. Onset Mortality (equation in Table J-7): Example impulse thresholds (units of Pa·s) for all animal masses (kg) in Table J-6, for selected animal submersion depths between 1 and 60 m. The assessment considered all possible submersion depths to find the maximum acoustic ranges.

Submersion depth (m)	5 kg	8 kg	40 kg	49 kg	60 kg	200 kg	366 kg	680 kg	4,000 kg	16,000 kg
1	178.9	209.3	357.8	382.9	409.6	611.9	748.5	920.1	1,661.0	2,636.6
10	197.5	231.0	395.1	422.7	452.2	675.6	826.3	1,015.8	1,833.7	2,910.9
20	211.3	247.1	422.6	452.1	483.7	722.6	883.8	1,086.5	1,961.4	3,113.5
30	221.6	259.2	443.3	474.3	507.4	758.0	927.1	1,139.8	2,057.4	3,266.0
40	230.0	269.0	460.0	492.2	526.6	786.6	962.2	1,182.8	2,135.2	3,389.5
50	237.1	277.3	474.2	507.4	542.8	810.8	991.8	1,219.3	2,201.0	3,493.8
60	243.3	284.5	486.5	520.6	556.9	831.9	1,017.6	1,250.9	2,258.2	3,584.6

J.6.3. Marine Mammals and Sea Turtles: Behavioral Disturbance

The acoustic criteria relevant for behavioral disturbance include L_{pk} and $L_{E,\mathrm{w}}$ thresholds. All SEL modeling in this study assumes a single detonation per day because the assessment criteria and thresholds are different when more than one detonation occurs in a 24-hour period, as discussed below.

Single blast events within a 24-hour period are not presently considered by NMFS to produce significant adverse behavioral effects if received levels are below the onset of TTS thresholds for $L_{E,\mathrm{w}}$ and L_{pk} (Table J-5). When multiple blast events occur within a 24-hour period, the US Navy approach applies a disturbance threshold of TTS $L_{E,\mathrm{w}}$ minus 5 dB. Thus, the effective behavioral threshold for single events in each 24-hour period is the $L_{E,w}$ for TTS onset, and for multiple events it is the $L_{E,w}$ for TTS minus 5 dB. When multiple blasts occur within a 24-hour period, marine mammals and sea turtles could receive partial doses of SEL from different detonations. The individual event doses depend on the charge sizes and relative detonation timing, which are not known in advance. However, since Vineyard Mid-Atlantic plans on only one charge detonation per day, a single event SEL model scenario is sufficient to calculate an $L_{E,\mathrm{w}}$ map around each charge, and the TTS zones can be evaluated using the TTS criteria from Table J-5.

For multiple blast events, an SPL-based disturbance threshold of L_p = 175 dB re 1 µPa^2 would be relevant. Here, we are considering only a single blast event per day, so we have not considered that threshold. The approach for calculating L_p is defined in ISO (18405:2017), but that metric is not currently applied by the Bureau of Ocean Energy Management (BOEM) or NMFS for explosives effects assessment of single blast events. Modeling of SPL requires using full wave source and propagation models that are not required for SEL-based assessments. That has not been done here, but these models are available if required.

J.6.4. Fish Injury

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) and are provided in Table J-10. The injurious effects thresholds for all fish species groups are the same: L_{pk} = 229–234 dB re 1 µPa. The present assessment has applied the lower range value of L_{pk} = 229 dB re 1 µPa for potential mortal injury and mortality. Table J-11 presents thresholds to fish injury for L_{pk} and $L_{E,24h}$ defined by NMFS (FHWG 2008).

Table J-10. Recommended fish injury thresholds (L_{pk} in dB re µPa) for explosives from Popper et al. (2014). Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Type of animal	Mortality and potential mortal injury threshold	Impairment recoverable injury	Impairment TTS	Impairment masking	Behavior
Fish: no swim bladder (particle motion detection)	229–234	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	n/a	(N) High (I) Moderate (F) Low
Fish: where swim bladder is not involved in hearing (particle motion detection)	229–234	(N) High (I) High (F) Low	(N) High (I) Moderate (F) Low	n/a	(N) High (I) High (F) Low
Fish: where swim bladder is involved in hearing (primarily pressure detection)	229–234	(N) High (I) High (F) Low	(N) High (I) High (F) Low	n/a	(N) High (I) High (F) Low

Table J-11. Acoustic metrics and thresholds for fish currently used by National Marine Fisheries Service (NMFS) for explosives (impulsive).

Hearing group	Injury, impulsive signals (L_{pk})	Injury, impulsive signals ($L_{E,24h}$)
Fish greater than or equal 2 g [a]	206	187
Fish less than 2 g [a]	206	183

L_{pk} – peak sound pressure level (dB re 1 µPa), $L_{E,24h}$ – sound exposure level (dB re 1 µPa^2·s),

[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).

J.6.5. Fish Behavioral Disturbance

This assessment has not quantitatively assessed zones of non-injurious effects to fish from explosive detonations because the Popper et al. (2014) guidelines (see Table J-10) are qualitative and vague on that subject. For fish species that use swim bladders for hearing, Popper et al. (2014) suggests a high likelihood of TTS and recoverable injury at near and intermediate distances, where ‘near’ refers to within a few tens of meters and ‘intermediate’ refers to a few hundreds of meters. For fish species with swim bladders not used for hearing, the guidelines indicate a high likelihood of recoverable impairment at near and intermediate distances but low levels of TTS at intermediate distances. For fish without swim bladders, the guidelines indicate a low likelihood of recoverable injury at intermediate distances, moderate likelihood of TTS at intermediate distances, and low levels of both effects at far distances, where ‘far’ refers to a few kilometers.

J.7. Acoustic Modeling

J.7.1. Peak Pressure and Impulse

J.7.1.1. Shock Pulse Source Function

Modeling of acoustic fields generated by UXO detonations is performed using a combination of semi-empirical and physics-based computational models. The source pressure function used for estimating L_{pk} and J_p metrics is calculated using a semiempirical model that approximates the rapid conversion (within approximately 1 μs for high explosive) of solid explosive to gaseous form in a small gas bubble under high pressure, followed by an exponential pressure decay as that bubble expands. This behavior imparts an initial pressure “shock pulse” into the water that is commonly approximated by an instantaneous rise to peak pressure P_0 followed by an exponentially decaying pressure function of the form:

$$P(t) = P_0 e^{-t/\tau} . \tag{J-1}$$

The shape and amplitude of the pressure versus time signature of the shock pulse changes with distance from the detonation location due to non-linear propagation effects caused by its high L_{pk}. Arons and Yennie (1948) made measurements of the detonations of a range of charge sizes, and derived empirical formulae for P_0 in Pascals, and exponential time constant t in seconds as functions of equivalent TNT charge mass W in kilograms, and distance from the detonation r in meters (note the original equations used different mass and distance units and those have been converted to metric system units in the formulae presented here:

$$P_0 = 5.24 \times 10^7 \left(\frac{W^{\frac{1}{3}}}{r}\right)^{1.13} \text{Pa} \tag{J-2}$$

and

$$\tau = 9.25 \times 10^{-5} W^{\frac{1}{3}} \left(\frac{W^{\frac{1}{3}}}{r}\right)^{-0.22} \text{s} . \tag{J-3}$$

J.7.1.2. Shock Pulse Pressure Range Dependence

The shock pulse source function variation with distance described above is valid only close to the source, where pressures lead to non-linear effects. Beyond a certain distance R_0, the functional dependence of P_0 and τ on W and r are better described by weak shock theory that leads to a gradual transition to linear pressure decay with distance (Rogers 1977). The transition distance was defined by Gaspin (1983) as $R_0 = 4.76\,W^{1/3}$ meters. For example, R_0 is 47.6 m for a 1,000 kg charge. At distances greater than R_0, the L_{pk} and time constant are obtained by modified formulae (Rogers 1977):

$$\tau(r > R_0) = \tau(R_0)\left[1 + 2\left(\frac{R_0}{L_0}\right)\ln\frac{r}{R_0}\right]^{\frac{1}{2}} \quad \text{s} \quad \text{and} \tag{J-4}$$

$$P_0(r > R_0) = \frac{P_0(R_0)\left\{\left[1 + \frac{2R_0}{L_0}\ln\frac{r}{R_0}\right]^{\frac{1}{2}} - 1\right\}}{\left(\frac{r}{L_0}\right)\ln\frac{r}{R_0}} \quad \text{Pa} \,, \tag{J-5}$$

$$\text{where } L_0 = (\rho_0 {c_0}^3 \tau(R_0))/(\beta P_0(R_0).$$

In equations J-4 and J-5, ρ_0 is the water density expressed in kg/m^3, c_0 is the water sound speed expressed in m/s, and β = 3.5. These equations lead to a pressure decay with range r that transitions to spherical spreading at long distances. The time constant also increases as the higher frequencies of the shock pulse, responsible for its sharp peak, are preferentially attenuated by absorptive loss. Pressure calculations were performed for the charge sizes in Table J-1 with ρ_0 = 1,026 kg/m^3 and c_0 = 1,500 m/s, and these results are graphed as a function of distance from the charges in Figure J-3. The corresponding shock pulse time constant versus distance from equations J-3 and J-5 is plotted in Figure J-4.

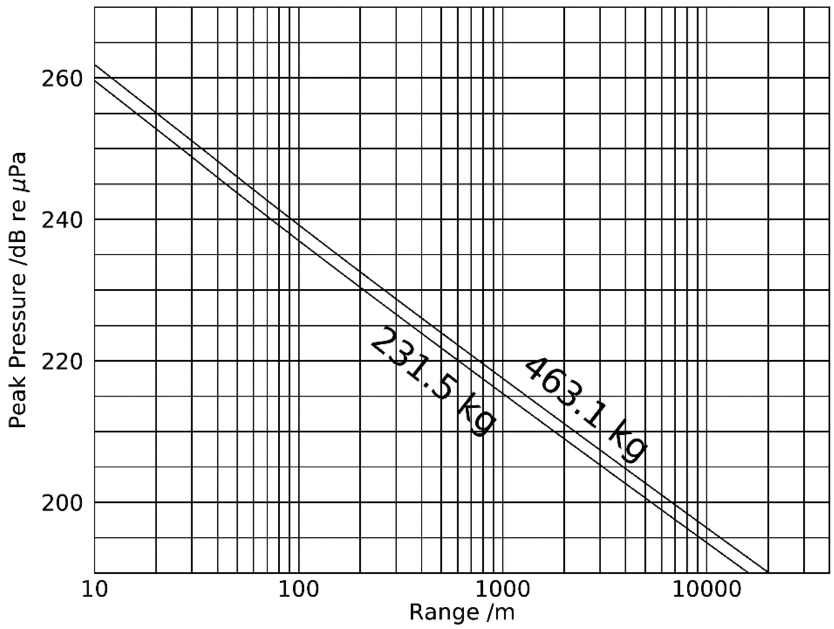

Figure J-3. Peak pressures versus distance from detonations of the charge masses and donors listed in Table J-1, calculated with equations J-2 and J-4.

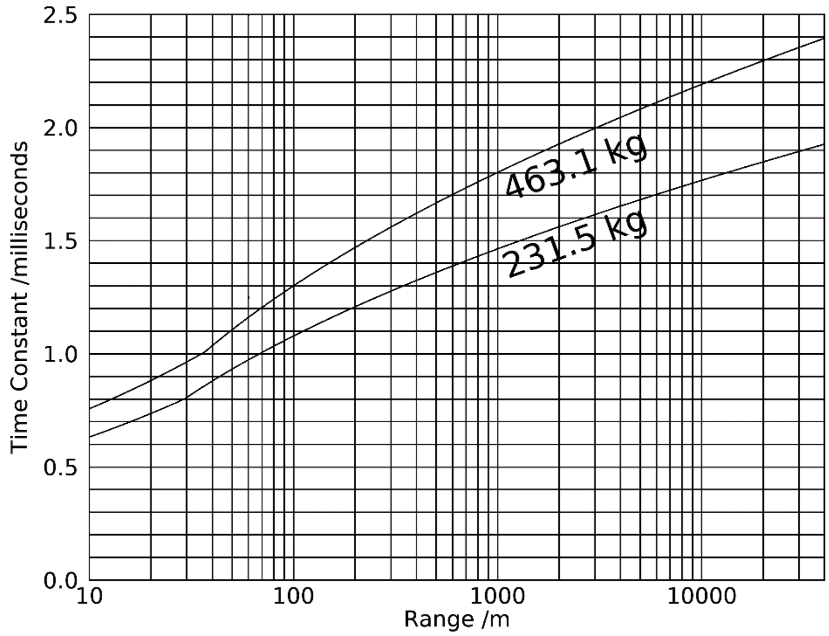

Figure J-4. Time constants for the exponential decay approximation of the shock pulse versus distance from detonation, calculated with equations J-3 and J-5 and converted to milliseconds, for each of the charge masses with donors listed in Table J-1.

J.7.1.3. Impulse

Acoustic impulse is defined as the integral of pressure through time. Assuming the onset of the pressure signal of the direct acoustic path starts at $t = 0$ and ends at $t = T$, the impulse is given by:

$$J_p = \int_0^T P(t)\,dt \quad \text{J-6}$$

If the integration end time T is within the part of the shock pulse pressure waveform approximated well by the exponential function (equation J-1) then (equation J-6) can be expressed:

$$J_p(r) = P_0(r)\tau(r)\left(1 - e^{-T/\tau(r)}\right) \quad \text{J-7}$$

In practice, this approximation is accurate for integration times somewhat larger than the time constant because most of the contribution to impulse occurs near the shock pulse onset and the right bracketed term in (equation J-7) approaches 1.0 as the integration time exceeds a few time constants.

The US Navy applies an integration time window starting at the onset of the shock pulse and ending at the lesser of the arrival time of the surface reflection and 20% of the oscillation period of an exposed animal's lung, i.e., T = *minimum*(T_{surf}, 0.2 T_{lung}) (US Navy 2017). The arrival time of the surface-reflected path relative to the direct path can be calculated from the depths of the source charge z_s and the exposed animal z_r, their horizontal separation x and the water sound speed c_0:

$$T_{surf} = \left(\sqrt{x^2 + (z_s + z_r)^2} - \sqrt{x^2 + (z_s - z_r)^2}\right)/c_0 \quad \text{J-8}$$

The lung oscillation period can be approximated by the oscillation period of a gas sphere of the same volume. The lung volume of animals at atmospheric pressure is approximately proportional to the animal's mass M in kilograms, and this volume decreases with animal submersion depth z_r due to compression by hydrostatic pressure. Goertner (1982) provides the following approximation for lung volume V and equivalent volume fundamental oscillation period t_{osc} for a submerged animal:

$$V = 3.5 \times 10^{-5}\, M \frac{p_{atm}}{(\rho_0 g z_r + p_{atm})} \quad \mathrm{m}^3 \quad \text{(J-9)}$$

$$t_{osc} = 97.1\,(V 4\pi/3)^{\frac{1}{3}} / \sqrt{\rho_0 g z_r + p_{atm}} \quad \mathrm{s} \quad \text{(J-10)}$$

Where $g = 9.81\ \mathrm{m/s^2}$ is the gravitational acceleration and p_{atm} is the atmospheric pressure in pascals at the sea surface. Figure J-5 shows lung fundamental oscillation periods calculated from (equation J-10) for four animal masses, versus submersion depth.

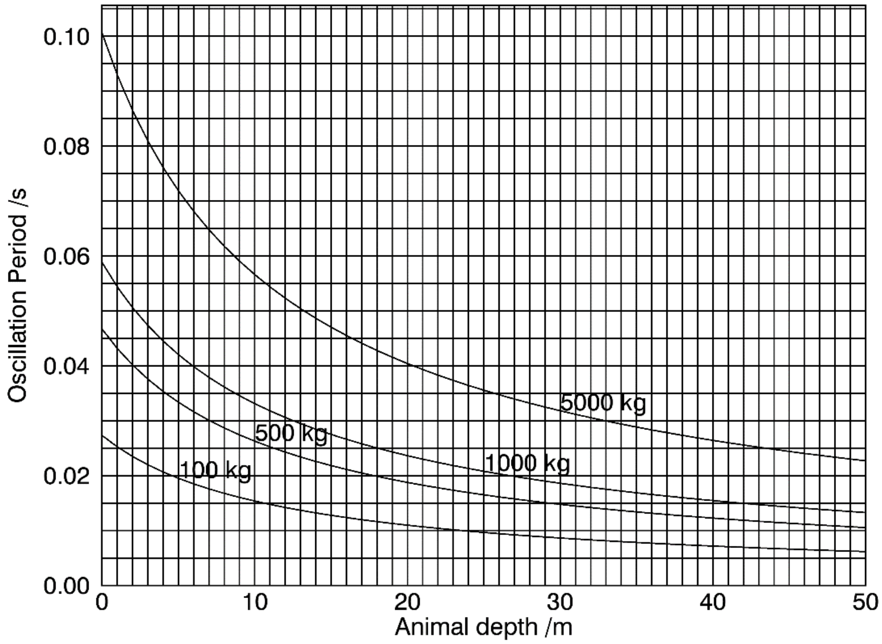

Figure J-5. Lung oscillation periods for animal masses of 100, 500, 1,000, and 5,000 kg versus submersion depth, calculated using equation J-10.

J.7.2. Sound Exposure Level Model

SEL and SPL calculations for blast pressure waveforms depend on the characteristics of the initial shock pulse (see Section J.7.1.1) and the subsequent oscillation of the detonation gas bubble. The oscillations lead to a series of alternating negative and positive pressure phases trailing the initial positive pressure shock pulse (Figure J-6). The positive pressures (relative to hydrostatic pressure) occur when the bubble volume is at its minima, and the negative pressures occur when the bubble volume is at its maxima. The shape of the resulting pressure waveform can be calculated using an explosive waveform model (e.g., Wakeley 1977) that includes the shock pulse model of equation J-1 and extends the pressure prediction in time through several oscillations of the bubble. The negative phase pressure troughs and bubble pulse peaks following the shock pulse are responsible for most of the low-frequency energy of the overall blast waveform.

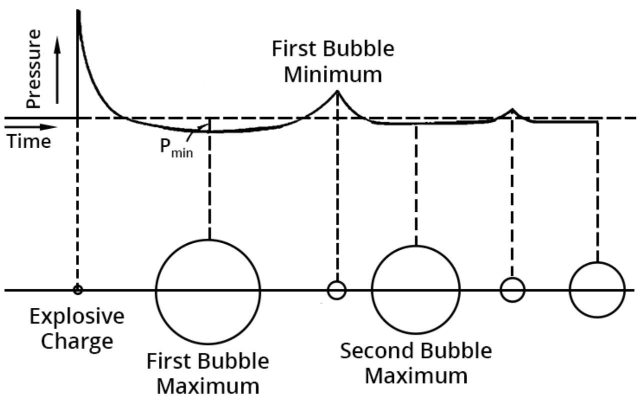

Figure J-6. Pictorial representation of the relationship between the radiated pressure signal and the volume of the gas bubble as it oscillates in size after the detonation. This figure is reproduced from the Discovery of Sound in the Sea (DOSITS) website https://dosits.org/galleries/technology-gallery/basic-technology/explosive-sound-sources.

The SEL thresholds for PTS and TTS typically occur at distances of several water depths in the relatively shallow waters of Vineyard Mid-Atlantic's project area. The sound field at larger distances becomes increasingly influenced by the contributions of energy reflected from the sea surface and sea bottom multiple times. In most instances, the reflected paths become dominant over the direct acoustic path at horizontal distances greater than a few water depths. Some acoustic energy is also transmitted into the seafloor on each reflection and that energy can propagate partly through the seafloor before re-emerging into the water column and interacting in a complex way with waterborne energy. We apply acoustic propagation models to account for the effects of multiple reflections and sound propagation partly in the seabed. The modeling of SEL does not require use of a full waveform signature model. Nevertheless, the rate of decay of L_E with distance from the detonation varies in a complex way with sound frequency, so a source model that accounts for frequency dependence is necessary. The modeling of $L_{E,\mathrm{w}}$ performed here was carried out by first modeling L_E in decidecade frequency bands using the marine operations noise model (MONM; JASCO Applied Sciences). This model uses an energy source level model, described in the next section, and then calculates acoustic propagation loss using parabolic equation (PE) approach for frequencies below 4 kHz, and a Gaussian beam ray trace model at higher frequencies. The PE model applied here also accounts for shear wave conversion losses from reflections at layer interfaces.

J.7.2.1. Energy Source Levels in Decidecade Frequency Bands

A key input for the MONM model is the energy source level (ESL), which quantifies the acoustic energy (SEL) and its distribution across different frequency bands for each of the charges considered. The distribution depends on the charge mass and detonation depth. The ESL is calculated using an approach described by Urick (1971a, 1971b) and Urick (1983). A series of energy source level spectral density curves for normalized underwater explosion events at various depths (Figure J-7) are defined in terms of frequency relative to the frequency of the first bubble pulse. The first bubble pulse frequency is the inverse of the time of the first bubble pulse peak relative to the time of the shock pulse peak. It is calculated using an equation provided by Chapman (1985):

$$f_{b1} = (2.11 W^{\frac{1}{3}} z_0^{-5/6})^{-1} \quad \text{J-11}$$

Where W is the mass of the charge in kg of equivalent TNT and z_0 is the hydrostatic depth of the charge

$$z_o \approx z_s + 10.1 \text{ meter} \quad \text{J-12}$$

The energy source level scaling factor for charge mass is calculated as:

$$\Delta\text{ESL} = 13.3 \log W. \quad \text{J-13}$$

The ESL in decidecade bands is calculated as follows:

1. The appropriate energy source level spectral density (ESLSD) curve is selected from the chart (see Figure J-7) based on the charge depth;
2. The first bubble pulse frequency fb1 is calculated using equation J-11 and absolute frequencies for the ESLSD curve are obtained by scaling their normalized frequency by multiplying by fb1;
3. The spectral levels are adjusted for the charge mass using equation J-12 and J-13; and
4. The ESL is calculated by integrating the corrected ESLSD spectral function through the bandwidth of each decidecade band (Figure J-8).

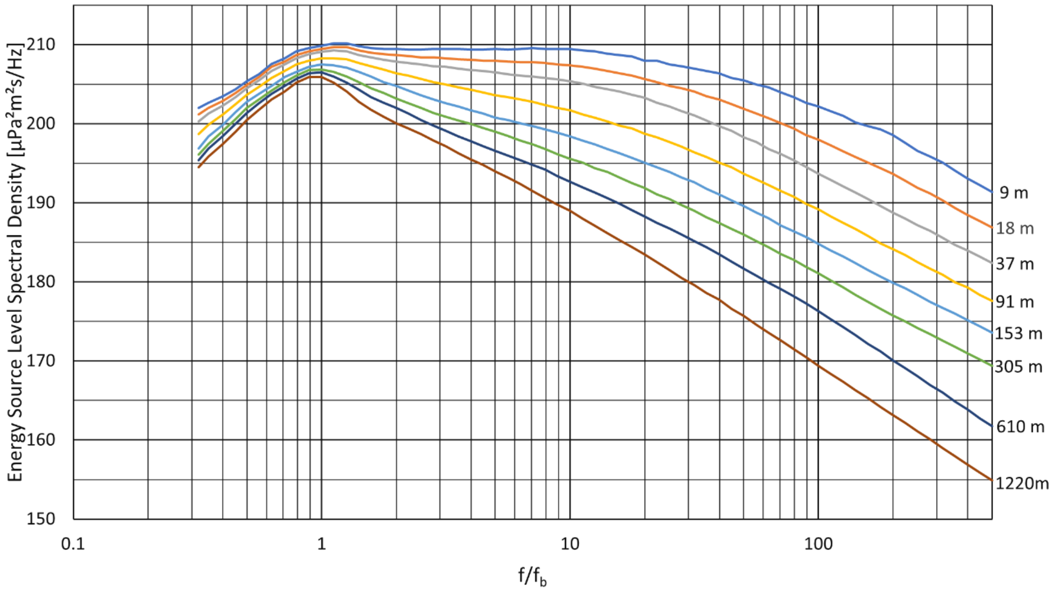

Figure J-7. Energy source level spectral density (ESLSD) curves for underwater explosion events at various depths expressed in normalized frequency, relative to the frequency f_{b1} of the first bubble pulse (after Urick (1983)).

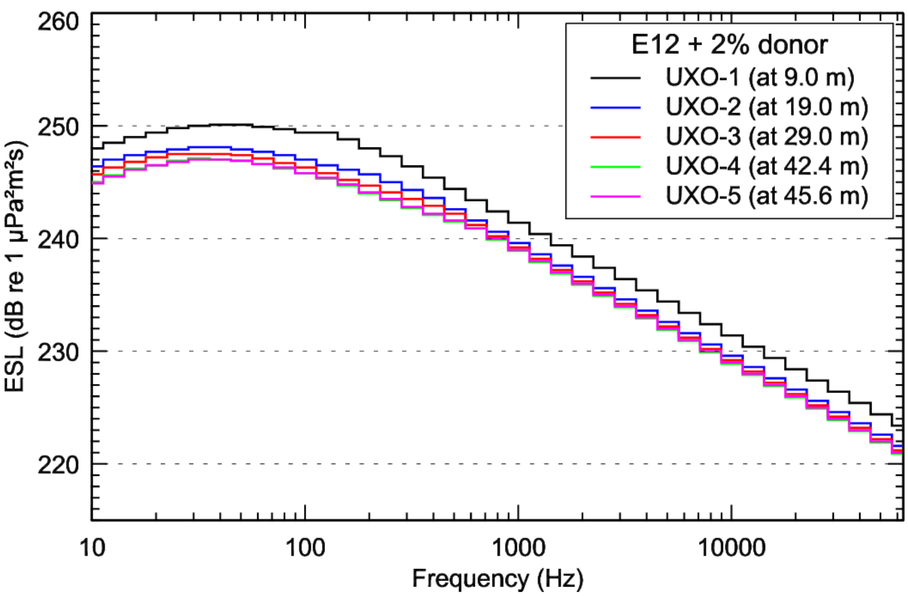

Figure J-8. Decidecade-band energy source levels (ESL) for detonation of a 463.1 kg (TNT equivalent) underwater charge at various depths.

J.8. Acoustic Range Results (Unmitigated)

This section provides acoustic range results to injury and behavioral thresholds for detonations when noise abatement systems (NAS) are not used. Supplement J.9 provides the corresponding acoustic ranges with a NAS in use, providing 10 dB peak pressure, impulse, and SEL reductions.

J.8.1. Marine Mammals and Sea Turtles TTS and PTS by Peak Pressure Distances (Unmitigated)

Peak pressure (L_{pk}) acoustic ranges are not dependent on water depth or seabed properties, so the results of Table J-12 are relevant for all sites.

Table J-12. Marine mammals and sea turtles permanent threshold shift (PTS) and temporary threshold shift (TTS) maximum acoustic ranges for peak pressure (L_{pk}) for two UXO charge sizes with donor charges for all sites, based on thresholds from Table J-5.

Hearing group	TTS / PTS L_{pk} threshold (dB re 1 µPa)	Maximum distances (m) to TTS thresholds for peak pressure E10 + donor (231.5 kg)	Maximum distances (m) to PTS thresholds for peak pressure E10 + donor (231.5 kg)	Maximum distances (m) to TTS thresholds for peak pressure E12 + donor (463.1 kg)	Maximum distances (m) to PTS thresholds for peak pressure E12 + donor (463.1 kg)
Low-frequency cetaceans	213 / 219	3,850	2,000	4,850	2,520
Mid-frequency cetaceans	224 / 230	1,160	607	1,460	765
High-frequency cetaceans	196 / 202	24,900	12,900	31,400	16,200
Phocid pinnipeds	212 / 218	4,290	2,230	5,410	2,810
Sea turtles	226 / 232	935	490	1,180	617

J.8.2. Marine Mammals and Sea Turtles Gastrointestinal Injury by Peak Pressure Distances (Unmitigated)

The acoustic range results to injury thresholds in Table J-13 are for Onset Gastrointestinal Injury (based on effects observed in 1% of exposed animals) and Gastrointestinal Injury (effects observed in 50% of exposed animals). The peak pressure threshold listed here is based on studies on humans and mid-sized terrestrial animals and may not be conservative for smaller marine animals, less than approximately 50 kg. Further examination of this threshold is recommended before it is applied for smaller animals.

Table J-13. Maximum unmitigated acoustic ranges for Onset Gastrointestinal Injury (1% of exposed animals) and Gastrointestinal Injury (effects observed in 50% of exposed animals) due to peak pressure exposures for two UXO charge sizes with donor charge for all sites. The peak pressure threshold applied here is from row 6 of Table J-7. We do not recommend applying this threshold for animals with mass less than 50 kg.

Effect	L_{pk} Threshold (dB re 1 µPa)	Maximum distance to L_{pk} threshold for gastrointestinal injury (m) E10 + donor (231.5 kg)	Maximum distance to L_{pk} threshold for gastrointestinal injury (m) E12 + donor (463.1 kg)
Onset gastrointestinal injury (1% of exposed animals)	237	287	361
Gastrointestinal injury (50% of exposed animals)	243	152	191

J.8.3. Marine Mammals and Sea Turtles Onset Lung Injury by Impulse Distances (Unmitigated)

The impulse acoustic range results in this section represent the onset of lung injury based on the threshold formula in row 5 of Table J-7. These thresholds represent effects observed in 1% of exposed animals. Impulse levels and thresholds are depth-dependent, so maximum acoustic ranges vary between sites with different depths. Tables J-14 through J-18 present the results for the five sites evaluated.

Table J-14. Site UXO-1 (10.0 m water depth): Impulse acoustic range results (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	198	108	230	130
Minke whales	246	142	284	168
Beaked whales	314	221	361	256
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	428	303	489	349
Porpoises	463	325	529	373

Table J-15. Site UXO-2 (20.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	344	161	418	215
Minke whales	441	231	527	293
Beaked whales	579	391	681	471
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	809	558	938	657
Porpoises	880	602	1,020	707

Table J-16. Site UXO-3 (30.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	430	170	556	253
Minke whales	577	262	719	368
Beaked whales	775	501	947	634
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	1,040	749	1,280	911
Porpoises	1,120	804	1,370	985

Table J-17. Site UXO-4 (43.4 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	465	175	647	264
Minke whales	631	273	838	404
Beaked whales	840	546	1,080	744
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	1,140	814	1,410	1,050
Porpoises	1,220	876	1,510	1,120

Table J-18. Site UXO-5 (46.6 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	469	175	656	265
Minke whales	639	274	852	408
Beaked whales	854	553	1,090	754
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	1,160	824	1,430	1,060
Porpoises	1,240	888	1,530	1,140

J.8.4. Marine Mammals and Sea Turtles Onset of Mortality by Impulse Distances (Unmitigated)

The acoustic ranges in this section represent the onset of mortality based on the threshold formula in row 4 of Table J-7. These thresholds represent effects observed in 1% of exposed animals.

Impulse exposure levels and impulse effects thresholds are depth-dependent, so maximum acoustic ranges vary between sites with different depths. Interestingly, the trends of maximum horizontal exposure effects distance with water depth at each site are not always consistent. This occurs due to three reasons:

1. Impulse exposure, for a given animal submersion depth, depends on water depth because the seabed (and charge location) is further from the animal in deeper environments.
2. The impulse exposure is site and submersion depth-dependent because the impulse integration time depends on the minimum of arrival time of surface reflection and 20% of the lung oscillation period (which also depends on submersion depth)
3. The impulse criteria decrease with increased animal submersion depth.

The trends would be consistent had we calculated each table at a fixed animal submersion depth, but instead, we search for the maximum criterion exceedance distance over all possible animal submersion depths, in 1 m depth increments from the surface to seafloor. The maximum horizontal effects criteria acoustic ranges over all submersion depths are presented in Tables J-19 through J-23.

Table J-19. Site UXO-1 (10.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	128	65	152	82.2
Minke whales	161	89	190	109
Beaked whales	209	144	243	170
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	288	201	331	235
Porpoises	312	217	359	251

Table J-20. Site UXO-2 (20.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	201	77.4	260	117
Minke whales	270	121	337	172
Beaked whales	367	235	444	297
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	526	351	622	427
Porpoises	573	382	677	461

Table J-21. Site UXO-3 (30.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	221	78.2	318	121
Minke whales	309	126	424	189
Beaked whales	424	265	556	370
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	587	407	735	533
Porpoises	629	443	783	572

Table J-22. Site UXO-4 (43.4 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	229	75	336	123
Minke whales	326	127	453	196
Beaked whales	456	276	603	393
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	635	437	800	578
Porpoises	678	473	854	621

Table J-23. Site UXO-5 (46.6 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	230	73.4	339	123
Minke whales	329	127	458	197
Beaked whales	461	279	609	397
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	643	439	821	586
Porpoises	698	483	878	635

J.8.5. Fish Mortality and Injury (Unmitigated)

The acoustic ranges in this section represent the onset of mortality or injury based on the thresholds presented in Tables J-10 and J-11. Peak pressure (L_{pk}) acoustic ranges are not dependent on water depth or seabed properties, so the results of Table J-24 are relevant for all sites. The methods discussed in Supplement J.7.2 were applied to calculate SEL, at receiver depths from the surface to the seabed, versus distance and direction from each charge detonation. The maximum-over-depth results were extracted to estimate range to injury threshold for fish in Tables J-25 to Table J-35.

Table J-24. Maximum acoustic ranges for Onset of Injury or Mortality for all fish hearing groups due to peak pressure exposures for various UXO charge sizes with donor charge. The thresholds are described in this report's Tables J-10 and J-11.

Threshold	L_{pk} (dB re 1 µPa)	All sites: Maximum distance to L_{pk} threshold exceedance (m) E10 + donor (231.5 kg)	All sites: Maximum distance to L_{pk} threshold exceedance (m) E12 + donor (463.1 kg)
Onset injury	206	8,280	10,400
Onset mortality	229	676	852

Table J-25. Site UXO-1 (10.0 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	8,980	8,050	10,600	9,520
Fish greater than 2 g	187	6,340	5,680	7,500	6,770

Table J-26. Site UXO-2 (20.0 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	8,450	7,500	10,000	8,920
Fish greater than 2 g	187	5,940	5,260	7,170	6,350

Table J-27. Site UXO-3 (30.0 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	9,190	8,150	11,000	9,800
Fish greater than 2 g	187	6,500	5,770	7,820	6,990

Table J-28. Site UXO-4 (43.4 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing Group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	10,100	9,350	12,700	11,600
Fish greater than 2 g	187	6,980	6,440	8,550	7,950

Table J-29. Site UXO-5 (46.6 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing Group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	11,000	9,870	13,400	12,100
Fish greater than 2 g	187	7,510	6,930	9,400	8,530

Table J-30. Site UXO-1 (10.0 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	11,600	10,700	15,200	13,700
Fish greater than 2 g	187	7,250	6,460	9,170	8,280

Table J-31. Site UXO-2 (20.0 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	8,850	7,970	11,000	9,870
Fish greater than 2 g	187	5,870	5,300	7,340	6,540

Table J-32. Site UXO-3 (30.0 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	8,560	7,690	10,600	9,350
Fish greater than 2 g	187	6,160	5,460	7,400	6,600

Table J-33. Site UXO-4 (43.4 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing Group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	9,020	8,400	11,200	10,300
Fish greater than 2 g	187	6,390	5,930	7,820	7,280

Table J-34. Site UXO-5 (46.6 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing Group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	9,960	8,990	12,100	10,900
Fish greater than 2 g	187	7,090	6,480	8,690	7,880

J.8.6. Marine Mammals and Sea Turtles: PTS by SEL Distances (Unmitigated)

The methods discussed in Supplement J.7.2 were applied to calculate SEL, at receiver depths from the surface to the seabed, versus distance and direction from each charge detonation. The maximum-over-depth results were extracted over depth to create the type of noise maps shown in Figure J-9. Additional Information: PTS and TTS Exceedance Zone Maps (Unmitigated) provides this map and similar maps at all other sites for the 231.5 and 463.1 kg charge sizes.

Acoustic ranges to each of the marine mammal, sea turtle, and fish SEL PTS thresholds listed in Table J-5, were obtained from these maps in two ways:

- R_{max}: represents the maximum distance in any direction that the threshold was exceeded. This metric is often overly conservative for exposure estimates because it reflects the influence of coherent constructive interference effects, produced by most propagation loss models, due to model approximations of highly uniform environments. In practice, these coherent effects are almost always disrupted by rough interfaces and ocean inhomogeneities.
- $R_{95\%}$: represents the radius of a circle that encompasses 95% of the area predicted by the model to exceed the threshold. The circle radius is typically larger than the maximum distances in most directions, but it cuts off “fingers” of ensonification that protrude in a small number of directions. This metric is typically also conservative, but less so than the R_{max} distance.

The SEL effects thresholds are not dependent on animal depth, but SEL exposure levels generally are. For this reason, the acoustic ranges are based on the maximum exposure level over the entire water column depth. Tables J-35 to 44 provide the acoustic ranges to PTS thresholds.

The site-to-site variations in final acoustic ranges range 1–70% between sites and are attributed to dependence of propagation loss on water depth and bathymetry variations. The source spectrum of larger charges has greater relative low frequency sound energy than that of small charges, so propagation loss frequency dependence also affects the exceedance distance trends by charge size between sites. These features of location and charge size effects combine to produce non-uniform trends in acoustic ranges with site depth and charge size, although the trend variations are relatively small.

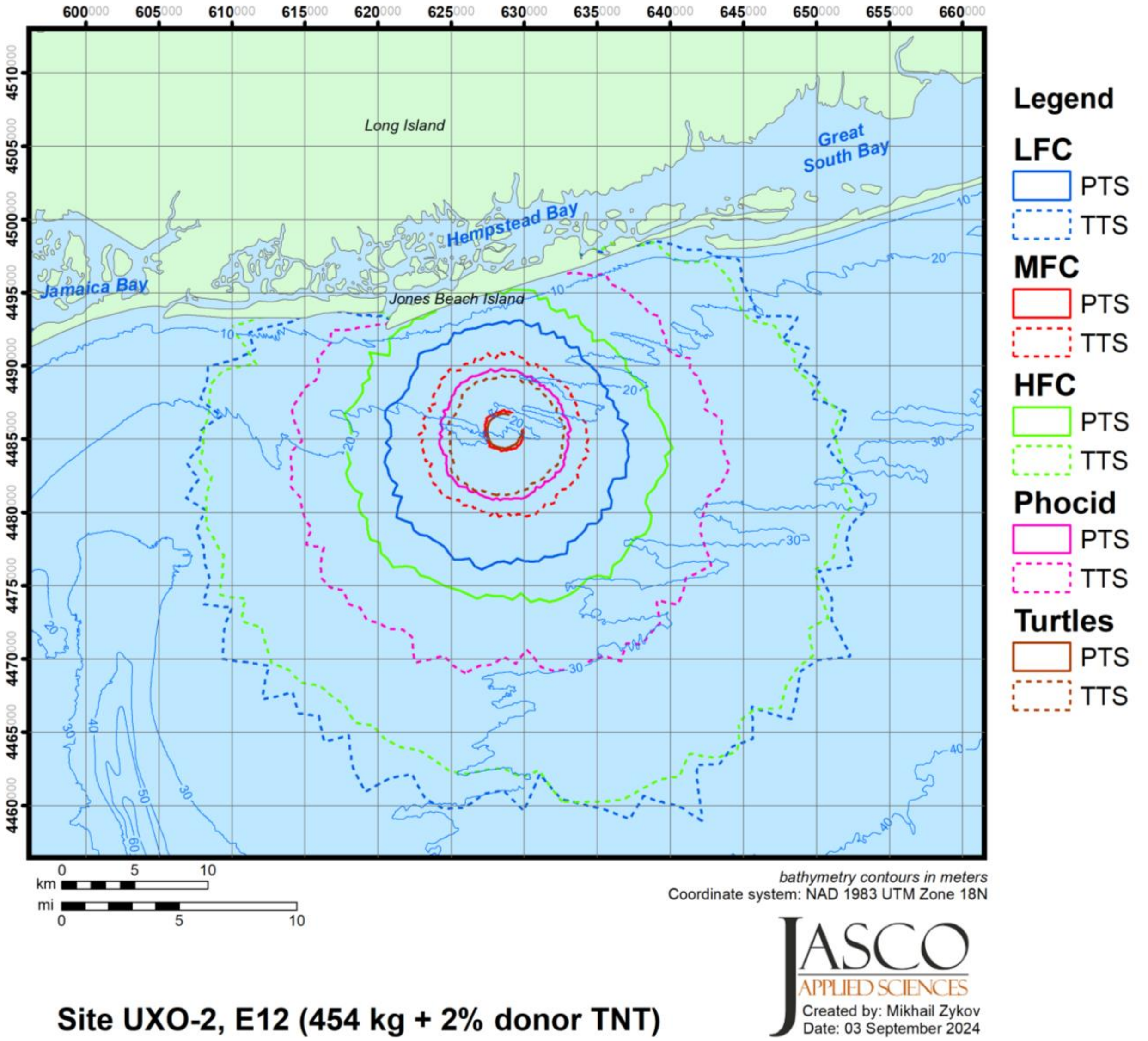

Figure J-9. Example of Frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone map, here for the 463.1 kg (454 kg + 2%) TNT equivalent charge size at Site UXO-2, for all species groups. The PTS and TTS thresholds are provided in Table J-5. The maps for 231.5 and 463.1 kg charge sizes at all other sites are provided in 0.

Table J-35. Site UXO-1 (10.0 m water depth), April: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 μPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	8,780	7,870	10,400	9,320
Mid-frequency cetaceans	185	1,230	1,060	1,560	1,350
High-frequency cetaceans	155	10,500	9,520	11,700	10,600
Phocid pinnipeds	185	4,550	4,190	5,570	5,070
Sea turtles	204	1,060	972	1,260	1,160

Table J-36. Site UXO-2 (20.0 m water depth), April: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 μPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	8,050	7,070	9,600	8,500
Mid-frequency cetaceans	185	1,190	1,070	1,480	1,320
High-frequency cetaceans	155	11,100	9,750	12,400	11,000
Phocid pinnipeds	185	4,000	3,600	4,890	4,420
Sea turtles	204	985	909	1,250	1,160

Table J-37. Site UXO-3 (30.0 m water depth), April: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 μPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	8,290	7,460	10,200	9,090
Mid-frequency cetaceans	185	981	900	1,500	1,280
High-frequency cetaceans	155	13,900	12,100	16,000	13,700
Phocid pinnipeds	185	4,130	3,690	5,280	4,680
Sea turtles	204	931	856	1,260	1,170

Table J-38. Site UXO-4 (43.4 m water depth), April: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	8,770	8,080	11,200	10,200
Mid-frequency cetaceans	185	1,030	838	1,280	1,210
High-frequency cetaceans	155	14,600	13,400	17,100	15,800
Phocid pinnipeds	185	3,710	3,460	4,980	4,510
Sea turtles	204	906	846	1,250	1,180

Table J-39. Site UXO-5 (46.6 m water depth), April: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	9,010	8,260	11,400	10,400
Mid-frequency cetaceans	185	1,130	904	1,310	1,260
High-frequency cetaceans	155	14,000	12,900	16,200	15,000
Phocid pinnipeds	185	3,790	3,420	4,380	4,160
Sea turtles	204	925	881	1,260	1,170

Table J-40. Site UXO-1 (10.0 m water depth), winter: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	11,300	10,400	14,800	13,400
Mid-frequency cetaceans	185	787	744	1,010	922
High-frequency cetaceans	155	11,600	10,800	14,400	13,400
Phocid pinnipeds	185	4,870	4,560	6,410	5,890
Sea turtles	204	1,050	960	1,240	1,140

Table J-41. Site UXO-2 (20.0 m water depth), winter: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	8,360	7,480	10,400	9,320
Mid-frequency cetaceans	185	651	605	789	734
High-frequency cetaceans	155	8,610	7,920	10,600	9,670
Phocid pinnipeds	185	3,740	3,310	4,440	4,080
Sea turtles	204	967	893	1,230	1,140

Table J-42. Site UXO-3 (30.0 m water depth), winter: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	7,550	6,810	9,420	8,390
Mid-frequency cetaceans	185	595	553	725	684
High-frequency cetaceans	155	8,310	7,590	9,810	8,480
Phocid pinnipeds	185	3,220	2,970	3,880	3,600
Sea turtles	204	908	837	1,230	1,140

Table J-43. Site UXO-4 (43.4 m water depth), winter: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	7,810	7,210	9,710	8,870
Mid-frequency cetaceans	185	550	523	700	660
High-frequency cetaceans	155	7,870	7,250	8,510	7,890
Phocid pinnipeds	185	3,000	2,800	3,730	3,460
Sea turtles	204	868	822	1,230	1,150

Table J-44. Site UXO-5 (46.6 m water depth), winter: SEL-based acoustic ranges for PTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	8,160	7,460	9,960	9,160
Mid-frequency cetaceans	185	556	523	705	660
High-frequency cetaceans	155	8,470	6,920	9,070	7,970
Phocid pinnipeds	185	3,130	2,860	3,950	3,640
Sea turtles	204	910	868	1,200	1,140

J.8.7. Marine Mammals and Sea Turtles: TTS by SEL Distances (Unmitigated)

The SEL distances thresholds are not dependent on animal depth, but the SEL exposure levels are. The TTS threshold acoustic ranges provided in Tables J-45 through J-54 are maximum-over-depth.

Table J-45. Site UXO-1 (10.0 m water depth), April: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	25,000	22,500	29,000	25,400
Mid-frequency cetaceans	170	5,440	4,920	6,410	57,10
High-frequency cetaceans	140	21,200	19,400	23,400	21,200
Phocid pinnipeds	170	15,400	14,100	17,700	16,100
Sea turtles	189	3,160	2,880	3,700	3,380

Table J-46. Site UXO-2 (20.0 m water depth), April: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	25,900	21,800	29,900	24,600
Mid-frequency cetaceans	170	5,260	4,770	6,110	5,550
High-frequency cetaceans	140	24,600	21,300	27,100	23,500
Phocid pinnipeds	170	15,200	13,300	17,700	15,300
Sea turtles	189	3,810	3,430	4,590	4,100

Table J-47. Site UXO-3 (30.0 m water depth), April: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	30,300	26,800	35,500	31,500
Mid-frequency cetaceans	170	5,980	5,360	7,140	6,410
High-frequency cetaceans	140	32,300	28,800	36,700	32,200
Phocid pinnipeds	170	18,600	16,200	21,500	18,900
Sea turtles	189	4,330	3,750	5,330	4,580

Table J-48. Site UXO-4 (43.4 m water depth), April: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	45,200	39,900	>50,000	>50,000
Mid-frequency cetaceans	170	5,470	5,100	6,900	6,180
High-frequency cetaceans	140	45,500	41,400	>50,000	>50,000
Phocid pinnipeds	170	22,600	20,400	28,100	25,200
Sea turtles	189	4,340	3,960	5,430	4,980

Table J-49. Site UXO-5 (46.6 m water depth), April: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	41,700	37,100	>50,000	>50,000
Mid-frequency cetaceans	170	5,400	5,060	6,660	5,990
High-frequency cetaceans	140	42,000	37,000	>50,000	>50,000
Phocid pinnipeds	170	20,400	18,500	25,200	22,200
Sea turtles	189	4,600	4,280	5,870	5,380

Table J-50. Site UXO-1 (10.0 m water depth), winter: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	>50,000	>50,000	>50,000	>50,000
Mid-frequency cetaceans	170	4,660	4,360	5,210	4,900
High-frequency cetaceans	140	48,900	44,900	>50,000	>50,000
Phocid pinnipeds	170	34,200	30,900	44,000	38,900
Sea turtles	189	3,170	2,890	3,730	3,410

Table J-51. Site UXO-2 (20.0 m water depth), winter: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	48,300	41,000	>50,000	>50,000
Mid-frequency cetaceans	170	3,900	3,500	4,330	4,050
High-frequency cetaceans	140	35,700	31,900	42,200	37,700
Phocid pinnipeds	170	21,100	18,700	26,500	23,400
Sea turtles	189	3,850	3,450	4,650	4,150

Table J-52. Site UXO-3 (30.0 m water depth), winter: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	37,700	33,700	48,400	43,200
Mid-frequency cetaceans	170	3,300	3,020	3,660	3,470
High-frequency cetaceans	140	33,100	29,500	38,900	34,900
Phocid pinnipeds	170	18,000	16,000	22,600	20,100
Sea turtles	189	4,220	3,690	5,240	4,530

Table J-53. Site UXO-4 (43.4 m water depth), winter: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	38,300	34,100	>50,000	>50,000
Mid-frequency cetaceans	170	3,010	2,770	3,370	3,130
High-frequency cetaceans	140	30,100	27,200	35,300	32,100
Phocid pinnipeds	170	17,500	15,600	21,900	19,600
Sea turtles	189	4,200	3,840	5,230	4,790

Table J-54. Site UXO-5 (46.6 m water depth), winter: SEL-based acoustic ranges for TTS onset for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	36,800	32,000	45,900	40,500
Mid-frequency cetaceans	170	3,140	2,890	3,410	3,160
High-frequency cetaceans	140	29,000	25,700	34,000	30,100
Phocid pinnipeds	170	16,900	14,800	20,800	18,500
Sea turtles	189	4,500	4,180	5,660	5,210

J.9. Exceedance Distance Results with 10 dB Mitigation

This section provides acoustic ranges assuming a 10 dB reduction to the exposure pressures and SEL achieved via mitigation measures (e.g., bubble curtain or similar system).

J.9.1. Marine Mammals and Sea Turtles TTS and PTS by Peak Pressure Distances with 10 dB Mitigation

Peak pressure (L_{pk}) acoustic ranges are not dependent on water depth or seabed properties, so the results in Table J-55 are relevant for all sites.

Table J-55. Marine mammals and sea turtles permanent threshold shift (PTS) and temporary threshold shift (TTS) maximum acoustic ranges for peak pressure (L_{pk}) using 10 dB mitigation for various UXO charge sizes with donor charges for all sites, based on thresholds from Table J-5.

Hearing group	TTS / PTS L_{pk} Threshold (dB re 1 µPa)	Maximum distances (m) to threshold for peak pressure E10 + donor (231.5 kg) TTS	Maximum distances (m) to threshold for peak pressure E10 + donor (231.5 kg) PTS	Maximum distances (m) to threshold for peak pressure E12 + donor (463.1 kg) TTS	Maximum distances (m) to threshold for peak pressure E12 + donor (463.1 kg) PTS
Low-frequency cetaceans	213 / 219	1,290	676	1,630	852
Mid-frequency cetaceans	224 / 230	395	209	498	263
High-frequency cetaceans	196 / 202	8,280	4,290	10,400	5,410
Phocid pinnipeds	212 / 218	1,440	753	1,820	949
Sea turtles	226 / 232	319	169	402	213

J.9.2. Marine Mammals and Sea Turtles Gastrointestinal Injury by Peak Pressure Distances with 10 dB Mitigation

The acoustic ranges to threshold in Table J-56 are for Onset Gastrointestinal Injury (effects observed in 1% of exposed animals) and Gastrointestinal Injury (effects observed in 50% of exposed animals).

Table J-56. Maximum mitigated acoustic ranges for Onset Gastrointestinal Injury (1% of exposed animals) and Gastrointestinal Injury (effects observed in 50% of exposed animals) due to peak pressure exposures for two UXO charge sizes with donor charge. The peak pressure threshold applied here is from row 6 of Table J-7. We do not recommend applying this threshold for animals with mass less than 50 kg.

Effect	L_{pk} threshold (dB re 1 µPa)	All sites: Maximum distance to L_{pk} threshold for gastrointestinal injury (m) E10 + donor (231.5 kg)	All sites: Maximum distance to L_{pk} threshold for gastrointestinal injury (m) E12 + donor (463.1 kg)
Onset gastrointestinal injury (1% of exposed animals)	237	99.8	126
Gastrointestinal Injury (50% of exposed animals)	243	53.8	67.8

J.9.3. Marine Mammals and Sea Turtles Onset of Lung Injury Distances for Impulse with 10 dB Mitigation

The impulse threshold acoustic ranges in this section represent the onset of lung injury based on the threshold formula in row 5 of Table J-7. These thresholds represent effects observed in 1% of exposed animals and this section assumes 10 dB mitigation.

Impulse levels and thresholds are depth-dependent, so maximum acoustic ranges could vary between sites with different depths. The results for each of the sites evaluated are presented in Tables J-57 to J-61.

Table J-57. Site UXO-1 (10.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12+ donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	102	48.2	123	64.2
Minke whales	130	69	155	87
Beaked whales	170	116	199	139
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	236	164	273	192
Porpoises	256	177	296	207

Table J-58. Site UXO-2 (20.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	148	52.2	201	81
Minke whales	206	84.2	265	126
Beaked whales	287	176	356	232
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	400	275	505	341
Porpoises	432	301	540	371

Table J-59. Site UXO-3 (30.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	155	50.2	229	82.6
Minke whales	223	85.4	310	132
Beaked whales	314	187	415	269
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	438	299	555	398
Porpoises	471	326	595	430

Table J-60. Site UXO-4 (43.4 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	158	45.4	238	80.2
Minke whales	233	83	329	134
Beaked whales	333	194	445	284
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	473	318	606	431
Porpoises	510	346	651	463

Table J-61. Site UXO-5 (46.6 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 5 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	159	44.6	240	79.4
Minke whales	233	82.2	334	135
Beaked whales	335	194	454	286
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	476	319	613	434
Porpoises	517	351	654	470

J.9.4. Marine Mammals and Sea Turtles Onset of Mortality Distances by Impulse with 10 dB Mitigation

The acoustic ranges in this section represent the onset of mortality based on the threshold formula in row 4 of Table J-7 and assuming 10 dB of sound level reduction is obtained through a noise mitigation device. These thresholds represent effects observed in 1% of exposed animals.

Impulse levels and thresholds are depth-dependent, so maximum acoustic ranges vary between sites with different depths. The results for the five sites evaluated are presented in Tables J-62 to J-66.

Table J-62. Site UXO-1 (10.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	60.2	22.2	77.4	34.2
Minke whales	80.6	36.2	99.4	51
Beaked whales	109	70.2	131	88.2
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	155	104	182	126
Porpoises	169	113	198	136

Table J-63. Site UXO-2 (20.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	70.2	21	106	35
Minke whales	105	36.6	151	59
Beaked whales	153	86.2	207	128
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	221	145	284	198
Porpoises	237	160	303	215

Table J-64. Site UXO-3 (30.0 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	70.2	19.8	110	32.2
Minke whales	107	33.4	159	58.2
Beaked whales	161	87.8	222	134
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	236	152	306	213
Porpoises	256	169	333	231

Table J-65. Site UXO-4 (43.4 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	65.8	18.6	111	30.2
Minke whales	107	31.4	165	52.6
Beaked whales	167	85.4	235	137
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	251	157	327	223
Porpoises	269	175	357	246

Table J-66. Site UXO-5 (46.6 m water depth): Impulse acoustic ranges (meters) for marine mammals and sea turtles, for Onset of Mortality with 10 dB mitigation for two UXO charge sizes with donor charge. The Impulse threshold is dependent on animal mass and submersion depth and based on the formula in row 4 of Table J-7.

Marine mammal group	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E10 + donor (231.5 kg) Adult	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Calf/Pup	Impulse threshold acoustic ranges for onset lung injury (m) E12 + donor (463.1 kg) Adult
Large baleen whales and sperm whales	64.2	18.2	110	29.8
Minke whales	107	30.6	165	51.4
Beaked whales	166	84.6	237	137
Dolphins, *Kogia* spp., pinnipeds, and sea turtles	250	157	336	227
Porpoises	273	175	357	246

J.9.5. Fish Mortality and Injury Distances with 10 dB Mitigation

The acoustic ranges in this section represent the onset of mortality or injury based on the thresholds presented in Tables J-10 and J-11. Peak pressure (L_{pk}) acoustic ranges are not dependent on water depth or seabed properties, so the results of Table J-67 are relevant for all sites. The methods discussed in Supplement J.7.2 were applied to calculate SEL, at receiver depths from the surface to the seabed, versus distance and direction from each charge detonation. The maximum-over-depth ranges to injury threshold for fish are presented in in Tables J-67 to J-77

Table J-67. Maximum acoustic ranges for Onset of Injury for fish without and with a swim bladder due to peak pressure exposures with 10 dB mitigation for two UXO charge sizes with donor charge. The thresholds are described in this report's Tables J-10 and J-11.

Threshold	L_{pk} (dB re 1 µPa)	All sites: Maximum distance to L_{pk} onset injury threshold exceedance (m) E10 + donor (231.5 kg)	All sites: Maximum distance to L_{pk} onset injury threshold exceedance (m) E12 + donor (463.1 kg)
Onset injury	206	2,770	3,490
Onset mortality	229	232	292

Table J-68. Site UXO-1 (10.0 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	3,540	3,250	4,330	3,980
Fish greater than 2 g	187	2,430	2,240	2,960	2,700

Table J-69. Site UXO-2 (20.0 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	3,460	3,160	4,280	3,840
Fish greater than 2 g	187	2,450	2,230	2,990	2,720

Table J-70. Site UXO-3 (30.0 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	3,850	3,460	4,790	4,210
Fish greater than 2 g	187	2,680	2,460	3,320	3,000

Table J-71. Site UXO-4 (43.4 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	4,040	3,710	5,070	4,660
Fish greater than 2 g	187	2,780	2,590	3,560	3,240

Table J-72. Site UXO-5 (46.6 m water depth), April: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	4,380	4,120	5,540	5,150
Fish greater than 2 g	187	3,020	2,870	3,900	3,660

Table J-73. Site UXO-1 (10.0 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	3,610	3,320	4,610	4,240
Fish greater than 2 g	187	2,420	2,220	3,000	2,740

Table J-74. Site UXO-2 (20.0 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	3,390	3,090	4,230	3,800
Fish greater than 2 g	187	2,400	2,170	2,930	2,660

Table J-75. Site UXO-3 (30.0 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	3,650	3,290	4,550	3,990
Fish greater than 2 g	187	2,530	2,350	3,190	2,900

Table J-76. Site UXO-4 (43.4 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	3,820	3,520	4,750	4,380
Fish greater than 2 g	187	2,660	2,480	3,380	3,100

Table J-77. Site UXO-5 (46.6 m water depth), winter: SEL-based acoustic ranges for NMFS criteria for all fish hearing groups for two UXO charge sizes including 2% donor charge with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Tables J-10 and J-11.

Hearing group	Threshold $L_{E,24h}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Fish less than or equal 2 g	183	4,230	3,960	5,250	4,900
Fish greater than 2 g	187	2,940	2,790	3,760	3,530

J.9.6. Marine Mammals and Sea Turtles: PTS Distances by SEL with 10 dB Mitigation

The SEL effects thresholds are not dependent on animal depth, but the exposure levels are. The PTS threshold acoustic ranges provided in Tables J-78 to J-87 are maximum-over-depth.

Table J-78. Site UXO-1 (10.0 m water depth), April: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	3,380	3,070	4,140	3,800
Mid-frequency cetaceans	185	272	253	437	382
High-frequency cetaceans	155	5,700	5,120	6,600	5,870
Phocid pinnipeds	185	1,430	1,320	1,870	1,710
Sea turtles	204	422	398	544	509

Table J-79. Site UXO-2 (20.0 m water depth), April: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	3,010	2,750	3,750	3,400
Mid-frequency cetaceans	185	224	201	405	368
High-frequency cetaceans	155	5,550	5,050	6,460	5,810
Phocid pinnipeds	185	1,180	1,100	1,590	1,420
Sea turtles	204	291	272	418	386

Table J-80. Site UXO-3 (30.0 m water depth), April: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	3,020	2,780	3,840	3,490
Mid-frequency cetaceans	185	172	161	234	221
High-frequency cetaceans	155	6,340	5,730	7,520	6,760
Phocid pinnipeds	185	1,010	961	1,560	1,370
Sea turtles	204	244	228	342	322

Table J-81. Site UXO-4 (43.4 m water depth), April: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	2,860	2,690	3,830	3,580
Mid-frequency cetaceans	185	156	144	201	189
High-frequency cetaceans	155	5,790	5,390	7,190	6,680
Phocid pinnipeds	185	1,040	978	1,350	1,290
Sea turtles	204	228	209	311	291

Table J-82. Site UXO-5 (46.6 m water depth), April: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	2,990	2,810	3,920	3,680
Mid-frequency cetaceans	185	144	141	204	189
High-frequency cetaceans	155	5,880	5,430	7,130	6,390
Phocid pinnipeds	185	988	948	1,290	1,230
Sea turtles	204	184	184	312	301

Table J-83. Site UXO-1 (10.0 m water depth), winter: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	3,430	3,160	4,420	4,040
Mid-frequency cetaceans	185	260	243	333	310
High-frequency cetaceans	155	3,730	3,500	4,930	4,680
Phocid pinnipeds	185	1,400	1,280	1,790	1,640
Sea turtles	204	412	393	533	500

Table J-84. Site UXO-2 (20.0 m water depth), winter: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	2,900	2,630	3,710	3,330
Mid-frequency cetaceans	185	190	184	247	234
High-frequency cetaceans	155	3,830	2,850	4,260	3,960
Phocid pinnipeds	185	1,000	914	1,330	1,210
Sea turtles	204	286	268	405	381

Table J-85. Site UXO-3 (30.0 m water depth), winter: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	2,880	2,620	3,560	3,230
Mid-frequency cetaceans	185	161	152	216	209
High-frequency cetaceans	155	3,300	3,010	3,610	3,420
Phocid pinnipeds	185	865	814	1,190	1,070
Sea turtles	204	234	224	341	316

Table J-86. Site UXO-4 (43.4 m water depth), winter: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	2,820	2,640	3,530	3,260
Mid-frequency cetaceans	185	152	141	200	184
High-frequency cetaceans	155	3,010	2,780	3,330	3,100
Phocid pinnipeds	185	761	716	1,020	973
Sea turtles	204	228	209	306	291

Table J-87. Site UXO-5 (46.6 m water depth), winter: SEL-based acoustic ranges for PTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	183	2,950	2,740	3,720	3,470
Mid-frequency cetaceans	185	141	140	200	184
High-frequency cetaceans	155	3,160	2,920	3,350	3,120
Phocid pinnipeds	185	735	702	1,020	956
Sea turtles	204	184	184	310	301

J.9.7. Marine Mammals and Sea Turtles: TTS Distances by SEL with 10 dB Mitigation

The SEL effects thresholds are not dependent on animal depth, but the exposure levels are. The TTS threshold acoustic ranges provided in Tables J-88 to J-97are maximum-over-depth.

Table J-88. Site UXO-1 (10.0 m water depth), April: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	12,900	11,800	14,800	13,600
Mid-frequency cetaceans	170	2,140	1,940	2,740	2,410
High-frequency cetaceans	140	13,600	12,300	14,900	13,500
Phocid pinnipeds	170	7,380	6,660	8,690	7,910
Sea turtles	189	1,550	1,410	1,820	1,660

Table J-89. Site UXO-2 (20.0 m water depth), April: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	12,300	10,700	14,300	12,600
Mid-frequency cetaceans	170	2,130	1,850	2,680	2,350
High-frequency cetaceans	140	14,800	12,900	16,700	14,400
Phocid pinnipeds	170	6,510	5,850	7,910	7,080
Sea turtles	189	1,580	1,460	2,010	1,840

Table J-90. Site UXO-3 (30.0 m water depth), April: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	13,400	11,800	16,000	14,100
Mid-frequency cetaceans	170	2,100	1,770	2,550	2,310
High-frequency cetaceans	140	19,000	16,500	21,200	18,600
Phocid pinnipeds	170	7,220	6,450	8,860	7,910
Sea turtles	189	1,620	1,500	2,120	1,970

Table J-91. Site UXO-4 (43.4 m water depth), April: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	15,300	13,900	19,700	17,600
Mid-frequency cetaceans	170	1,530	1,450	1,910	1,790
High-frequency cetaceans	140	22,000	20,100	25,600	23,400
Phocid pinnipeds	170	7,100	6,510	9,070	8,310
Sea turtles	189	1,620	1,530	2,090	1,950

Table J-92. Site UXO-5 (46.6 m water depth), April: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	15,000	13,800	18,700	16,900
Mid-frequency cetaceans	170	1,520	1,440	1,770	1,640
High-frequency cetaceans	140	20,400	18,600	23,800	21,300
Phocid pinnipeds	170	6,750	6,280	8,820	8,070
Sea turtles	189	1,690	1,600	2,210	2,090

Table J-93. Site UXO-1 (10.0 m water depth), winter: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	21,800	19,700	28,100	25,300
Mid-frequency cetaceans	170	1,580	1,450	1,850	1,730
High-frequency cetaceans	140	19,600	18,200	23,800	22,100
Phocid pinnipeds	170	9,470	8,650	12,300	11,300
Sea turtles	189	1,530	1,400	1,800	1,640

Table J-94. Site UXO-2 (20.0 m water depth), winter: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	14,300	12,800	18,300	16,100
Mid-frequency cetaceans	170	1,100	985	1,480	1,300
High-frequency cetaceans	140	14,400	12,900	17,500	15,600
Phocid pinnipeds	170	6,330	5,820	8,230	7,490
Sea turtles	189	1,560	1,440	2,000	1,820

Table J-95. Site UXO-3 (30.0 m water depth), winter: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	12,900	11,800	16,300	14,700
Mid-frequency cetaceans	170	996	928	1,200	1,140
High-frequency cetaceans	140	12,200	10,600	14,600	13,100
Phocid pinnipeds	170	5,580	5,120	7,480	6,450
Sea turtles	189	1,590	1,500	2,030	1,900

Table J-96. Site UXO-4 (43.4 m water depth), winter: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	12,900	11,800	16,300	14,700
Mid-frequency cetaceans	170	996	928	1,200	1,140
High-frequency cetaceans	140	12,200	10,600	14,600	13,100
Phocid pinnipeds	170	5,580	5,120	7,480	6,450
Sea turtles	189	1,590	1,500	2,030	1,900

Table J-97. Site UXO-5 (46.6 m water depth), winter: SEL-based acoustic ranges for TTS onset with 10 dB mitigation for two UXO charge sizes including 2% donor charge: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to thresholds from Table J-5.

Hearing group	Threshold $L_{E,w}$ (dB re 1 µPa²s)	E10 + donor (231.5 kg) R_{max}	E10 + donor (231.5 kg) $R_{95\%}$	E12 + donor (463.1 kg) R_{max}	E12 + donor (463.1 kg) $R_{95\%}$
Low-frequency cetaceans	168	12,900	11,900	16,100	14,600
Mid-frequency cetaceans	170	1,010	923	1,180	1,120
High-frequency cetaceans	140	11,900	10,500	14,500	12,800
Phocid pinnipeds	170	5,850	5,220	7,070	6,480
Sea turtles	189	1,670	1,570	2,170	2,050

J.10. Exposure Calculations

J.10.1. Summary Acoustic Range Results

Acoustic area results from Supplement J.8 and J.9 used to calculate exposures are summarized in the tables below for both the unmitigated and 10 dB attenuation cases. In addition to SEL-based $R_{95\%}$ PTS (Level-A) and TTS (Level-B) isopleths reported in the previous sections, Tables J-98 and J-105 report equivalent areas at each of the five modeling sites, representing various water depths, which were used to calculate exposures as described in Supplement J.10.3.

Table J-98. E10 charge size: SEL-based equivalent areas (km²) to Level A (PTS onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming no attenuation.

Hearing group	Threshold (dB re 1 µPa²s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	183	108.71	149.48	179.39	213.03	225.48	168.51	152.84	145.60	165.68	183.08
MF	185	3.6216	3.5936	2.6652	1.6440	1.7612	1.8288	1.2092	1.0052	0.9020	0.9028
HF	155	169.69	284.77	453.45	585.26	550.53	199.99	175.16	167.37	155.54	144.62
PW	185	37.452	41.208	44.050	38.283	36.661	41.331	32.575	27.642	25.113	26.629
TU	204	2.6780	2.6688	2.4156	2.3688	2.5684	2.6172	2.5532	2.2952	2.2368	2.4984

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

Table J-99. E10 charge size: SEL-based equivalent areas (km^2) to Level B (TTS-onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming no attenuation.

Hearing group	Threshold (dB re 1 µPa^{2}s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	168	803.40	1,098.5	1,783.5	3,770.5	3,750.2	3,661.5	2,794.8	2,340.2	2,837.7	2,774.5
MF	170	50.266	71.220	93.363	83.231	75.718	36.359	28.991	27.937	24.429	25.880
HF	140	667.19	1,075.1	2,048.8	4,215.9	3,918.6	3,135.6	2,060.1	1,897.6	1,895.7	1,755.2
PW	170	344.15	493.83	753.76	1,237.3	1,120.9	1,389.0	779.32	679.89	704.79	690.87
TU	189	17.182	35.676	44.063	51.621	60.348	17.126	35.664	42.292	48.346	57.444

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

Table J-100. E12 charge size: SEL-based equivalent areas (km^2) to Level A (PTS onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming no attenuation.

Hearing group	Threshold (dB re 1 µPa^{2}s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	183	148.25	210.03	262.74	336.16	356.52	269.65	227.03	218.78	249.20	276.54
MF	185	5.6892	5.6596	3.9732	4.8320	5.2388	2.7496	1.7768	1.5472	1.4272	1.4384
HF	155	207.97	353.74	573.98	796.48	743.24	297.75	249.99	219.54	196.20	199.60
PW	185	52.488	61.254	71.288	65.588	57.258	63.868	1,134.1	42.263	39.254	43.309
TU	204	3.6292	4.2884	4.2304	4.5376	4.5236	3.5384	4.1576	4.0444	4.2692	4.2980

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

Table J-101. E12 charge size: SEL-based equivalent areas (km^2) to Level B (TTS-onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming no attenuation.

Hearing group	Threshold (dB re 1 µPa^{2}s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	168	1,014.6	1,355.4	2,307.9	5,093.8	5,338.8	3,781.6	39,89.7	3,467.6	4,224.1	4,215.2
MF	170	65.570	96.060	133.63	124.07	117.22	49.460	49.402	39.047	31.834	32.913
HF	140	786.83	1,256.0	2,441.9	5,261.9	4,918.3	3,742.5	2,772.6	2,528.0	2,535.4	2,358.9
PW	170	439.65	623.20	989.69	1,780.6	1,594.1	2,196.2	1,134.1	994.59	1,060.5	1,017.4
TU	189	22.266	50.008	66.006	81.298	95.254	22.410	50.560	63.900	75.314	89.055

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

Table J-102. E10 charge size: SEL-based equivalent areas (km^2) to Level A (PTS onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming 10 dB attenuation.

Hearing group	Threshold (dB re 1 µPa^{2}s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	183	21.136	24.250	24.498	23.815	26.101	21.484	22.136	21.161	22.416	24.824
MF	185	0.2088	0.1316	0.0824	0.0680	0.0620	0.1952	0.1108	0.0780	0.0636	0.0600
HF	155	54.158	80.126	107.11	94.613	94.597	28.056	25.676	27.499	24.546	26.176
PW	185	5.3576	3.8976	3.0480	2.8796	2.9716	4.8568	2.7548	2.1880	1.6940	1.6316
TU	204	0.4972	0.2488	0.1656	0.1392	0.1108	0.4824	0.2364	0.1616	0.1264	0.1108

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

Table J-103. E10 charge size: SEL-based equivalent areas (km²) to Level B (TTS-onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming 10 dB attenuation.

Hearing group	Threshold (dB re 1 µPa²s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	168	230.22	328.45	428.71	605.17	624.16	549.25	399.95	370.34	428.86	463.46
MF	170	10.473	10.906	9.9408	6.9684	6.8360	5.8616	3.2008	2.9636	2.8480	2.8248
HF	140	276.01	470.13	797.77	1,233.4	1,133.4	535.89	421.40	383.81	346.76	340.83
PW	170	84.838	107.15	134.96	138.56	129.41	126.72	99.855	88.151	82.956	89.113
TU	189	5.1552	6.8396	6.9836	7.5436	8.4120	5.0424	6.6308	6.7036	7.2756	8.0436

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

Table J-104. E12 charge size: SEL-based equivalent areas (km²) to Level A (PTS onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming 10 dB attenuation.

Hearing group	Threshold (dB re 1 µPa²s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	183	30.136	36.570	38.938	42.100	44.534	31.984	34.106	32.716	34.704	39.742
MF	185	0.4160	0.3112	0.1472	0.1168	0.1148	0.3164	0.1812	0.1396	0.1128	0.1108
HF	155	69.011	105.20	148.55	144.56	132.17	44.534	45.861	37.452	31.032	31.877
PW	185	8.3444	6.6032	5.6348	5.5320	5.0164	7.4932	4.7696	3.7448	3.1268	3.0176
TU	204	0.8028	0.4952	0.3392	0.2832	0.3020	0.7780	0.4680	0.3300	0.2816	0.3004

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

Table J-105. E12 charge size: SEL-based equivalent areas (km²) to Level B (TTS-onset) ($R_{95\%}$) for modeling sites UXO-1 to UXO-5 assuming 10 dB attenuation.

Hearing group	Threshold (dB re 1 µPa²s)	UXO-1 Summer	UXO-2 Summer	UXO-3 Summer	UXO-4 Summer	UXO-5 Summer	UXO-1 Winter	UXO-2 Winter	UXO-3 Winter	UXO-4 Winter	UXO-5 Winter
LF	168	302.25	436.40	598.13	931.45	939.82	887.87	590.22	551.93	651.67	686.91
MF	170	15.037	17.358	16.276	10.440	8.8560	8.2324	5.3980	4.4624	4.2760	4.1600
HF	140	333.01	560.33	980.09	1,614.3	1,472.3	781.14	588.34	542.60	505.04	489.00
PW	170	115.70	153.60	201.58	226.45	215.00	207.26	154.67	128.13	131.68	138.60
TU	189	6.7848	10.806	11.714	12.546	14.485	6.6444	10.537	11.105	11.894	13.933

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

J.10.2. Density Calculations

Marine mammal densities in the project area were estimated using the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Density Models for the US Atlantic (Roberts et al. 2016, 2023, 2024). 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 in the potential impact area were estimated using the East Coast sea turtle density models developed by the US Naval Undersea Warfare Center (NUWC; DiMatteo et al. 2024).

Figure J-3 shows the five acoustic modeling locations, and Table J-2 summarizes their depths. For density calculations, sites were separated based on their location within the project area; UXO-1, UXO-2, and UXO-3 are along the OECC, while UXO-4, and UXO-5 are in the Lease Area. Even though modeling site UXO-3 is situated along the OECC, its modeled ensonified area fell within the density perimeter around the Lease Area, so it was conservatively treated as part of the Lease Area. Monthly density was then calculated for each species within the two distinct areas. To capture all density data within the highest impact area, the largest SEL-based TTS-onset acoustic ranges (see Table J-45 to J-54) were applied to the two areas across all hearing groups. Figure J-10 shows the two areas and their density perimeters used in these calculations, which are summarized in Tables J-106 and J-107. It is expected that UXO detonation will only occur during the months of May to December. As a conservative measure, the month in this range with the highest density among the areas of interest for each species was applied to the exposure calculations. Monthly densities for each species in these perimeters were calculated as the average of the densities from all MGEL/Duke model grid cells that overlap partially or completely with each area of interest. Cells entirely on land were not included, but cells that overlap only partially with land were included. To obtain the most conservative exposure estimates, the maximum monthly density for each species in winter and summer was used to calculate exposures.

The MGEL/Duke models report densities for two species guilds considered in this study: pilot whales and seals. When calculating exposures for individual pilot whale and seal species, the guild densities provided by Roberts et al. (2016, 2023, 2024) 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 were downloaded from the Ocean Biodiversity Information System (OBIS) data repository (available at https://obis.org). The best data available for pilot whales came from the Mystic Aquarium data set of marine mammal strandings in the region, due to their overlap with the project area. The proportions of 0.93 for long-finned and 0.07 for short-finned pilot whales were used (Smith 2014). For the two seal species, 2022–2023 protected species observer (PSO) sighting data from the 0544 Lease Area was insufficient, so proportions of seals were determined from OBIS data as cited in the Final Rule for the adjacent Empire Wind project: 0.34 for gray seals and 0.66 for harbor seals (DoC and NOAA 2024). The maximum monthly densities for each species from May through December used to estimate exposures above the Levels A and B acoustic thresholds during potential UXO detonations for 0544 are shown in Table J-106 for marine mammals and sea turtles.

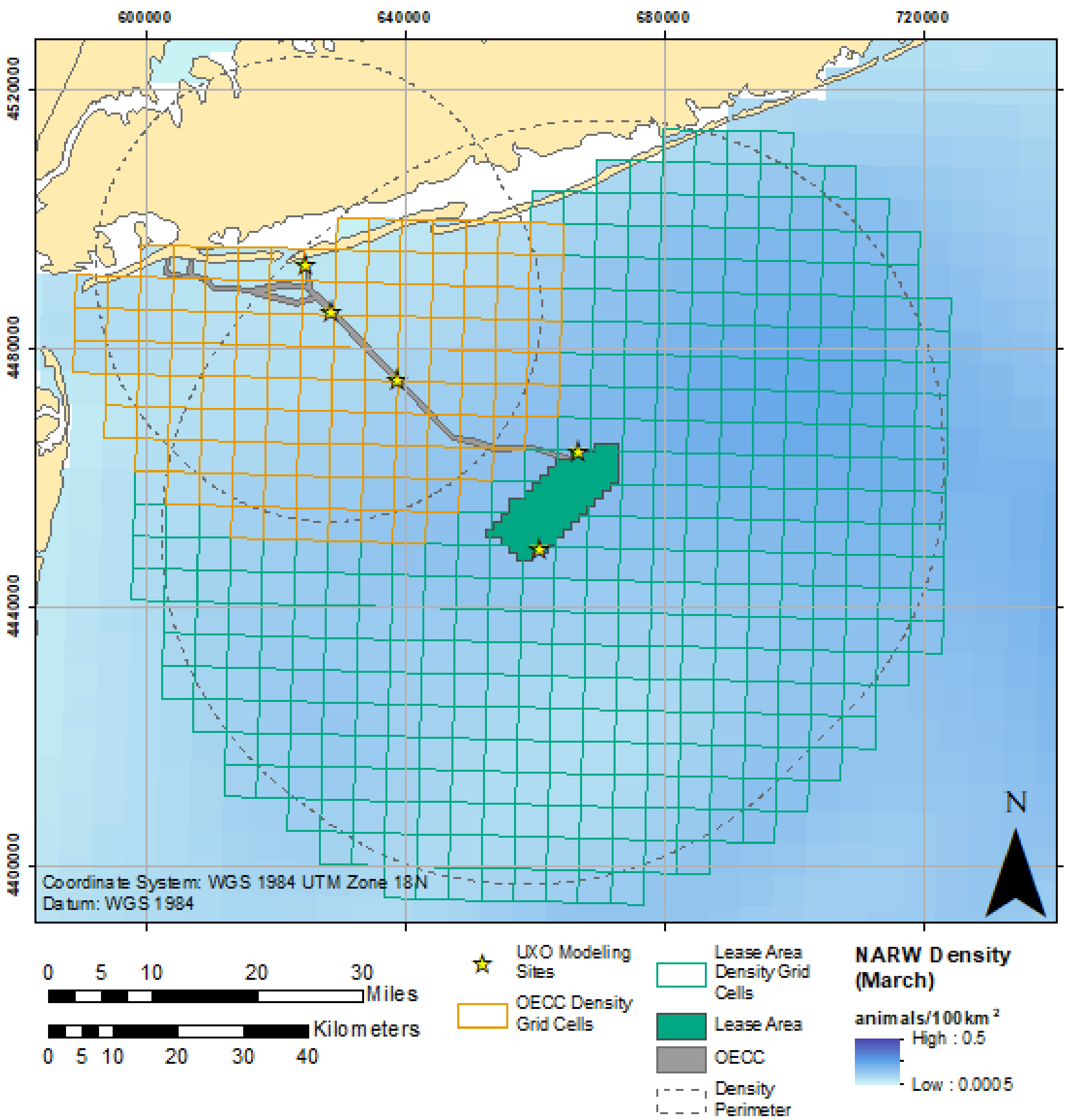

Figure J-10. Marine mammal (e.g., NARW) density map (Roberts et al. 2016, 2023, 2024) showing highlighted grid cells used to calculate mean monthly species density estimates within 50 km perimeters around the Lease Area used to estimate exposures resulting from UXO detonation sounds. Note that the modeled densities are in units of animals/100 km^2, even when grid cells are 5 × 5 km.

Table J-106. Maximum monthly marine mammal and sea turtle density estimates (animals/100 km^2) [a] for all species within 50 km density perimeter, in summer (May to November).

Species of interest	OECC UXO-1 & UXO-2 Summer	Lease Area UXO-3, UXO-4, & UXO-5 Summer
Fin whale	0.074	0.347
Humpback whale	0.115	0.218
Common minke whale (migrating)	0.859	1.534
North Atlantic right whale	0.013	0.035
Sei whale (migrating)	0.026	0.085
Sperm whale	0.008	0.028
Atlantic spotted dolphin	0.032	1.055
Atlantic white sided dolphin	0.454	2.378
Common bottlenose dolphin	7.013	3.685
Long-finned pilot whale	0.005	0.161
Short-finned pilot whale	<0.001	0.012
Goose-beaked whale	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001
Striped dolphin	<0.001	0.004
Risso's dolphin	0.012	0.133
Common dolphin	3.873	18.138
Harbor porpoise (sensitive)	1.104	2.508
Gray seal	5.906	5.018
Harbor seal	11.464	9.742
Kemp's ridley sea turtle	0.013	0.012
Leatherback sea turtle	0.091	0.176
Loggerhead sea turtle	0.035	0.137
Green sea turtle	0.133	0.317

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).

Table J-107. Maximum monthly marine mammal and sea turtle density estimates (animals/100 km^2) [a] for all species within 50 km density perimeter, in winter (December).

Species of interest	OECC UXO-1 & UXO-2 Winter	Lease Area UXO-3, UXO-4, & UXO-5 Winter
Fin whale	0.098	0.123
Humpback whale	0.118	0.084
Common minke whale (migrating)	0.039	0.064
North Atlantic right whale	0.040	0.042
Sei whale (migrating)	0.042	0.037
Sperm whale	0.005	0.012
Atlantic spotted dolphin	0.007	0.053
Atlantic white sided dolphin	0.637	1.207
Common bottlenose dolphin	3.082	2.863
Long-finned pilot whale	0.025	0.161
Short-finned pilot whale	0.002	0.012
Goose-beaked whale	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001
Striped dolphin	<0.001	0.004
Risso's dolphin	0.105	0.257
Common dolphin	5.863	19.322
Harbor porpoise (sensitive)	2.775	2.998
Gray seal	4.178	4.060
Harbor seal	8.110	7.881
Kemp's ridley sea turtle	0	0
Leatherback sea turtle	0.001	0.004
Loggerhead sea turtle	0.008	0.033
Green sea turtle	0	0

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016, 2023, 2024).

J.10.3. Exposure Calculations

To calculate potential marine mammal and sea turtle exposures, the ensonified areas in Tables J-108 to J-127 were multiplied by the highest monthly species density in their respective zones (Lease Area and OECCs), as shown in Figure J-10. These estimates assume that no more than one detonation will occur within a given 24-hour period, and that detonations will only occur between May and December.

J.10.3.1. Estimated Exposures – E10 Charge Mass

Table J-108. Site UXO-1, no attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.08	0.59	0.16	3.58
Humpback whale	0.13	0.93	0.20	4.33
Common minke whale (migrating)	0.93	6.90	0.07	1.43
North Atlantic right whale	0.01	0.10	0.07	1.46
Sei whale (migrating)	0.03	0.21	0.07	1.54
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.02	<0.01	<0.01
Atlantic white sided dolphin	0.02	0.23	0.01	0.23
Common bottlenose dolphin	0.25	3.53	0.06	1.12
Long-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	<0.01	<0.01	0.04
Common dolphin	0.14	1.95	0.11	2.13
Harbor porpoise (sensitive)	1.87	7.36	5.55	87.00
Gray seal	2.21	20.33	1.73	58.03
Harbor seal	4.29	39.46	3.35	112.64
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.02	<0.01	<0.01
Loggerhead sea turtle	<0.01	<0.01	<0.01	<0.01
Green sea turtle	<0.01	0.02	0	0

Table J-109. Site UXO-1, 10 dB attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.02	0.17	0.02	0.54
Humpback whale	0.02	0.27	0.03	0.65
Common minke whale (migrating)	0.18	1.98	<0.01	0.21
North Atlantic right whale	<0.01	0.03	<0.01	0.22
Sei whale (migrating)	<0.01	0.06	<0.01	0.23
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	<0.01	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.05	<0.01	0.04
Common bottlenose dolphin	0.01	0.73	<0.01	0.18
Long-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	<0.01	<0.01	<0.01
Common dolphin	<0.01	0.41	0.01	0.34
Harbor porpoise (sensitive)	0.60	3.05	0.78	14.87
Gray seal	0.32	5.01	0.20	5.29
Harbor seal	0.61	9.73	0.39	10.28
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	<0.01	<0.01	<0.01
Loggerhead sea turtle	<0.01	<0.01	<0.01	<0.01
Green sea turtle	<0.01	<0.01	0	0

Table J-110. Site UXO-2, no attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.11	0.81	0.15	2.73
Humpback whale	0.17	1.27	0.18	3.30
Common minke whale (migrating)	1.28	9.44	0.06	1.09
North Atlantic right whale	0.02	0.14	0.06	1.11
Sei whale (migrating)	0.04	0.29	0.06	1.18
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.02	<0.01	<0.01
Atlantic white sided dolphin	0.02	0.32	<0.01	0.18
Common bottlenose dolphin	0.25	4.99	0.04	0.89
Long-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville’s beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso’s dolphin	<0.01	<0.01	<0.01	0.03
Common dolphin	0.14	2.76	0.07	1.70
Harbor porpoise (sensitive)	3.14	11.87	4.86	57.16
Gray seal	2.43	29.17	1.36	32.56
Harbor seal	4.72	56.62	2.64	63.20
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.03	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.01	<0.01	<0.01
Green sea turtle	<0.01	0.05	0	0

Table J-111. Site UXO-2, 10 dB attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.02	0.24	0.02	0.39
Humpback whale	0.03	0.38	0.03	0.47
Common minke whale (migrating)	0.21	2.82	<0.01	0.16
North Atlantic right whale	<0.01	0.04	<0.01	0.16
Sei whale (migrating)	<0.01	0.09	<0.01	0.17
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	<0.01	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.05	<0.01	0.02
Common bottlenose dolphin	<0.01	0.76	<0.01	0.10
Long-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	<0.01	<0.01	<0.01
Common dolphin	<0.01	0.42	<0.01	0.19
Harbor porpoise (sensitive)	0.88	5.19	0.71	11.69
Gray seal	0.23	6.33	0.12	4.17
Harbor seal	0.45	12.28	0.22	8.10
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	<0.01	<0.01	<0.01
Loggerhead sea turtle	<0.01	<0.01	<0.01	<0.01
Green sea turtle	<0.01	<0.01	0	0

Table J-112. Site UXO-3, no attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.62	6.19	0.18	2.87
Humpback whale	0.39	3.88	0.12	1.97
Common minke whale (migrating)	2.75	27.37	0.09	1.50
North Atlantic right whale	0.06	0.62	0.06	0.99
Sei whale (migrating)	0.15	1.51	0.05	0.87
Sperm whale	<0.01	0.03	<0.01	<0.01
Atlantic spotted dolphin	0.03	0.99	<0.01	0.01
Atlantic white sided dolphin	0.06	2.22	0.01	0.34
Common bottlenose dolphin	0.10	3.44	0.03	0.80
Long-finned pilot whale	<0.01	0.15	<0.01	0.05
Short-finned pilot whale	<0.01	0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.12	<0.01	0.07
Common dolphin	0.48	16.93	0.19	5.40
Harbor porpoise (sensitive)	11.37	51.38	5.02	56.90
Gray seal	2.21	37.83	1.12	27.60
Harbor seal	4.29	73.43	2.18	53.58
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.08	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.06	<0.01	0.01
Green sea turtle	<0.01	0.14	0	0

Table J-113. Site UXO-3, 10 dB attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.09	1.49	0.03	0.45
Humpback whale	0.05	0.93	0.02	0.31
Common minke whale (migrating)	0.38	6.58	0.01	0.24
North Atlantic right whale	<0.01	0.15	<0.01	0.16
Sei whale (migrating)	0.02	0.36	<0.01	0.14
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.10	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.24	<0.01	0.04
Common bottlenose dolphin	<0.01	0.37	<0.01	0.08
Long-finned pilot whale	<0.01	0.02	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.01	<0.01	<0.01
Common dolphin	0.01	1.80	0.02	0.57
Harbor porpoise (sensitive)	2.69	20.01	0.82	11.51
Gray seal	0.15	6.77	0.09	3.58
Harbor seal	0.30	13.15	0.17	6.95
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.01	<0.01	<0.01
Loggerhead sea turtle	<0.01	<0.01	<0.01	<0.01
Green sea turtle	<0.01	0.02	0	0

Table J-114. Site UXO-4, no attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.74	13.09	0.20	3.48
Humpback whale	0.46	8.20	0.14	2.39
Common minke whale (migrating)	3.27	57.85	0.11	1.82
North Atlantic right whale	0.07	1.31	0.07	1.20
Sei whale (migrating)	0.18	3.19	0.06	1.05
Sperm whale	<0.01	0.02	<0.01	<0.01
Atlantic spotted dolphin	0.02	0.88	<0.01	0.01
Atlantic white sided dolphin	0.04	1.98	0.01	0.29
Common bottlenose dolphin	0.06	3.07	0.03	0.70
Long-finned pilot whale	<0.01	0.13	<0.01	0.04
Short-finned pilot whale	<0.01	0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.11	<0.01	0.06
Common dolphin	0.30	15.10	0.17	4.72
Harbor porpoise (sensitive)	14.68	105.73	4.66	56.84
Gray seal	1.92	62.09	1.02	28.61
Harbor seal	3.73	120.53	1.98	55.55
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.09	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.07	<0.01	0.02
Green sea turtle	<0.01	0.16	0	0

Table J-115. Site UXO-4, 10 dB attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.08	2.10	0.03	0.53
Humpback whale	0.05	1.32	0.02	0.36
Common minke whale (migrating)	0.37	9.29	0.01	0.28
North Atlantic right whale	<0.01	0.21	<0.01	0.18
Sei whale (migrating)	0.02	0.51	<0.01	0.16
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.07	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.17	<0.01	0.03
Common bottlenose dolphin	<0.01	0.26	<0.01	0.08
Long-finned pilot whale	<0.01	0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville’s beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso’s dolphin	<0.01	<0.01	<0.01	<0.01
Common dolphin	0.01	1.26	0.01	0.55
Harbor porpoise (sensitive)	2.37	30.93	0.74	10.40
Gray seal	0.14	6.95	0.07	3.37
Harbor seal	0.28	13.50	0.13	6.54
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.01	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.01	<0.01	<0.01
Green sea turtle	<0.01	0.02	0	0

Table J-116. Site UXO-5, no attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.78	13.02	0.22	3.40
Humpback whale	0.49	8.16	0.15	2.33
Common minke whale (migrating)	3.46	57.54	0.12	1.78
North Atlantic right whale	0.08	1.30	0.08	1.17
Sei whale (migrating)	0.19	3.17	0.07	1.03
Sperm whale	<0.01	0.02	<0.01	<0.01
Atlantic spotted dolphin	0.02	0.80	<0.01	0.01
Atlantic white sided dolphin	0.04	1.80	0.01	0.31
Common bottlenose dolphin	0.06	2.79	0.03	0.74
Long-finned pilot whale	<0.01	0.12	<0.01	0.04
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.10	<0.01	0.07
Common dolphin	0.32	13.73	0.17	5.00
Harbor porpoise (sensitive)	13.81	98.27	4.34	52.63
Gray seal	1.84	56.25	1.08	28.05
Harbor seal	3.57	109.19	2.10	54.45
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.11	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.08	<0.01	0.02
Green sea turtle	<0.01	0.19	0	0

Table J-117. Site UXO-5, 10 dB attenuation: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.09	2.17	0.03	0.57
Humpback whale	0.06	1.36	0.02	0.39
Common minke whale (migrating)	0.40	9.58	0.02	0.30
North Atlantic right whale	<0.01	0.22	0.01	0.20
Sei whale (migrating)	0.02	0.53	<0.01	0.17
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.07	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.16	<0.01	0.03
Common bottlenose dolphin	<0.01	0.25	<0.01	0.08
Long-finned pilot whale	<0.01	0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	<0.01	<0.01	<0.01
Common dolphin	0.01	1.24	0.01	0.55
Harbor porpoise (sensitive)	2.37	28.42	0.78	10.22
Gray seal	0.15	6.49	0.07	3.62
Harbor seal	0.29	12.61	0.13	7.02
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.01	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.01	<0.01	<0.01
Green sea turtle	<0.01	0.03	0	0

J.10.3.2. Estimated Exposures – E12 Charge Mass

Table J-118. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-1, assuming no attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.11	0.75	0.26	3.70
Humpback whale	0.17	1.17	0.32	4.47
Common minke whale (migrating)	1.27	8.72	0.11	1.48
North Atlantic right whale	0.02	0.13	0.11	1.51
Sei whale (migrating)	0.04	0.26	0.11	1.59
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.02	<0.01	<0.01
Atlantic white sided dolphin	0.03	0.30	0.02	0.31
Common bottlenose dolphin	0.40	4.60	0.08	1.52
Long-finned pilot whale	<0.01	<0.01	<0.01	0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville’s beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso’s dolphin	<0.01	<0.01	<0.01	0.05
Common dolphin	0.22	2.54	0.16	2.90
Harbor porpoise (sensitive)	2.30	8.68	8.26	103.84
Gray seal	3.10	25.97	2.67	91.75
Harbor seal	6.02	50.40	5.18	178.11
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.02	<0.01	<0.01
Loggerhead sea turtle	<0.01	<0.01	<0.01	<0.01
Green sea turtle	<0.01	0.03	0	0

Table J-119. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-1, assuming 10 dB attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.02	0.22	0.03	0.87
Humpback whale	0.03	0.35	0.04	1.05
Common minke whale (migrating)	0.26	2.60	0.01	0.35
North Atlantic right whale	<0.01	0.04	0.01	0.35
Sei whale (migrating)	<0.01	0.08	0.01	0.37
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	<0.01	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.07	<0.01	0.05
Common bottlenose dolphin	0.03	1.05	<0.01	0.25
Long-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville’s beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso’s dolphin	<0.01	<0.01	<0.01	<0.01
Common dolphin	0.02	0.58	0.02	0.48
Harbor porpoise (sensitive)	0.76	3.68	1.24	21.67
Gray seal	0.49	6.83	0.31	8.66
Harbor seal	0.96	13.26	0.61	16.81
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	<0.01	<0.01	<0.01
Loggerhead sea turtle	<0.01	<0.01	<0.01	<0.01
Green sea turtle	<0.01	<0.01	0	0

Table J-120. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at modeling site UXO-2, assuming no attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.16	1.00	0.22	3.90
Humpback whale	0.24	1.56	0.27	4.72
Common minke whale (migrating)	1.80	11.65	0.09	1.56
North Atlantic right whale	0.03	0.17	0.09	1.59
Sei whale (migrating)	0.05	0.35	0.10	1.68
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.03	<0.01	<0.01
Atlantic white sided dolphin	0.03	0.44	0.01	0.31
Common bottlenose dolphin	0.40	6.74	0.05	1.52
Long-finned pilot whale	<0.01	<0.01	<0.01	0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.01	<0.01	0.05
Common dolphin	0.22	3.72	0.10	2.90
Harbor porpoise (sensitive)	3.90	13.86	6.94	76.93
Gray seal	3.62	36.81	47.38	47.38
Harbor seal	7.02	71.45	91.97	91.97
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.05	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.02	<0.01	<0.01
Green sea turtle	<0.01	0.07	0	0

Table J-121. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-2, assuming 10 dB attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.03	0.32	0.03	0.58
Humpback whale	0.04	0.50	0.04	0.70
Common minke whale (migrating)	0.31	3.75	0.01	0.23
North Atlantic right whale	<0.01	0.06	0.01	0.24
Sei whale (migrating)	<0.01	0.11	0.01	0.25
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	<0.01	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.08	<0.01	0.03
Common bottlenose dolphin	0.02	1.22	<0.01	0.17
Long-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	<0.01	<0.01	<0.01
Common dolphin	0.01	0.67	0.01	0.32
Harbor porpoise (sensitive)	1.16	6.18	1.27	16.32
Gray seal	0.39	9.07	0.20	6.46
Harbor seal	0.76	17.61	0.39	12.54
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	<0.01	<0.01	<0.01
Loggerhead sea turtle	<0.01	<0.01	<0.01	<0.01
Green sea turtle	<0.01	0.01	0	0

Table J-122. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-3, assuming no attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.91	8.01	0.27	4.25
Humpback whale	0.57	5.02	0.18	2.92
Common minke whale (migrating)	4.03	35.41	0.14	2.22
North Atlantic right whale	0.09	0.80	0.09	1.46
Sei whale (migrating)	0.22	1.95	0.08	1.29
Sperm whale	<0.01	0.04	<0.01	<0.01
Atlantic spotted dolphin	0.04	1.41	<0.01	0.02
Atlantic white sided dolphin	0.09	3.18	0.02	0.47
Common bottlenose dolphin	0.15	4.92	0.04	1.12
Long-finned pilot whale	<0.01	0.22	<0.01	0.06
Short-finned pilot whale	<0.01	0.02	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville’s beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso’s dolphin	<0.01	0.18	<0.01	0.10
Common dolphin	0.72	24.24	0.30	7.54
Harbor porpoise (sensitive)	14.39	61.24	6.58	75.80
Gray seal	3.58	49.67	1.72	40.38
Harbor seal	6.94	96.41	3.33	78.38
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.12	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.09	<0.01	0.02
Green sea turtle	0.01	0.21	0	0

Table J-123. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-3, assuming 10 dB attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.14	2.08	0.04	0.68
Humpback whale	0.08	1.30	0.03	0.46
Common minke whale (migrating)	0.60	9.18	0.02	0.35
North Atlantic right whale	0.01	0.21	0.01	0.23
Sei whale (migrating)	0.03	0.51	0.01	0.21
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.17	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.39	<0.01	0.05
Common bottlenose dolphin	<0.01	0.60	<0.01	0.13
Long-finned pilot whale	<0.01	0.03	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.02	<0.01	0.01
Common dolphin	0.03	2.95	0.03	0.86
Harbor porpoise (sensitive)	3.73	24.58	1.12	16.27
Gray seal	0.28	10.12	0.15	5.20
Harbor seal	0.55	19.64	0.30	10.10
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.02	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.02	<0.01	<0.01
Green sea turtle	<0.01	0.04	0	0

Table J-124. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-4, assuming no attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	1.17	17.68	0.31	5.17
Humpback whale	0.73	11.08	0.21	3.55
Common minke whale (migrating)	5.16	78.16	0.16	2.71
North Atlantic right whale	0.12	1.77	0.11	1.78
Sei whale (migrating)	0.28	4.31	0.09	1.57
Sperm whale	<0.01	0.03	<0.01	<0.01
Atlantic spotted dolphin	0.05	1.31	<0.01	0.02
Atlantic white sided dolphin	0.11	2.95	0.02	0.38
Common bottlenose dolphin	0.18	4.57	0.04	0.91
Long-finned pilot whale	<0.01	0.20	<0.01	0.05
Short-finned pilot whale	<0.01	0.02	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville’s beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso’s dolphin	<0.01	0.17	<0.01	0.08
Common dolphin	0.88	22.50	0.28	6.15
Harbor porpoise (sensitive)	19.97	131.96	5.88	76.02
Gray seal	3.29	89.36	1.59	43.06
Harbor seal	6.39	173.46	3.09	83.58
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.14	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.11	<0.01	0.02
Green sea turtle	0.01	0.26	0	0

Table J-125. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-4, assuming 10 dB attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.15	3.23	0.04	0.80
Humpback whale	0.09	2.03	0.03	0.55
Common minke whale (migrating)	0.65	14.29	0.02	0.42
North Atlantic right whale	0.01	0.32	0.01	0.28
Sei whale (migrating)	0.04	0.79	0.01	0.24
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.11	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.25	<0.01	0.05
Common bottlenose dolphin	<0.01	0.38	<0.01	0.12
Long-finned pilot whale	<0.01	0.02	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville’s beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso’s dolphin	<0.01	0.01	<0.01	0.01
Common dolphin	0.02	1.89	0.02	0.83
Harbor porpoise (sensitive)	3.63	40.48	0.93	15.14
Gray seal	0.28	11.36	0.13	5.35
Harbor seal	0.54	22.06	0.25	10.38
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.02	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.02	<0.01	<0.01
Green sea turtle	<0.01	0.04	0	0

Table J-126. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-5, assuming no attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	1.24	18.53	0.34	5.16
Humpback whale	0.78	11.61	0.23	3.54
Common minke whale (migrating)	5.47	81.92	0.18	2.70
North Atlantic right whale	0.12	1.85	0.12	1.78
Sei whale (migrating)	0.30	4.51	0.10	1.57
Sperm whale	<0.01	0.03	<0.01	<0.01
Atlantic spotted dolphin	0.06	1.24	<0.01	0.02
Atlantic white sided dolphin	0.12	2.79	0.02	0.40
Common bottlenose dolphin	0.19	4.32	0.04	0.94
Long-finned pilot whale	<0.01	0.19	<0.01	0.05
Short-finned pilot whale	<0.01	0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.16	<0.01	0.08
Common dolphin	0.95	21.26	0.28	6.36
Harbor porpoise (sensitive)	18.64	123.34	5.98	70.73
Gray seal	2.87	80.00	1.76	41.31
Harbor seal	5.58	155.29	3.41	80.18
Kemp's ridley sea turtle	<0.01	0.01	0	0
Leatherback sea turtle	<0.01	0.17	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.13	<0.01	0.03
Green sea turtle	0.01	0.30	0	0

Table J-127. Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of one UXO at Site UXO-5, assuming 10 dB attenuation.

Species	PTS Summer	TTS Summer	PTS Winter	TTS Winter
Fin whale	0.15	3.26	0.05	0.84
Humpback whale	0.10	2.04	0.03	0.58
Common minke whale (migrating)	0.68	14.42	0.03	0.44
North Atlantic right whale	0.02	0.33	0.02	0.29
Sei whale (migrating)	0.04	0.79	0.01	0.26
Sperm whale	<0.01	<0.01	<0.01	<0.01
Atlantic spotted dolphin	<0.01	0.09	<0.01	<0.01
Atlantic white sided dolphin	<0.01	0.21	<0.01	0.05
Common bottlenose dolphin	<0.01	0.33	<0.01	0.12
Long-finned pilot whale	<0.01	0.01	<0.01	<0.01
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	<0.01	<0.01
Risso's dolphin	<0.01	0.01	<0.01	0.01
Common dolphin	0.02	1.61	0.02	0.80
Harbor porpoise (sensitive)	3.31	36.92	0.96	14.66
Gray seal	0.25	10.79	0.12	5.63
Harbor seal	0.49	20.94	0.24	10.92
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	0.03	<0.01	<0.01
Loggerhead sea turtle	<0.01	0.02	<0.01	<0.01
Green sea turtle	<0.01	0.05	0	0

J.10.4. Total Estimated Exposures

Total exposure estimates were calculated assuming one UXO detonation at each of the five modeling sites. Table J-128. below shows the total number of Level A and Level B exposures possible across all five locations for the E12 charge size, with and without attenuation, assuming detonation in summer. UXO detonation may also occur during winter, in December. Winter exposure results are found above, in Section J.10.3.2. for the E12 charge size.

Table J-128. All sites: Estimated potential maximum Level A exposures (PTS SEL) and Level B exposures (TTS SEL) of marine mammals and sea turtles resulting from the possible detonation of up to 5 UXOs during summer.

Species	PTS 0 dB	PTS 10 dB	TTS 0 dB	TTS 10 dB
Fin whale	3.58	0.49	45.97	9.12
Humpback whale	2.49	0.35	30.45	6.22
Common minke whale (migrating)	17.74	2.50	215.86	44.24
North Atlantic right whale	0.38	0.05	4.73	0.95
Sei whale (migrating)	0.90	0.12	11.38	2.28
Sperm whale	<0.01	<0.01	0.12	0.01
Atlantic spotted dolphin	0.15	<0.01	4.01	0.39
Atlantic white sided dolphin	0.39	0.01	9.65	0.99
Common bottlenose dolphin	1.31	0.06	25.15	3.58
Long-finned pilot whale	0.02	<0.01	0.61	0.06
Short-finned pilot whale	<0.01	<0.01	0.05	<0.01
Goose-beaked whale	<0.01	<0.01	<0.01	<0.01
Blainville's beaked whale	<0.01	<0.01	<0.01	<0.01
Striped dolphin	<0.01	<0.01	0.01	<0.01
Risso's dolphin	0.02	<0.01	0.52	0.05
Common dolphin	2.99	0.10	74.26	7.71
Harbor porpoise (sensitive)	59.21	12.59	339.09	111.84
Gray seal	16.46	1.69	281.80	48.17
Harbor seal	31.95	3.29	547.02	93.52
Kemp's ridley sea turtle	<0.01	<0.01	0.04	<0.01
Leatherback sea turtle	0.03	<0.01	0.49	0.08
Loggerhead sea turtle	0.02	<0.01	0.36	0.06
Green sea turtle	0.05	<0.01	0.86	0.15

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Additional Information: PTS and TTS Exceedance Zone Maps (Unmitigated)

This sub-supplement presents PTS and TTS exceedance zone maps for several marine mammal hearing groups, and for sea turtles, for 231.5 and 463.1 kg charges at each of the five sites. Only the unmitigated scenario maps are included here. The corresponding maps for mitigated scenarios have smaller exceedance zone sizes (see Figures J-11 to J-20).

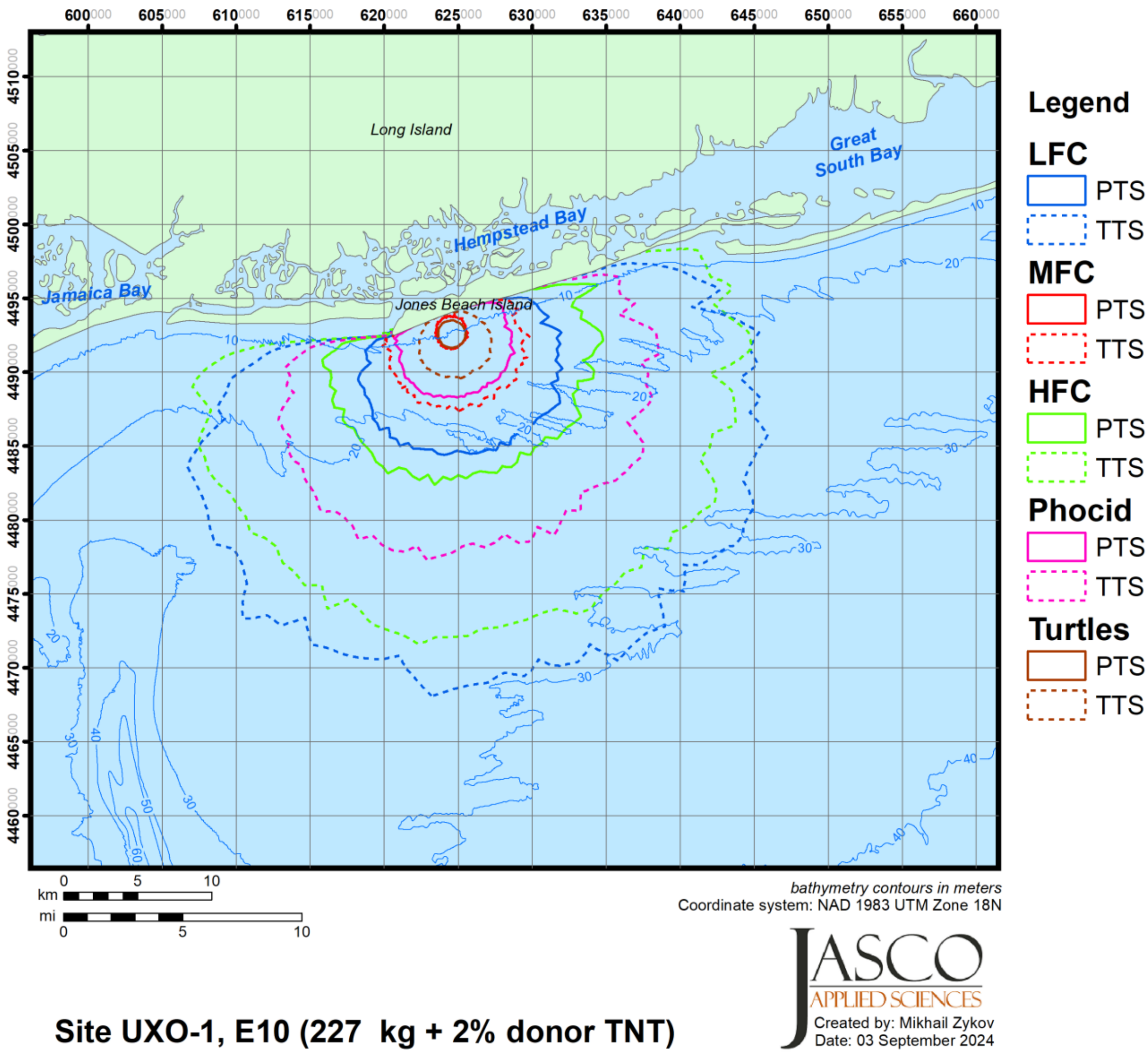

Figure J-11. Site UXO-1, April, 227 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

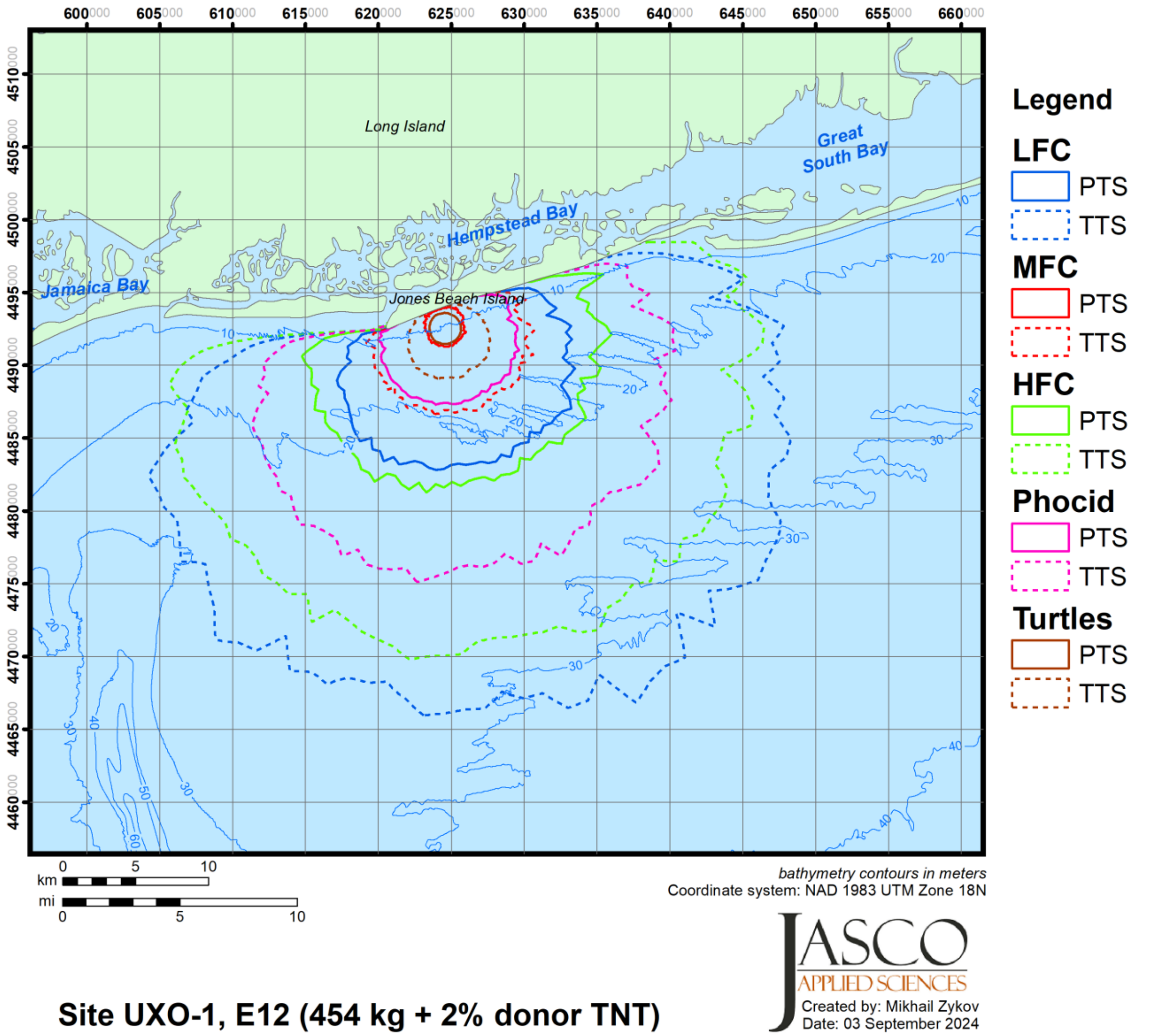

Figure J-12. Site UXO-1, April, 454 kg plus donor charge: :Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

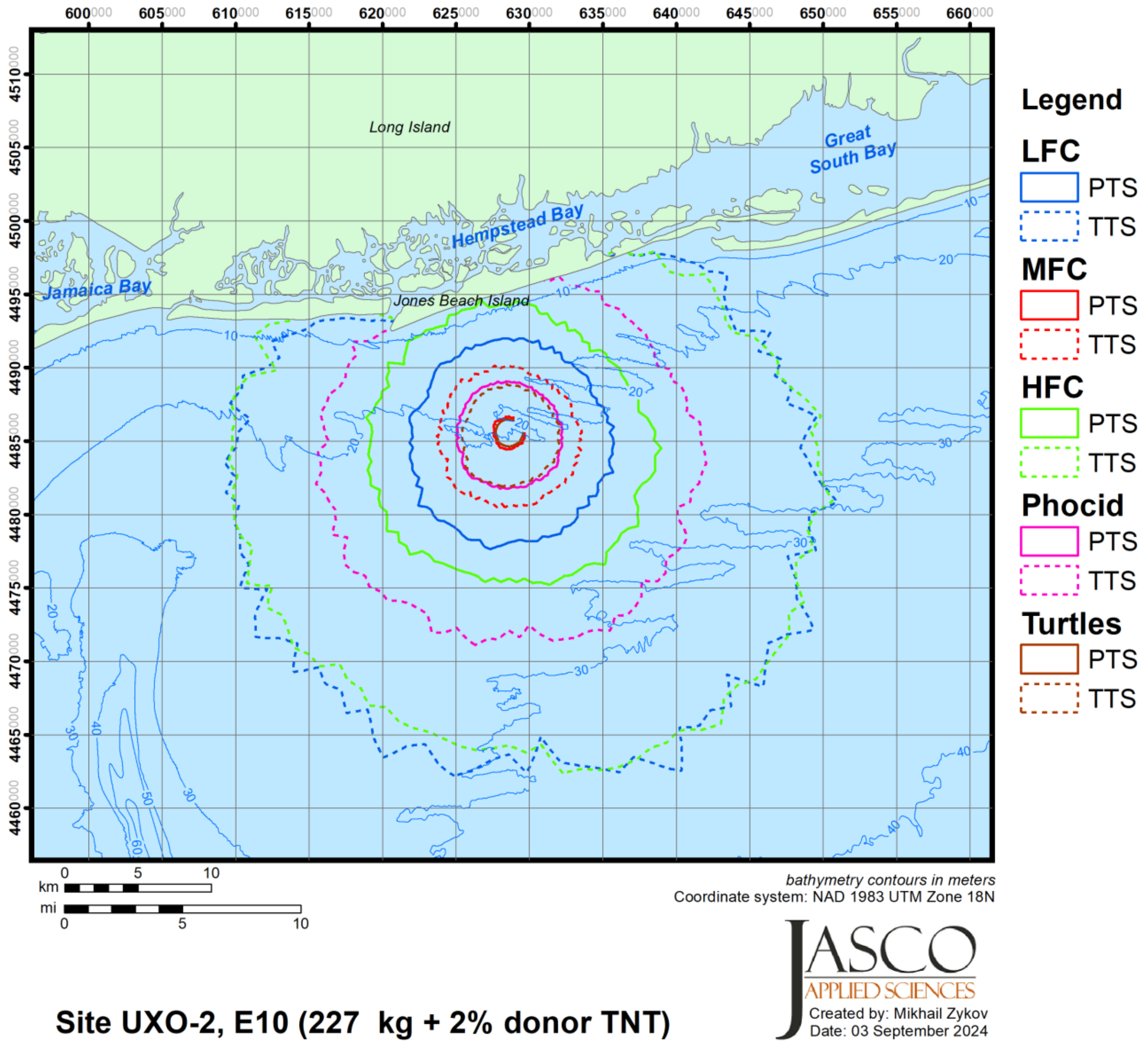

Figure J-13. Site UXO-2, April, 227 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

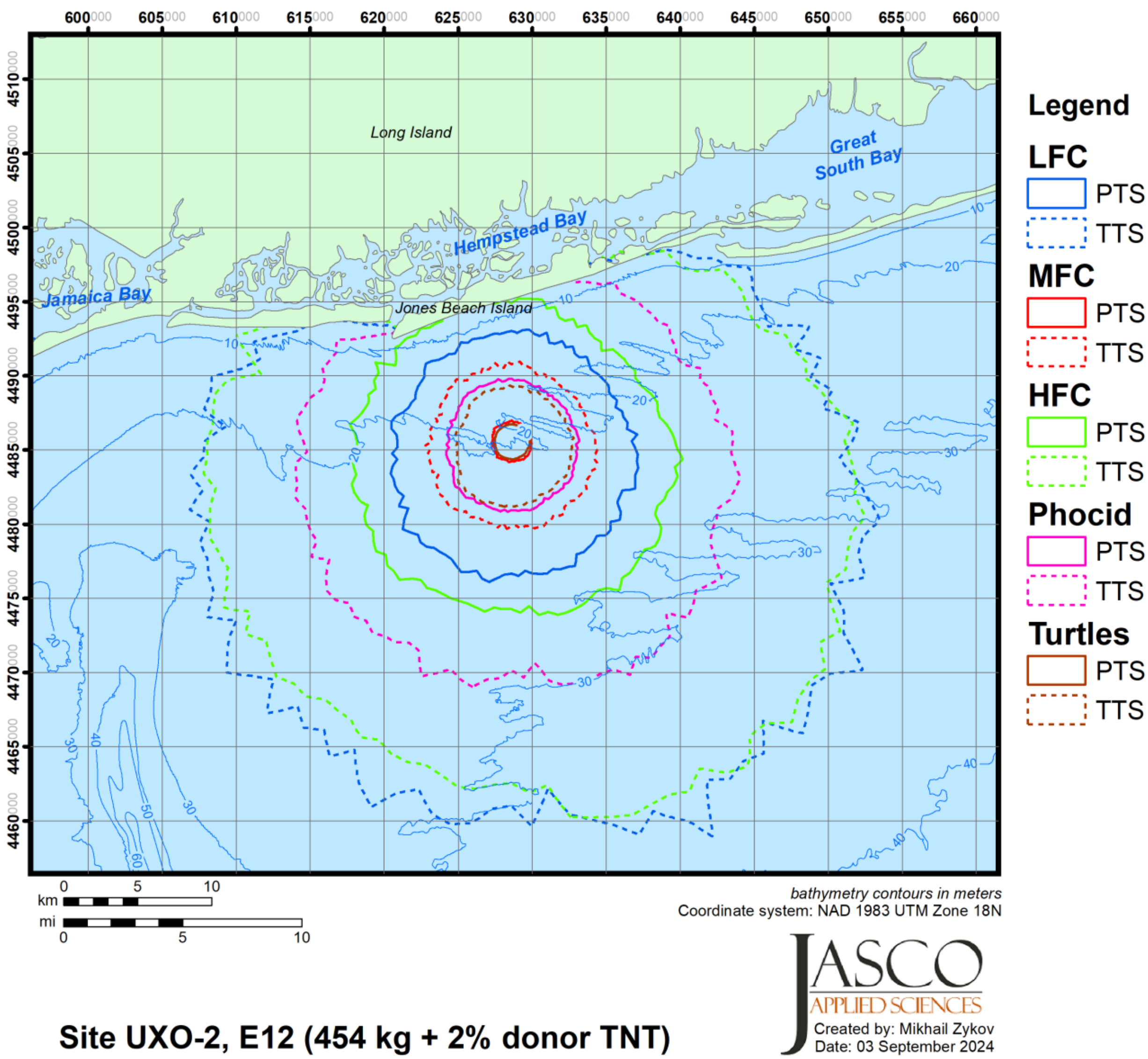

Figure J-14. Site UXO-2, April, 454 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

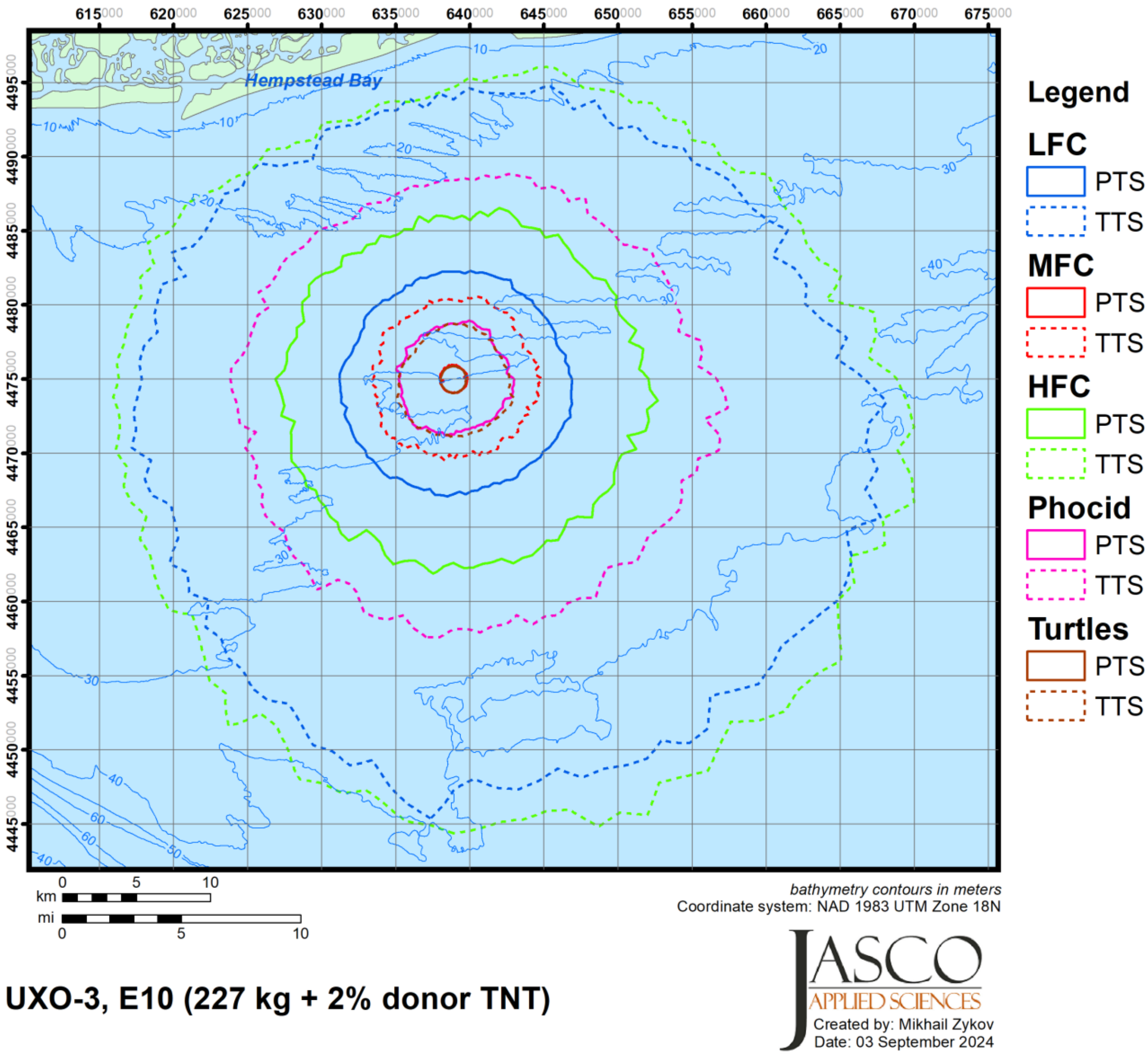

Figure J-15. Site UXO-3, April, 227 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

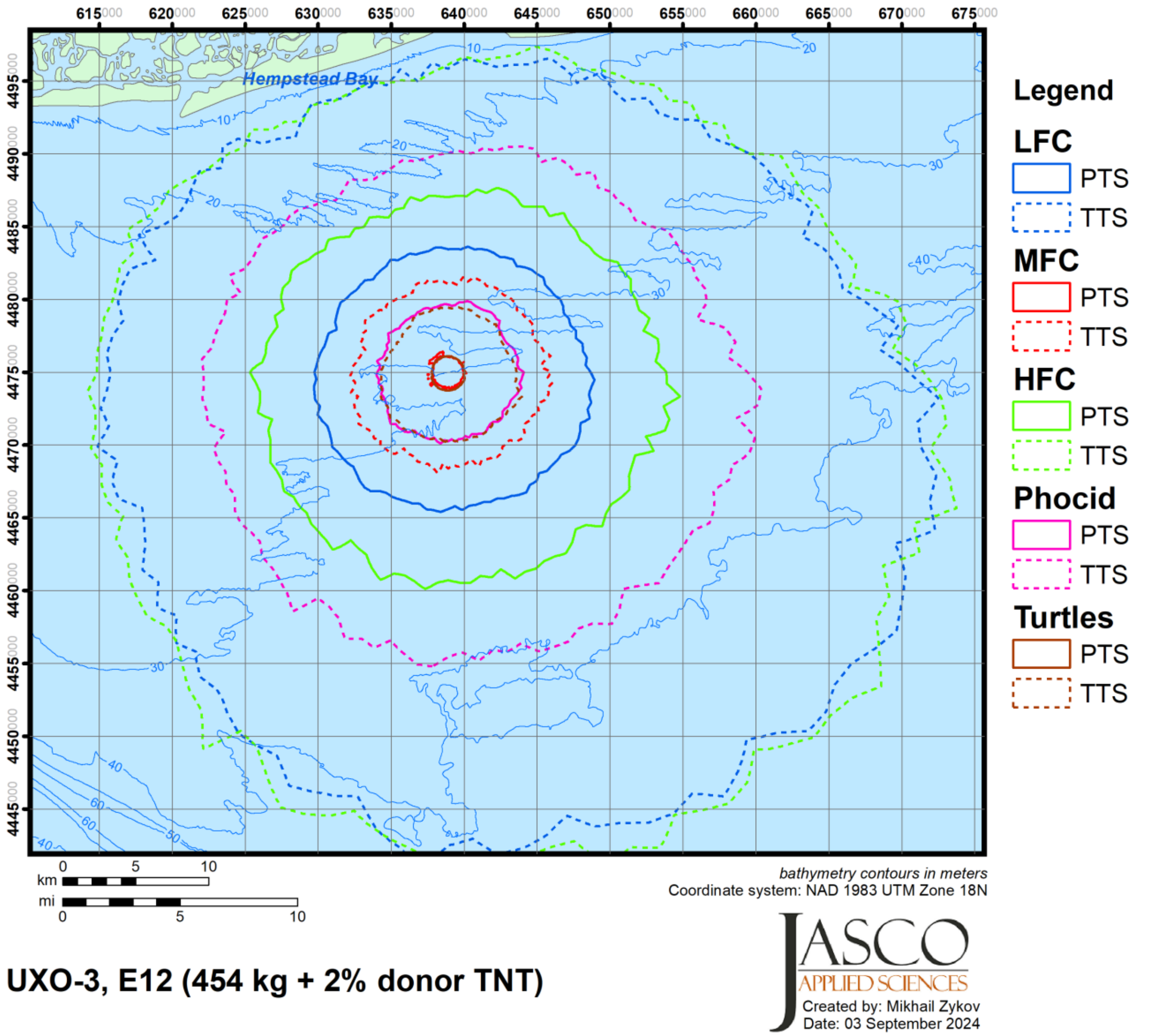

Figure J-16. Site UXO-3, April, 454 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

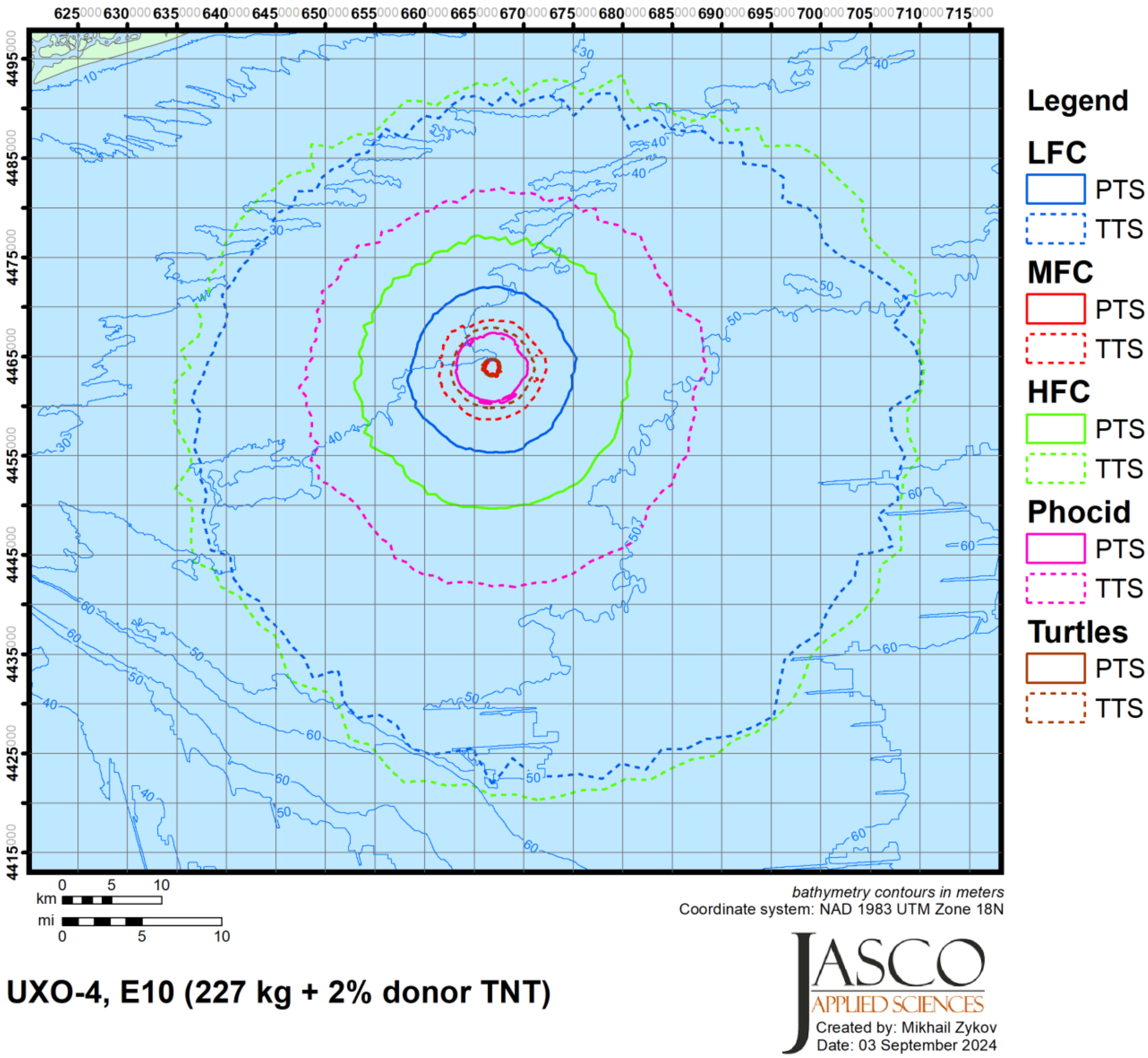

Figure J-17. Site UXO-4, April, 227 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

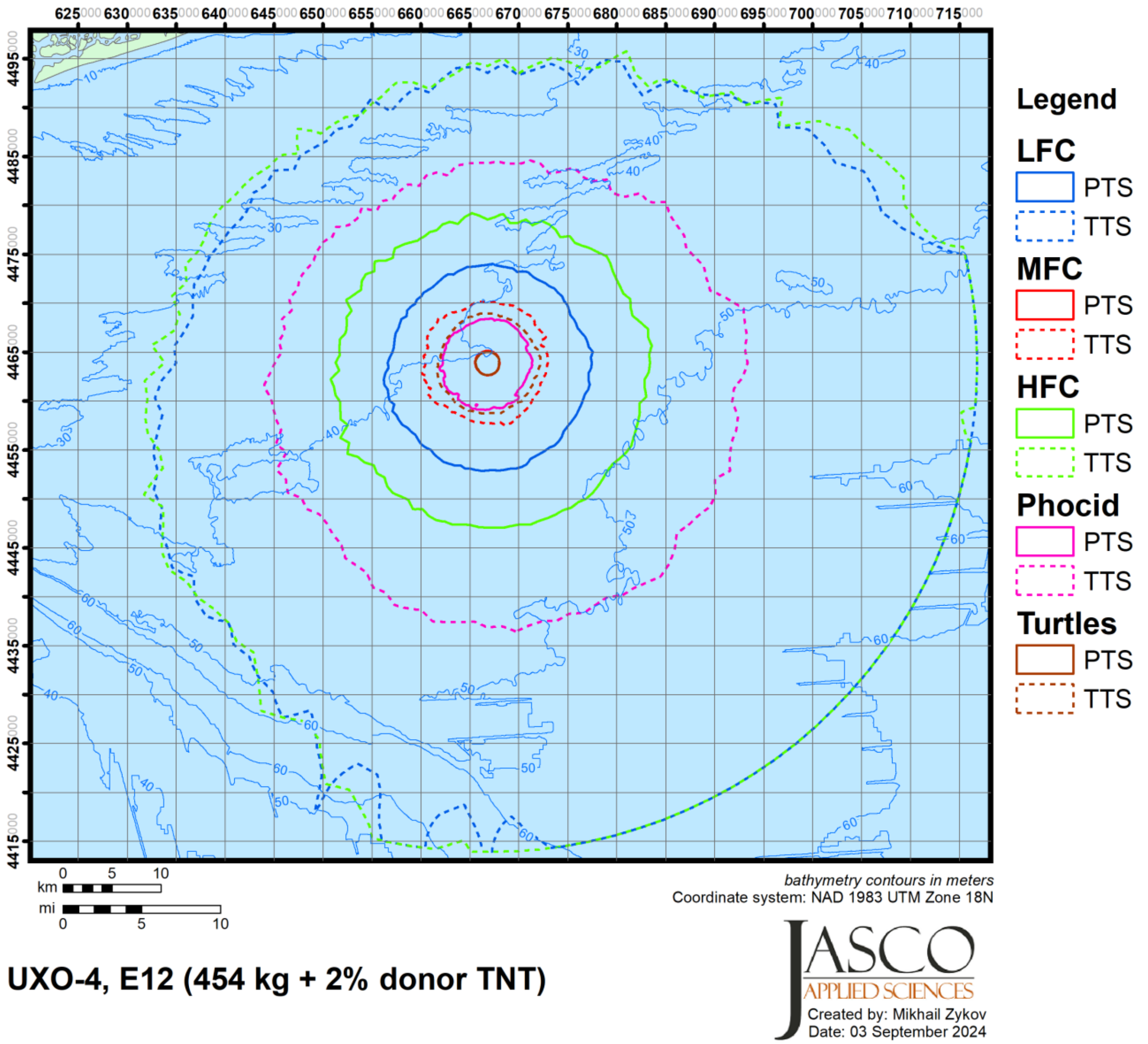

Figure J-18. Site UXO-4, April, 454 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

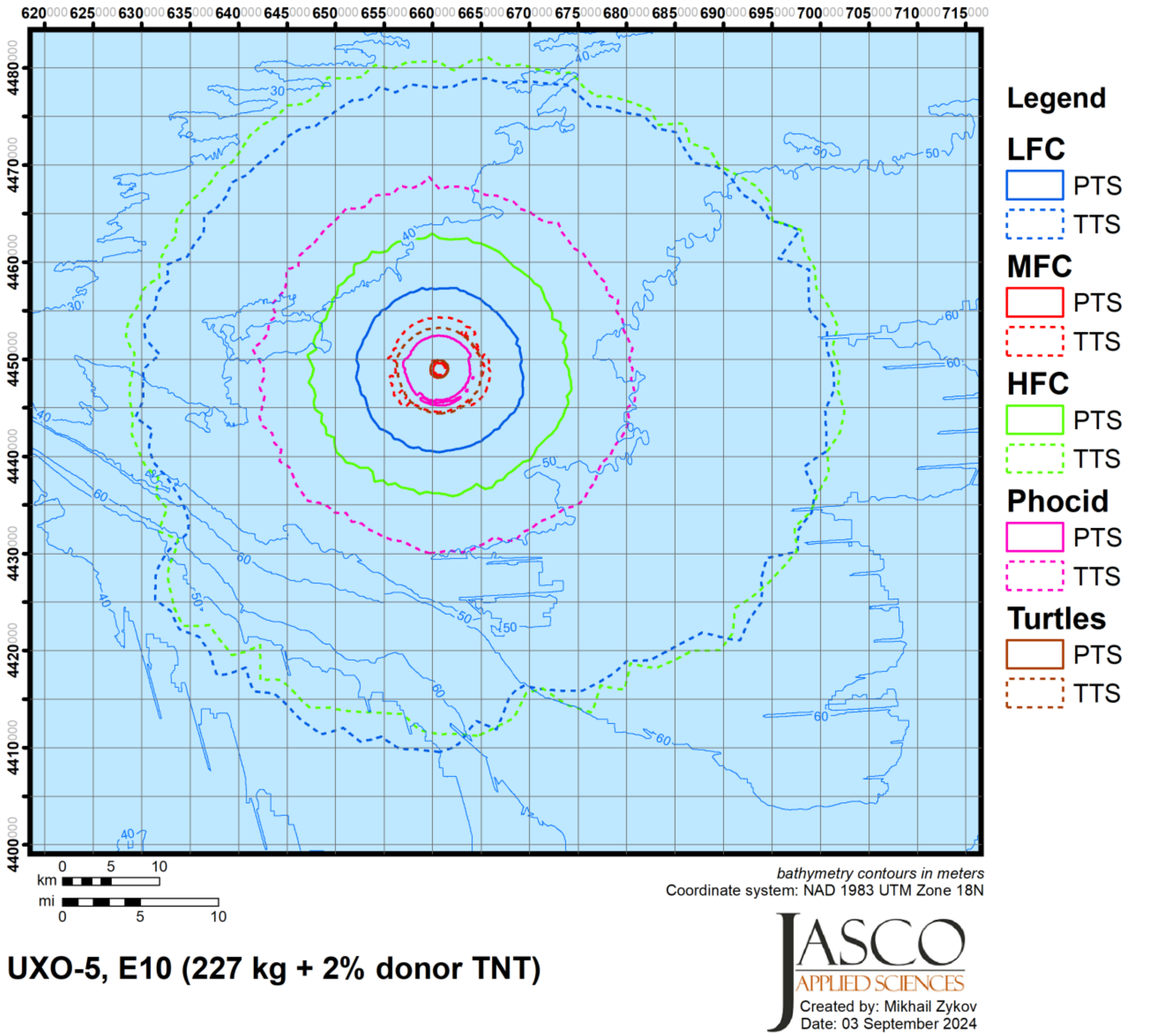

Figure J-19. Site UXO-5, April, 227 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

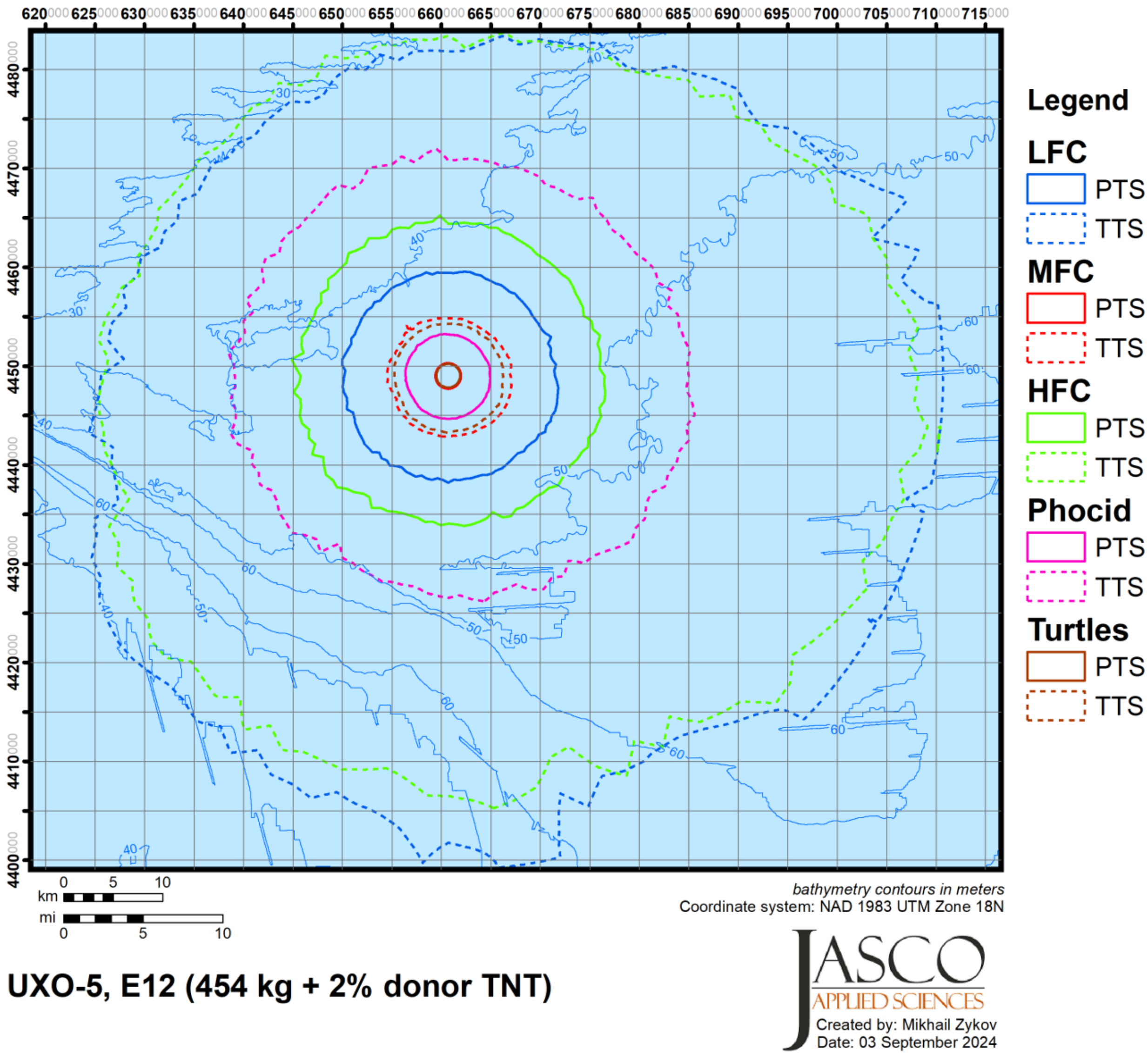

Figure J-20. Site UXO-5, April, 454 kg plus donor charge: Map of frequency-weighted sound exposure level (SEL), permanent threshold shift (PTS), and temporary threshold shift (TTS) exceedance zone for each species group.

Supplement K. Memo: Acoustic Ranges to Regulatory Thresholds for Vibratory Pile Driving of Sheet Piles for Installing a Cofferdam

Date: 11 November 2024

Version: 3.0

From: Forest M.C. Stothart and Bailey W. Jenkins

To: Maria Hartnett (Epsilon Associates, Inc.)

K.1. Introduction

Vineyard Mid-Atlantic LLC (the "Proponent") proposes to develop, construct, and operate offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0544 (the "Lease Area") along with associated offshore and onshore transmission systems. This proposed development is referred to as "Vineyard Mid-Atlantic."

JASCO Applied Sciences (USA) Inc. (JASCO) has been commissioned by the Proponent to perform underwater acoustic modeling associated with installation of Vineyard Mid-Atlantic, including offshore export cables. Between the Lease Area and shore, the offshore export cables will be installed within an Offshore Export Cable Corridor (OECC). Up to six high voltage alternating current (HVAC) cables, two high voltage direct current (HVDC) cable bundles, or a combination of up to four HVAC cables/HVDC cable bundles will be installed within the OECC. The OECC extends from the northern end of the Lease Area, continues west along the boundary of neighboring Lease Area OCS-A 0512, and then proceeds northwest towards the southern shore of Long Island, New York. As the OECC approaches shore, it splits into three variations to connect to three potential landfall sites (of which, up to two will be used): the Rockaway Beach Landfall Site, the Atlantic Beach Landfall Site, and the Jones Beach Landfall Site. The Proponent has also identified a "Western Landfall Sites OECC Variant" that may be used for routing offshore export cables to the Rockaway Beach and Atlantic Beach Landfall Sites. Figure K-1 provides an overview of the Vineyard Mid-Atlantic Lease Area OCS-A 0544 and the OECC.

The offshore export cables are expected to transition onshore through conduits installed using horizontal directional drilling (HDD) at each landfall site. An exit pit will be excavated at the seaward end of the HDD path for each offshore export cable, and a cofferdam may be installed at each exit pit. If installed, the cofferdams will be constructed using sheet piles. The pile driving operation will employ a vibratory hammer, which will produce continuous (non-impulsive) sound.

While the sound-generating activities are identical at each site, the environmental conditions, specifically bathymetry, vary between the three potential landfall sites. Therefore, underwater sound modeling was performed at each site (Figure K-1). One representative cofferdam is modeled at each site; up to six cofferdams could be installed in total, with up to four at a single landfall site.

The isopleth distances to regulatory thresholds corresponding to the potential injury and behavioral disruption of marine mammals, fish, and sea turtles were computed by modeling sounds expected to be produced by installing cofferdam sheet piles. The modeled ensonified areas were combined with the planned construction schedules and predicted species densities to estimate the number of animals that may be exposed to sound levels above injury and behavioral response thresholds.

The acoustic propagation modeling and animal exposure estimates were conducted for two seasons (winter and summer) at three potential landfall sites. The source function for the planned vibratory hammer model, an APE 200T, was obtained from measured data from the APE 300 and ICE-416 models that were adjusted for differences in driving power.

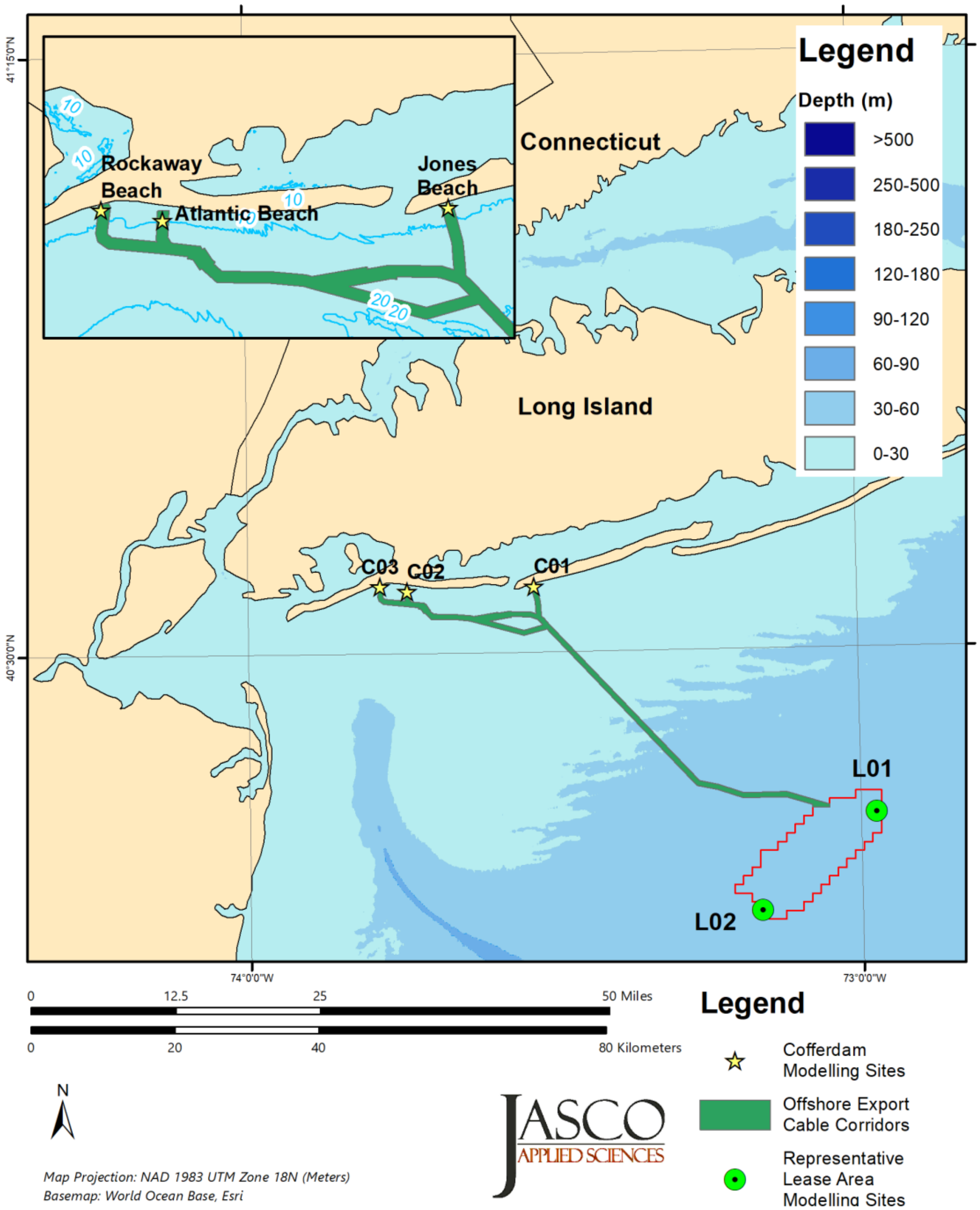

Figure K-1. Overview of the project area and the three potential landfall sites (yellow stars).

K.2. Methods

JASCO's Marine Operations Noise Model (MONM) was used to predict sound exposure level (SEL) and sound pressure level (SPL) sound fields due to vibratory piling using an APE 200T vibratory hammer at the three proposed cofferdam sites. Modeled sound fields were analyzed to produce predictions of expected distance to effects criteria, compiled based on best available evidence. The predicted sound fields were combined with predictions of animal density for marine mammals, sea turtles, and fish to produce a model of the expected number of animals exposed to potentially injurious or behaviorally disturbing sound levels.

K.2.1. Evaluation Criteria

K.2.1.1. Marine Mammals

Injury to the ears of a marine mammal may result from a single loud event or from a fatiguing stimulus of multiple impulses or prolonged lower-level sounds received over time. The potential for auditory injury is commonly assessed using the dose-like acoustic metric SEL, which includes both the level and duration of an exposure signal. A permanent reduction in hearing sensitivity, or permanent threshold shift (PTS), is considered an auditory injury. There are few published data on real exposures leading to measured PTS in marine mammals, but several experiments have been performed to measure the sound levels that lead to temporary threshold shift (TTS). PTS onset may 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 SEL accumulated within 24 hours (h).

NMFS (2018) also provided guidance on using frequency weighting functions to adjust the received sound levels according to the frequency-dependent hearing sensitivities of several marine species hearing groups. Acoustic threshold criteria and frequency weighting functions are specified for the functional hearing groups (low-, mid-, and high-frequency cetaceans, and phocid pinnipeds). Table K-1 shows the hearing group frequency ranges used to define the auditory weighting function.

There is not yet a consensus on appropriate acoustic metrics and thresholds for assessing behavioral effects to marine mammals. NMFS currently uses a behavioral response threshold of broadband unweighted SPL of 120 dB re 1 μPa^2 for continuous sounds for all marine mammal species (NMFS 2018). Table K-2 summarises all relevant PTS and behavioral thresholds that will be applied to the modelled soundscape.

For the modeling, marine mammals were considered static receivers. Acoustic distances where sound levels could exceed marine mammal thresholds were determined using a maximum-over-depth approach.

Table K-1. Marine mammal hearing groups and frequency ranges for species present (NMFS 2018).

Faunal group	Generalized hearing range [a]
Low-frequency (LF) cetaceans (mysticetes or baleen whales)	7 Hertz (Hz) to 35 kilohertz (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 (PW)	50 Hz to 86 kHz

[a] The generalized hearing range is for all species within a group. Individual hearing will vary.

Table K-2. Summary of permanent threshold shift (PTS) onset acoustic thresholds (dB re 1 µPa²s) and behavioral threshold levels (dB re 1 µPa²) for marine mammals exposed to non-impulsive sound sources (NMFS 2018).

Faunal group	PTS threshold $L_{E,\text{w},24\text{h}}$	Behavior threshold L_p
Low-frequency (LF) cetaceans	199	120
Mid-frequency (MF) cetaceans	198	120
High-frequency (HF) cetaceans	173	120
Phocid pinnipeds in water (PW)	201	120

$L_{E,\text{w},24h}$ – weighted sound exposure level (dB re 1 µPa²s) over 24 h time period.
L_p – root mean square sound pressure level (dB re 1 µPa²).

K.2.1.2. Fish and Sea Turtles

In a cooperative effort between US 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). The injury and behavioral response levels for fish were compiled and listed in NMFS (2023) for assessing the potential effects to Endangered Species Act (ESA)-listed fish exposed to elevated levels of underwater sound from pile driving. As there is limited research available for non-impulsive fish injury thresholds, adapted criteria from impulsive sources were used for this analysis (Table K-3).

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. It does indicate a high likelihood of response near impact pile driving (tens of meters), a moderate response at intermediate distances (hundreds of meters), and a low response far (thousands of meters) from the pile (Popper et al. 2014).

Injury, impairment, and behavioral thresholds for sea turtles were developed for use by the US Navy (Finneran et al. 2017) based on exposure studies (e.g., McCauley et al. 2000). Dual criteria (SEL and peak sound pressure (PK)) have been suggested for PTS, along with auditory weighting functions published by Finneran et al. (2017) used in conjunction with SEL thresholds for PTS. It should be noted that PK criteria do not apply to non-impulsive sound sources and were therefore not used to evaluate the impacts of the vibratory installation of sheet piles in this report. The recommended behavioral threshold is SPL 175 dB re 1 µPa² (McCauley et al. 2000, Finneran et al. 2017) (Table K-3).

Fish and sea turtles were considered static receivers. Acoustic distances where sound levels could exceed sea turtle (Finneran et al. 2017) and fish (FHWG 2008, Popper et al. 2014) thresholds were determined using a maximum-over-depth approach.

Table K-3. 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 pile driving. Fish injury thresholds from impulsive sources were used for this analysis since non-impulsive injury criteria for fish do not exist (Popper et al. 2014). Values in orange were used for this analysis.

Faunal group	Impulsive injury $L_{E,24h}$	Non-impulsive injury $L_{E,24h}$	Behavior L_p
Fish ≥ 2 grams (g) [a]	187	-	150
Fish < 2 g [a]	183	-	150
Fish without swim bladder [b]	216	-	-
Fish with swim bladder [b]	203	-	-
Sea turtles [c, d]	204	220	175

$L_{E,24h}$ – sound exposure level (dB re 1 µPa^{2}s) over 24 h time period.
L_p – root mean square sound pressure level (dB re 1 µPa^2).
A dash indicates that a threshold is not defined.
[a] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[b] Popper et al. (2014), used by BOEM.
[c] Finneran et al. (2017), used by BOEM.
[d] McCauley et al. (2000), used by BOEM.

K.2.2. Source and Propagation Modeling

K.2.2.1. Source Characteristics

Illingworth & Rodkin (2017) measured vibratory pile driving for four 12-inch (in) wide connected sheet piles (48-in total width) using both an APE Model 300 vibratory hammer (2300 kilonewton [kN] driving force) and an ICE-416 vibratory hammer (886 kilonewton [kN] driving force) at 10 m from the source. Analysis of the two hammers indicates that measured levels from the APE 300 are inconsistent with the hammer operating at full power and do not express the expected tonal features for the nominal driving frequency; therefore, source levels were modeled on the ICE-416 vibratory hammer. The source spectrum of vibratory pile driving across 5–25,000 Hz based on Figure B-12 of Illingworth & Rodkin (2017), corrected for 10 m of spherical spreading loss and scaled for the higher 1788 kN driving force of the APE 200T hammer (Figure K-2), was used to represent the source characteristics of the planned vibratory hammer for acoustic propagation modeling. The broadband energy source level is 188.4 dB re 1 μPa²m²s.

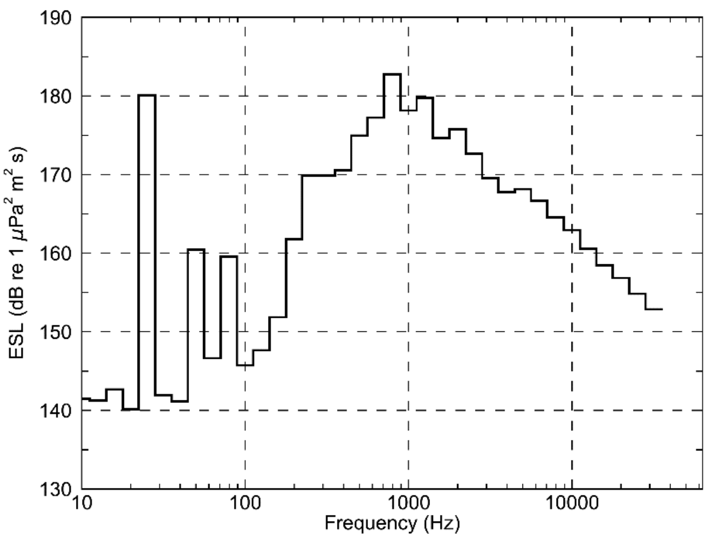

Figure K-2. Decidecade-band spectral energy source levels for vibratory driving of sheet piles, derived from Illingworth & Rodkin (2017).

K.2.2.2. Sound Propagation Modeling

JASCO's Marine Operations Noise Model (MONM) was used to predict SEL and SPL sound fields at the three locations near the proposed cofferdam sites. MONM employs two propagation subroutines: MONM-RAM, used for propagating acoustic energy at low frequencies (i.e., ≤1600 Hz), and MONM-BELLHOP, used for propagating acoustic energy at higher frequencies (i.e., >1600 Hz).

MONM-RAM computes acoustic propagation via 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 an elastic seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM-RAM accounts for the additional reflection loss at the seabed due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes compressional wave attenuation in all layers. MONM-RAM incorporates the following site-specific environmental properties: a modeled area bathymetric grid, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM-BELLHOP employs a Gaussian-beam acoustic ray-trace model (Porter and Liu 1994). This version of 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 seabed boundaries (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results. MONM-BELLHOP incorporates the following site-specific environmental properties: a modeled area bathymetric grid, water column sound speed as a function of depth, as well as temperature and salinity for calculating the sound attenuation due to energy absorption, geoacoustic properties of the surficial sediments, and surface roughness (due to wind).

The sheet pile was represented as a point source at depth equal to half the water depth at the pile location (i.e., a point source depth of 3.6 m at Site C01, 4.8 m at Site C02, and 3.7 m at Site C03), and total sound energy transmission loss was computed at the center frequencies of decidecade bands as a function of range and depth from the source. The acoustic field in three dimensions was generated by modeling acoustic propagation in two-dimensional (2-D) vertical planes azimuthally spaced at 3° in a 360° swath around the source (*N*×2-D approach). Composite broadband received SEL was computed by summing the received decidecade band levels across frequency and taking the maximum-over-depth. For weighted SEL, the appropriate weighting factor for the generalized hearing range of the target receiver (see Supplement C) was applied to each band level prior to summing. Table K-4 lists the principal modeling parameters.

Acoustic propagation modeling was performed for two seasons: summer and winter. The summer sound speed profile is downward refracting due to warmer surface waters, and the winter profile includes a surface duct caused by cooler surface temperature that leads to a positive sound speed gradient. The mean sustained wind speeds also differed by season.

The water level variation due to tides is approximately 1 meter (m) in the area and was deemed to have negligible effect on sound propagation.

Table K-4. Principal parameters for underwater acoustic modeling of vibratory driving of steel sheet piles.

Parameter	Value	Reference
Hammer	APE Model 200T (vibratory)	Provided by Vinyard Mid Atlantic LLC
Pile type	Sheet pile	Provided by Vinyard Mid Atlantic LLC
Pile Driving Source Level	Source level for ICE-416 vibratory hammering of sheet piles modified for APE Model 200T hammer power.	Illingworth & Rodkin (2017)
Bathymetry	1 arc-second US Coastal Relief Model (CRM)	National Center for Environmental Information (NCEI) (https://www.ngdc.noaa.gov/)
Tides	MHW [a] over MLW [b] ~1 m (3.3 feet [ft])	https://tidesandcurrents.noaa.gov/ (Approaches to Long Island)
Wind speed	Winter: 18.2 meters per second [m s^{-1}] Summer: 11.2 m s^{-1}	QuikSCAT (Ricciardulli et al. 2011)
Sound speed	Extreme seasonal profiles (December and Average of July-September)	GDEM v 3.0 (NAVO 2003)
Geoacoustics	Fine sand, terrigenous sediments	NAVOCEAN (2009), Hamilton (1980)

[a] MHW: mean high water
[b] MLW: mean low water

K.2.3. Exposure Estimates for Marine Mammals and Sea Turtles

K.2.3.1. 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, 2023, 2024). 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 in the potential impact area were estimated using the East Coast sea turtle density models developed by the US Naval Undersea Warfare Center (NUWC; DiMatteo et al. 2024).

To calculate marine mammal and sea turtle densities in the potential vibratory pile driving impact area, it was assumed that the activity will occur in three areas of interest along the southern coast of Long Island, New York. The density perimeter was determined using the longest 95th percentile acoustic range to threshold ($R_{95\%}$), rounded to the nearest 5 km, at each location. The $R_{95\%}$ at site C02 was found to be 39.1 km and encompassed the zones of influence of the other two sites, so a 40 km density perimeter centered around site C02 was used to calculate species density. Monthly densities for each species in this perimeter were calculated as the average of the densities from all MGEL/Duke model grid cells that overlap partially or completely with each area of interest. Cells entirely on land were not included, but cells that overlap only partially with land were included. To obtain the most conservative exposure estimates, the maximum monthly densities for each species in winter and summer were used to calculate exposures.

The MGEL/Duke models report densities for two species guilds considered in this study: pilot whales and seals. When calculating exposures for individual pilot whale and seal species, the guild densities provided by Roberts et al. (2016, 2023, 2024) 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 were downloaded from the Ocean Biodiversity Information System (OBIS) data repository (available at https://obis.org/). The best data available for pilot whales came from the Mystic Aquarium data set of marine mammal strandings in the region, due to their overlap with the project area. The proportions of 0.93 for long-finned and 0.07 for short-finned pilot whales were used (Smith 2014). For the two seal species, 2022–2023 protected species observer (PSO) sighting data from the 0544 Lease Area was insufficient, so proportions of seals were determined from OBIS data as cited in the Final Rule for the adjacent Empire Wind project: 0.34 for gray seals and 0.66 for harbor seals (DoC and NOAA 2024). Table K-5 below shows the maximum monthly densities calculated over winter (December to March) and summer (April to November) within the density perimeter centered around site C03. Figure K-3 shows the data cells used in these density calculations at the three modeling sites.

Table K-5. All sites: Maximum monthly density (animals per 100 square kilometer [km^2]) estimated during winter (December to March) and summer (April to November).

Common name	Winter	Summer
Fin whale [a]	0.088	0.085
Humpback whale	0.142	0.107
Common minke whale (migrating)	0.034	0.633
North Atlantic right whale [a]	0.066	0.039
Sei whale [a] (migrating)	0.045	0.026
Sperm whale [a]	0.004	0.006
Atlantic spotted dolphin	0.003	0.041
Atlantic white sided dolphin	0.329	0.383
Common bottlenose dolphin	3.976	7.705
Long-finned pilot whale	0.003	0.003
Short-finned pilot whale	<0.001	<0.001
Goose-beaked whale	<0.001	<0.001
Blainville's beaked whale	<0.001	<0.001
Striped dolphin	<0.001	<0.001
Risso's dolphin	0.037	0.010
Common dolphin	3.295	3.289
Harbor porpoise (sensitive)	2.509	3.118
Gray seal	3.818	5.567
Harbor seal	7.411	10.806
Kemp's ridley sea turtle [a]	0	0.013
Leatherback sea turtle [a]	<0.001	0.072
Loggerhead sea turtle	0.003	0.030
Green sea turtle	0	0.132

[a] Listed as Endangered under the ESA.

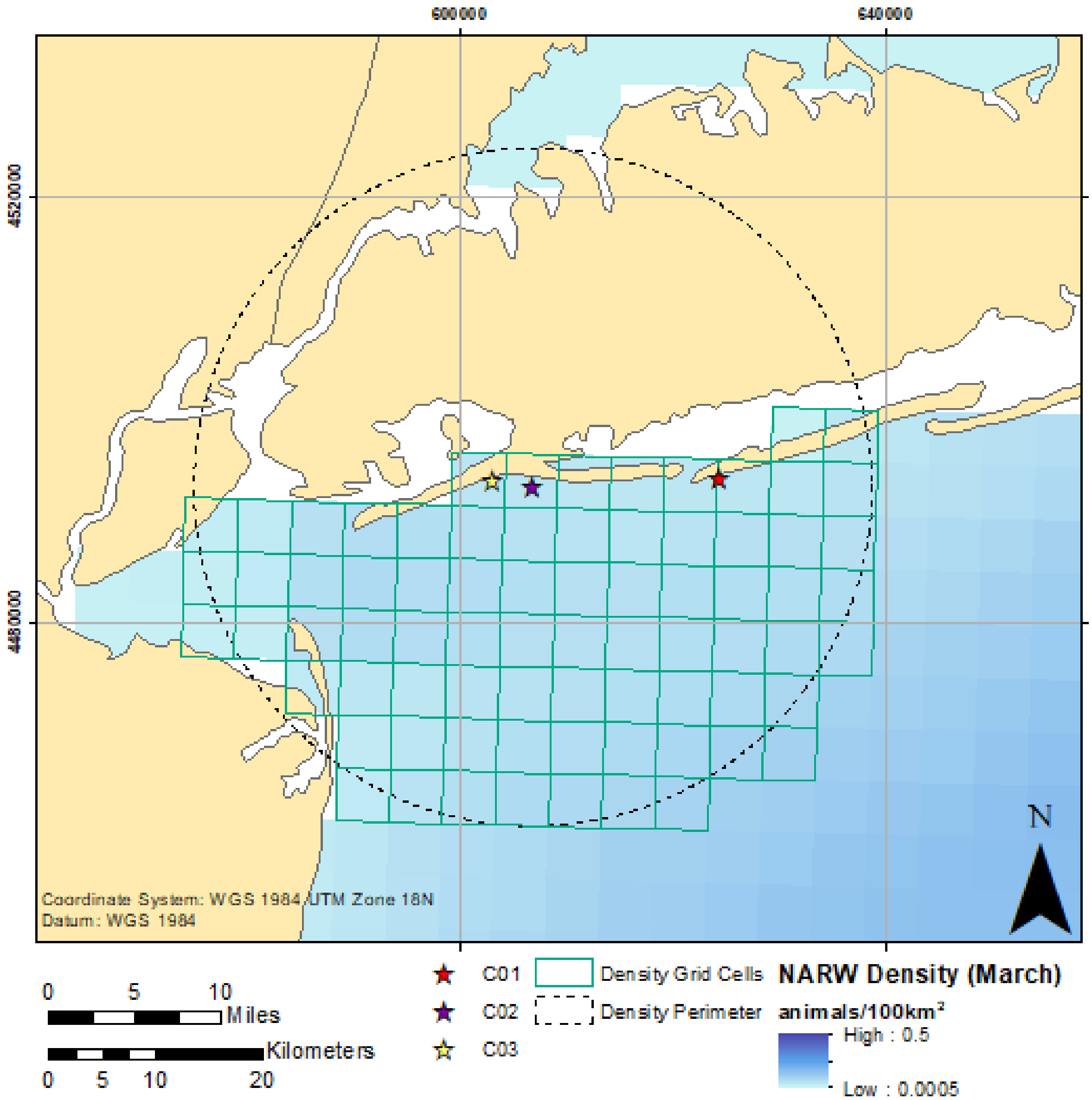

Figure K-3. Marine mammal (e.g., NARW) density map showing highlighted grid cells used to calculate maximum seasonal species densities (Roberts et al. 2016, 2023, 2024). The density perimeter was 40 km, calculated using the longest $R_{95\%}$ for vibratory pile driving, centered at site C03.

K.2.3.2. Exposure Estimation

A zone of influence (ZOI) is a representation of the maximum extent of an ensonified area around a sound source over a 24-h 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 marine mammal and sea turtle species by multiplying the maximum seasonal density from Table K-5 by the corresponding ZOI from Tables K-12 to K-14, and then multiplied by the number of days (10) required to install all cofferdam piles.

K.3. Results

K.3.1. Acoustic Ranges and Ensonified Areas

This analysis assumes that 10 h of vibratory pile driving will occur for cofferdam installation in a 24-h period. The distances to PTS for the marine mammal hearing groups (see Table K-2) and for fish and sea turtles (see Table K-3) in winter and summer are shown in Tables K-6 to K-8 for sites C01, C02, and C03 respectively. The potential injury distances were estimated based on frequency-weighted 24-h SEL ($L_{E,\mathrm{w},24\mathrm{h}}$) for marine mammals and turtles, and on unweighted 24-h SEL ($L_{E,24\mathrm{h}}$) for fish. The extent of the potential injury zones in winter and summer at all three sites are shown in Figure K-4 for marine mammals and Figure K-5 for fish.

The distances to behavioral response for the marine mammal hearing groups, fish, and sea turtles in winter and summer are shown in Table K-9 for site C01, Table K-10 for site C02, and Table K-11 for site C03. The behavioral distances were estimated based on the sound pressure level (L_p) of 120 dB re 1 μPa^2 for marine mammals, 150 dB re 1 μPa^2 for fish, and 175 dB re 1 μPa^2 for sea turtles. Figure K-6 shows the extent of the behavioral response zones, relevant for all species, in winter and summer at all sites.

The maximum distance to the 120 dB re 1 μPa^2 SPL threshold (NMFS 2018) for marine mammals was found to extend to the following:

- Jones Beach landfall site (C01): 23.7 km in winter and 6.1 km in summer,
- Atlantic Beach landfall site (C02): 44.8 km in winter and 6.6 km in summer, and
- Rockaway Beach landfall site (C03): 32.1 km in winter and 6.3 km in summer.

The 95 % radius ($R_{95\%}$) calculation, which excludes the farthest 5 % of exceedance area, gives the following behavioral threshold ranges

- Jones Beach landfall site (C01): 21.4 km in winter and 5.7 km in summer,
- Atlantic Beach landfall site (C02): 39.1 km in winter and 6.0 km in summer, and
- Rockaway Beach landfall site (C03): 28.6 km in winter and 5.8 km in summer.

Table K-6. Site C01, winter and summer: Distances R_{max} and $R_{95\%}$ (in meters [m]) to and total area (in square kilometers [km²]) exposed above permanent threshold shift (PTS) onset threshold levels (dB re 1 µPa²s) for marine mammal hearing groups based on frequency-weighted 24-hour sound exposure level (SEL) and injury threshold level (dB re 1 µPa²s) for fish based on unweighted 24-hour SEL and sea turtles based on frequency-weighted 24-hour SEL for non-impulsive sounds generated by vibratory driving of sheet piles. Corresponding criteria reference for each threshold level is indicated in the footnote. $R_{95\%}$ and areas were not calculated (marked as "nc") if R_{max} was less than 10 m.

Hearing group	Threshold	Winter R_{max}	Winter $R_{95\%}$	Winter Area	Summer R_{max}	Summer $R_{95\%}$	Summer area
Low-frequency cetaceans	199 [a]	215	202	0.137	209	198	0.129
Mid-frequency cetaceans	198 [a]	<10	nc	nc	<10	nc	nc
High-frequency cetaceans	173 [a]	139	130	0.056	166	153	0.078
Phocid pinnipeds in water	201 [a]	64	61	0.013	64	61	0.013
Fish ≥ 2 g	187 [b]	1114	1022	2.592	1017	944	2.290
Fish < 2 g	183 [b]	1941	1734	5.915	1595	1458	4.682
Fish without swim bladder	216 [c]	10	10	<0.001	10	10	<0.001
Fish with swim bladder	203 [c]	114	112	0.041	114	110	0.040
Sea turtles	220 [d]	<10	nc	nc	<10	nc	nc

[a] NMFS (2018).
[b] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[c] Popper et al. (2014).
[d] Finneran et al. (2017).

Table K-7. Site C02, winter and summer: Distances R_{max} and $R_{95\%}$ (in meters [m]) to and total area (in square kilometers [km²]) exposed above permanent threshold shift (PTS) onset threshold levels (dB re 1 µPa²s) for marine mammal hearing groups based on frequency-weighted 24-hour sound exposure level (SEL) and injury threshold level (dB re 1 µPa²s) for fish based on unweighted 24-hour SEL and sea turtles based on frequency-weighted 24-hour SEL for non-impulsive sounds generated by vibratory driving of sheet piles. Corresponding criteria reference for each threshold level is indicated in the footnote. $R_{95\%}$ and areas were not calculated (marked as "nc") if R_{max} was less than 10 m.

Hearing group	Threshold	Winter R_{max}	Winter $R_{95\%}$	Winter Area	Summer R_{max}	Summer $R_{95\%}$	Summer area
Low-frequency cetaceans	199 [a]	193	177	0.102	191	177	0.099
Mid-frequency cetaceans	198 [a]	<10	nc	nc	<10	nc	nc
High-frequency cetaceans	173 [a]	130	124	0.051	157	146	0.070
Phocid pinnipeds in water	201 [a]	42	41	0.006	42	42	0.006
Fish ≥ 2 g	187 [b]	1162	1085	3.457	1012	945	2.769
Fish < 2 g	183 [b]	2067	1910	8.551	1641	1521	6.042
Fish without swim bladder	216 [c]	10	10	<0.001	10	10	<0.001
Fish with swim bladder	203 [c]	89	85	0.024	91	89	0.025
Sea turtles	220 [d]	<10	nc	nc	<10	nc	nc

[a] NMFS (2018).
[b] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[c] Popper et al. (2014).
[d] Finneran et al. (2017).

Table K-8. Site C03, winter and summer: Distances R_{max} and $R_{95\%}$ (in meters [m]) to and total area (in square kilometers [km²]) exposed above permanent threshold shift (PTS) onset threshold levels (dB re 1 µPa²s) for marine mammal hearing based on frequency-weighted 24-hour sound exposure level (SEL) and injury threshold level (dB re 1 µPa²s) for fish based on unweighted 24-hour SEL and sea turtles based on frequency-weighted 24-hour SEL for non-impulsive sounds generated by vibratory driving of sheet piles. Corresponding criteria reference for each threshold level is indicated in the footnote. $R_{95\%}$ and areas were not calculated (marked as "nc") if R_{max} was less than 10 m.

Hearing group	Threshold	Winter R_{max}	Winter $R_{95\%}$	Winter Area	Summer R_{max}	Summer $R_{95\%}$	Summer area
Low-frequency cetaceans	199 [a]	210	197	0.125	205	190	0.117
Mid-frequency cetaceans	198 [a]	<10	nc	nc	<10	nc	nc
High-frequency cetaceans	173 [a]	141	130	0.056	166	151	0.075
Phocid pinnipeds in water	201 [a]	61	54	0.010	61	54	0.010
Fish ≥ 2 g	187 [b]	1140	1011	2.406	1016	914	2.086
Fish < 2 g	183 [b]	2040	1765	5.681	1592	1441	4.259
Fish without swim bladder	216 [c]	10	10	<0.001	10	10	<0.001
Fish with swim bladder	203 [c]	117	108	0.035	114	106	0.034
Sea turtles	220 [d]	<10	nc	nc	<10	nc	nc

[a] NMFS (2018).
[b] NMFS recommended criteria adopted from the Fisheries Hydroacoustic Working Group (FHWG 2008).
[c] Popper et al. (2014).
[d] Finneran et al. (2017).

Table K-9. Site C01, winter and summer: Distances R_{max} and $R_{95\%}$ (in meters [m]) to and total area (in square kilometers [km²]) exposed above behavioral threshold levels (dB re 1 µPa^2) for marine mammal hearing groups, fish, and sea turtles based on root-mean-square sound pressure level (dB re 1 µPa^2) for non-impulsive sounds generated by vibratory driving of sheet piles. Corresponding criteria reference for each threshold level is indicated in the footnote. $R_{95\%}$ and areas were not calculated (marked as "nc") if R_{max} was less than 10 m.

Hearing group	Threshold	Winter R_{max}	Winter $R_{95\%}$	Winter Area	Summer R_{max}	Summer $R_{95\%}$	Summer area
Marine mammals	120 [a]	23730	21379	472.560	6124	5756	57.171
Fish	150	365	340	0.372	349	326	0.344
Sea turtles	175 [b]	<10	nc	nc	<10	nc	nc

[a] NMFS (2018)
[b] McCauley et al. (2000) and Finneran et al. (2017).

Table K-10. Site C02, winter and summer: Distances R_{max} and $R_{95\%}$ (in meters [m]) to and total area (in square kilometers [km²]) exposed above behavioral threshold levels (dB re 1 µPa^2) for marine mammal hearing groups, fish, and sea turtles based on root-mean-square sound pressure level (dB re 1 µPa^2) for non-impulsive sounds generated by vibratory driving of sheet piles. Corresponding criteria reference for each threshold level is indicated in the footnote. $R_{95\%}$ and areas were not calculated (marked as "nc") if R_{max} was less than 10 m.

Hearing group	Threshold	Winter R_{max}	Winter $R_{95\%}$	Winter Area	Summer R_{max}	Summer $R_{95\%}$	Summer area
Marine mammals	120 [a]	44862	39061	1182.300	6594	5972	66.980
Fish	150	330	310	0.311	320	297	0.285
Sea turtles	175 [b]	<10	nc	nc	<10	nc	nc

[a] NMFS (2018)
[b] McCauley et al. (2000) and Finneran et al. (2017).

Table K-11. Site C03, winter and summer: Distances R_{max} and $R_{95\%}$ (in meters [m]) to and total area (in square kilometers [km²]) exposed above behavioral threshold levels (dB re 1 µPa^2) for marine mammal hearing groups, fish, and sea turtles based on root-mean-square sound pressure level (dB re 1 µPa^2) for non-impulsive sounds generated by vibratory driving of sheet piles. Corresponding criteria reference for each threshold level is indicated in the footnote. $R_{95\%}$ and areas were not calculated (marked as "nc") if R_{max} was less than 10 m.

Hearing group	Threshold	Winter R_{max}	Winter $R_{95\%}$	Winter Area	Summer R_{max}	Summer $R_{95\%}$	Summer area
Marine mammals	120 [a]	32097	28638	591.040	6298	5826	50.862
Fish	150	359	328	0.338	349	310	0.311
Sea turtles	175 [b]	<10	nc	nc	<10	nc	nc

[a] NMFS (2018)

[b] McCauley et al. (2000) and Finneran et al. (2017).

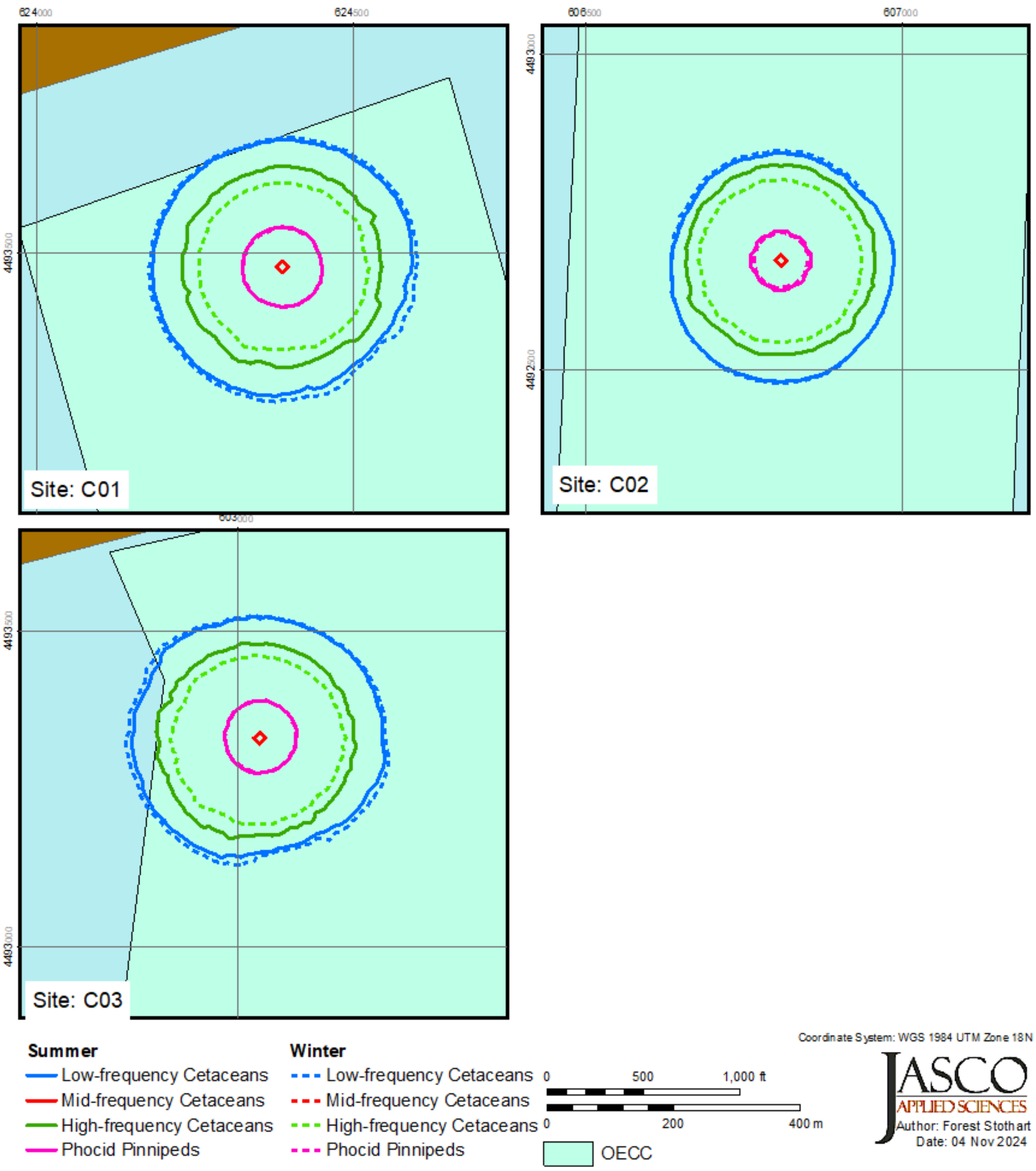

Figure K-4. Sites C01, C02, and C03, winter and summer: Marine mammals permanent threshold shift (PTS) onset threshold contours based on frequency weighted 24-hour sound exposure level (dB re 1 µPa^{2}s) for non-impulsive sounds generated by vibratory driving of sheet piles. Sea turtle PTS ranges were shorter than the modeling resolution and are not shown.

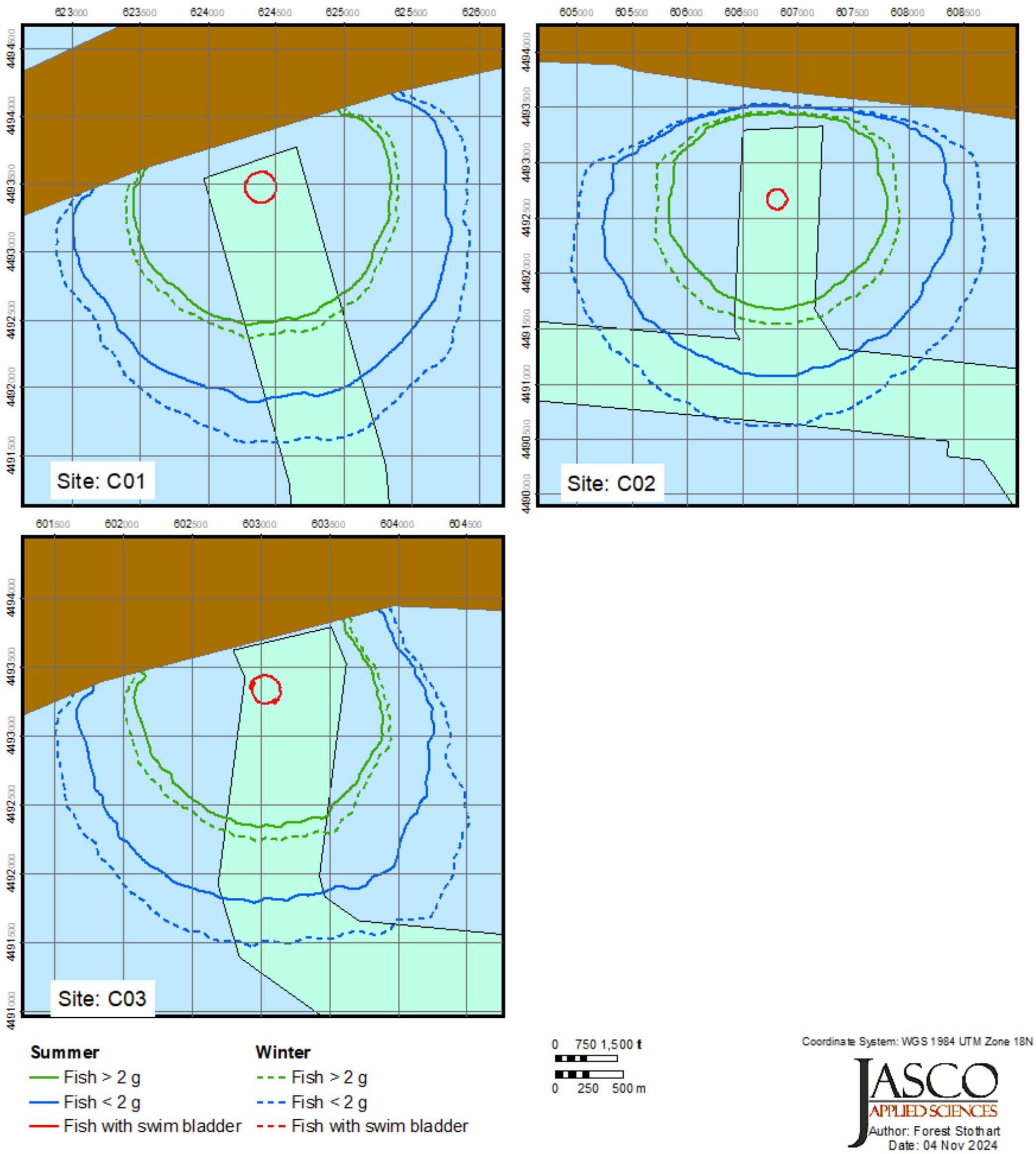

Figure K-5. Sites C01, C02, and C03, winter and summer: Fish permanent threshold shift (PTS) onset threshold contours based on unweighted 24-hour sound exposure level (dB re 1 µPa^{2}s) for non-impulsive sounds generated by vibratory driving of sheet piles.

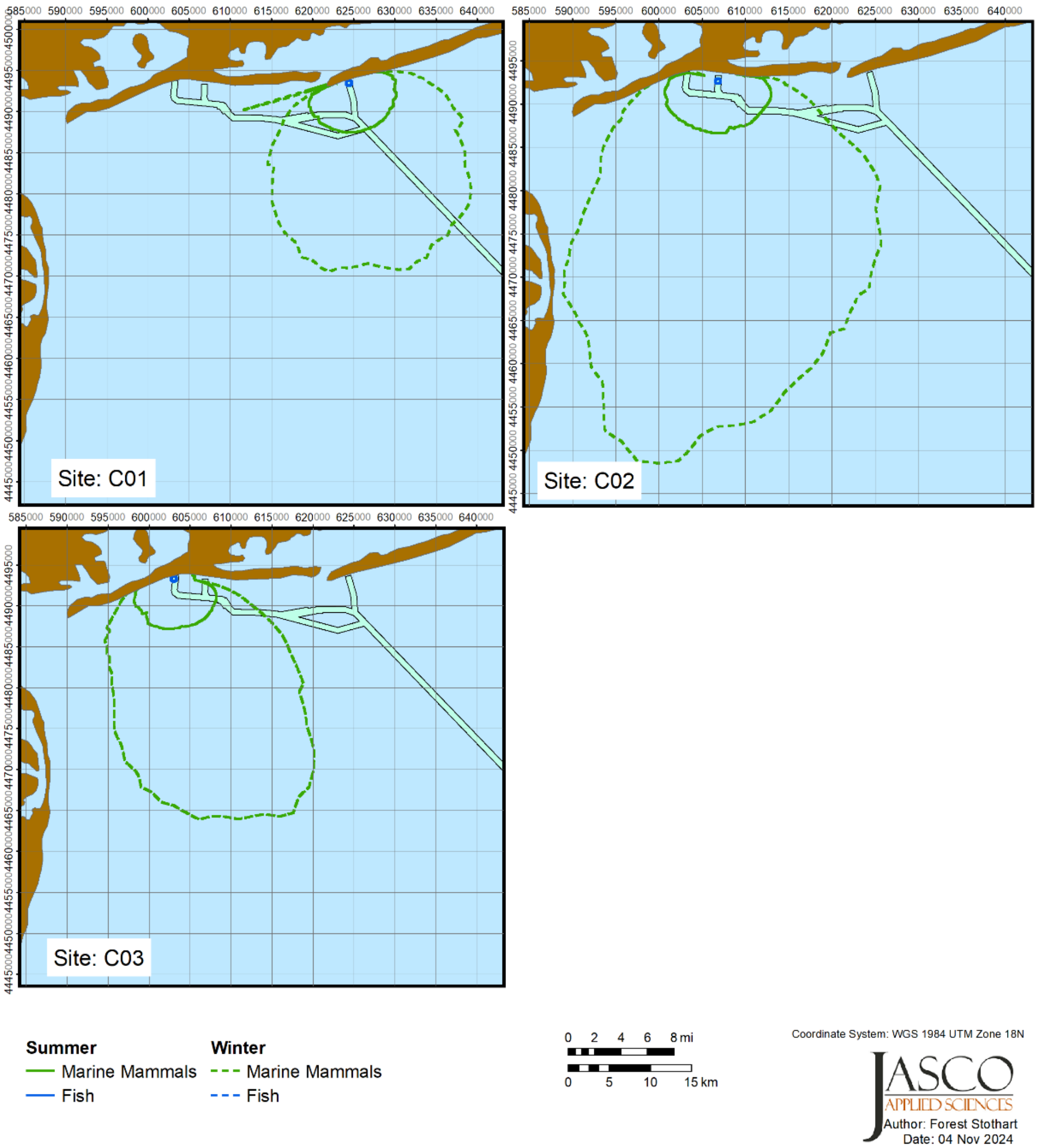

Figure K-6. Sites C01, C02, and C03,, winter and summer: Marine mammal and fish behavioral threshold contours based on root-mean-square sound pressure level (dB re 1 μPa^2) for non-impulsive sounds generated by vibratory driving of sheet piles. Sea turtle behavioral ranges were shorter than the modeling resolution and are not shown.

K.3.2. Exposure Estimates

Exposure estimates were calculated for winter and summer for installing one cofferdam over 10 days at the three projected landfall sites. Tables K-12 to K-14 provide the number of exposures to marine mammal and sea turtle injury and behavioral thresholds at sites C01, C02, and C03, respectively. Cofferdam removal is also anticipated to require 10 days of vibratory pile driving. Removal of piles is undertaken using the same vibratory hammer that installed the piles, and sound levels are expected to be the same or lower than during installation; therefore, predicted exposures in Tables K-12 to K-14 offer a conservative estimate of exposures which could occur during cofferdam removal.

Injury exposures are very low, with 0.01 animals or less for all marine mammal and sea turtle species at all three cofferdam locations, during all seasons.The number of total behavioral exposures is also low, with 1 or less animals per day for most marine mammal species, excluding some dolphin species and seals. Over the course of the 10-day cofferdam installation period, the greatest number of behavior exposures predicted is 883.61 (harbor seals, C02, winter). The maximum number of behavior exposures for North Atlantic right whales expected during the complete installation of a cofferdam is 7.81 (C02, winter). In general, for most species at each location, behavior exposures were greater during winter than summer.

Sea turtle exposures are less than 0.01 animals per day for all thresholds, seasons, and locations.

Table K-12. Site C01, summer and winter: Maximum number of marine mammals and sea turtles predicted to receive sound levels above injury and behavior thresholds resulting from installing one cofferdam.

Common name	Summer PTS/Injury	Summer Behavior	Winter PTS/Injury	Winter Behavior
Fin whale	<0.01	0.48	<0.01	4.15
Humpback whale	<0.01	0.61	<0.01	6.71
Common minke whale (migrating)	<0.01	3.63	<0.01	1.62
North Atlantic right whale	<0.01	0.22	<0.01	3.12
Sei whale (migrating)	<0.01	0.15	<0.01	2.11
Sperm whale	0	0	0	0
Atlantic spotted dolphin	<0.01	0.23	0	0
Atlantic white sided dolphin	<0.01	2.19	<0.01	15.61
Common bottlenose dolphin	<0.01	43.50	<0.01	17.04
Long-finned pilot whale	0	0	0	0
Short-finned pilot whale	0	0	0	0
Goose-beaked whale	0	0	0	0
Blainville’s beaked whale	0	0	0	0
Striped dolphin	0	0	0	0
Risso’s dolphin	<0.01	0.06	<0.01	1.74
Common dolphin	<0.01	3.97	<0.01	76.27
Harbor porpoise (sensitive)	<0.01	4.75	0.01	99.23
Gray seal	<0.01	31.86	<0.01	181.94
Harbor seal	0.01	54.03	<0.01	353.18
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	<0.01	0	0
Loggerhead sea turtle	<0.01	<0.01	0	0
Green sea turtle	<0.01	<0.01	0	0

Table K-13. Site C02, summer and winter: Maximum number of marine mammals and sea turtles predicted to receive sound levels above injury and behavior thresholds resulting from installing one cofferdam.

Common name	Summer PTS/Injury	Summer Behavior	Winter PTS/Injury	Winter Behavior
Fin whale	<0.01	0.56	<0.01	10.38
Humpback whale	<0.01	0.71	<0.01	16.78
Common minke whale (migrating)	<0.01	4.26	<0.01	4.05
North Atlantic right whale	<0.01	0.26	<0.01	7.81
Sei whale (migrating)	<0.01	0.18	<0.01	5.29
Sperm whale	0	0	0	0
Atlantic spotted dolphin	<0.01	0.27	0	0
Atlantic white sided dolphin	<0.01	2.57	<0.01	39.05
Common bottlenose dolphin	<0.01	50.96	<0.01	42.64
Long-finned pilot whale	0	0	0	0
Short-finned pilot whale	0	0	0	0
Goose-beaked whale	0	0	0	0
Blainville's beaked whale	0	0	0	0
Striped dolphin	0	0	0	0
Risso's dolphin	<0.01	0.07	<0.01	4.36
Common dolphin	<0.01	4.65	<0.01	190.82
Harbor porpoise (sensitive)	<0.01	5.56	0.01	248.25
Gray seal	<0.01	37.32	<0.01	455.19
Harbor seal	<0.01	63.30	<0.01	883.61
Kemp's ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	<0.01	0	0
Loggerhead sea turtle	<0.01	<0.01	0	0
Green sea turtle	<0.01	<0.01	0	0

Table K-14. Site C03, summer and winter: Maximum number of marine mammals and sea turtles predicted to receive sound levels above injury and behavior thresholds resulting from installing one cofferdam.

Common name	Summer PTS/Injury	Summer Behavior	Winter PTS/Injury	Winter Behavior
Fin whale	<0.01	0.43	<0.01	5.19
Humpback whale	<0.01	0.54	<0.01	8.39
Common minke whale (migrating)	<0.01	3.23	<0.01	2.03
North Atlantic right whale	<0.01	0.20	<0.01	3.90
Sei whale (migrating)	<0.01	0.13	<0.01	2.64
Sperm whale	0	0	0	0
Atlantic spotted dolphin	<0.01	0.21	0	0
Atlantic white sided dolphin	<0.01	1.95	<0.01	19.52
Common bottlenose dolphin	<0.01	38.70	<0.01	21.32
Long-finned pilot whale	0	0	0	0
Short-finned pilot whale	0	0	0	0
Goose-beaked whale	0	0	0	0
Blainville’s beaked whale	0	0	0	0
Striped dolphin	0	0	0	0
Risso’s dolphin	<0.01	0.05	<0.01	2.18
Common dolphin	<0.01	3.53	<0.01	95.39
Harbor porpoise (sensitive)	<0.01	4.22	0.01	124.10
Gray seal	<0.01	28.34	<0.01	227.55
Harbor seal	<0.01	48.06	<0.01	441.72
Kemp’s ridley sea turtle	<0.01	<0.01	0	0
Leatherback sea turtle	<0.01	<0.01	0	0
Loggerhead sea turtle	<0.01	<0.01	0	0
Green sea turtle	<0.01	<0.01	0	0

K.4. Summary

Vibratory piling during cofferdam installation produces non-impulsive sound that may cause hearing damage or behavioral responses in marine mammals, sea turtles, and fish. Distances to potential injury and behavioral disruption of marine fauna are computed here by propagating measured sound levels from vibratory pile driving of sheet piles (Illingworth & Rodkin 2017). The modeled ensonified areas are combined with the planned duration of vibratory piling per day and predicted species densities to estimate the number of marine mammals and sea turtles that will be exposed above thresholds for injury and behavioral response.

Marine mammal PTS injury is unlikely to occur from the proposed cofferdam construction. The maximum PTS range across all hearing groups from the modeled sites was 215 m at site C01 for low frequency cetaceans in winter. PTS ranges for all other seasons and hearing groups fell below this distance, though only phocid pinnipeds had PTS ranges less than 100 m. PTS ranges were slightly lower in summer (~10 m) for most hearing groups except for high frequency cetaceans, where PTS ranges were slightly higher (~10 m). Marine mammals are not likely to remain static across 24 h, and ranges to PTS are generally less than ~200 m thereby reducing sound exposure and likely eliminating possible injurious exposure. Fish weighing less than 2 g could sustain injury as far as ~2000 m from the cofferdam sites, and fish weighing greater than 2 g could sustain injury within ~1100 m. These distances may be considered conservative because the animals would have to remain within these ranges for the entire 10 h of pile driving.

The maximum distance to the 120 dB re 1 μPa^2 SPL threshold for marine mammals was found to extend to the following:

- Jones Beach landfall site (C01): 23.7 km in winter and 6.1 km in summer (Table K-9, Figure K-6),
- Atlantic Beach landfall site (C02: 44.8 km in winter and 6.6 km in summer (Table K-10, Figure K-6), and
- Rockaway Beach landfall site (C03): 32.1 km in winter and 6.3 km in summer (Table K-11, Figure K-6).

The behavioral threshold for fish is ≥150 dB re 1 μPa^2 (NMFS 2023), which corresponds to the following maximum acoustic ranges to threshold for installing cofferdam sheet piles using vibratory pile driving:

- Jones Beach landfall site (C01): 365 m in winter and 349 m in summer (Table K-9, Figure K-6),
- Atlantic Beach landfall site (C02): 330 m in winter and 320 m in summer (Table K-10, Figure K-6), and
- Rockaway Beach landfall site (C03): 359 m in winter and 349 m in summer (Table K-11, Figure K-6).

Sea turtles are expected to be unaffected by sounds from cofferdam installation in terms of injury and disturbance. The specific thresholds are predicted to be less than 10 m from the pile under all conditions.

Injury exposures resulting from the complete installation of a cofferdam are very low, with 0.01 animals or less for all marine mammal and sea turtle species at all three cofferdam locations for all seasons.

Behavior exposures for most species at each location were larger during winter than summer. The greatest number of behavior exposures expected in summer is predicted to be 63.3 for harbor seals at site C02. During winter, the greatest number of behavior exposures is 883.61, also for harbor seals at site C02. After seals, harbor porpoises have the second highest number of behavior exposures, with 248.25 at site C02 in winter. The maximum number of behavior exposures for North Atlantic right whales predicted during the complete installation of a cofferdam is 7.81 for site C02, in winter).

Sea turtle exposures are estimated to be less than 0.01 animals per day for all thresholds, seasons, and sites.

Exposure estimates presented in this report are conservative estimates, as they are based on maximum seasonal density data and treat marine fauna as static receivers. In addition, protected species monitoring during construction will further reduce the risk of PTS and behavioral exposures in marine mammals and sea turtles.

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