H1. Underwater Acoustic Assessment Report (June 2024)

Underwater Acoustic Assessment of Pile Driving during Construction at the Maryland Offshore Wind Project

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Research – Operations – Engineering – Design - Analysis

Executive Summary

The predicted effect on marine mammals and sea turtles associated with exposure to the underwater sound generated by impact and vibratory pile driving proposed to be conducted during the construction of the US Wind Maryland Offshore Wind Project (the Project) (OCS Lease 0490) were modeled. Parameters of the physical environment at the model location, including bathymetry, sediment properties, seasonal sound velocity profiles in the water column, and surface roughness, were all input into the acoustic propagation model. Representative sound source spectra for the impact hammers planned to drive piles with diameters of 11-,3- and 1.8-meters (m) were obtained from published literature and reports. As specified in the US Wind Construction and Operations Plan (COP), Volume I, Table 2-2, the Project Design Envelope includes use of monopiles up to 11-m in diameter. The resulting sound fields for each hammer sound source were then used to determine the ranges to regulatory isopleths (e.g., 160 dB re 1µPa RMS for marine mammal behavioral responses to impact pile driving).

Modeling assumptions included the use of a single modeling location within the proposed windfarm, as the bathymetry and sediment types are relatively uniform throughout the Project area. Volume II, Section 3.0 of the US Wind COP details the site geology in the Project area. Volume II, Appendix II-A of the COP includes geophysical and geotechnical reports for surveys conducted in the Project area. The May sound velocity profile was chosen to be representative of the proposed pile driving construction period. The May sound velocity profile represents the best acoustic propagation characteristics for the proposed time period (i.e., largest propagation ranges). Although three pile types were originally considered in the acoustic source modeling (Table ES-1), US Wind decided to forego vibratory pile driving and install the 1.8-m pin piles with impact pile driving.

Table ES-1. Summary of pile types and installation specifics for the Maryland Offshore Wind Project

Type of Structure	Pile Diameter (m)	Hammer Type	Hammer Weight (tons)	Maximum Hammer Energy (kJ)	Piling Time (min)
Monopile	11	Impact	220	4,400	120
Offshore Sub Station (OSS) Jacket (4 skirt piles)	3	Impact	92	1,500	480
Met Tower Jacket (3 piles)	1.8	Vibratory (Discontinued)	-	-	60
Met Tower Jacket (3 pin piles)	1.8	Impact	92	500	360

The Acoustic Integration Model© (AIM) was used in conjunction with the resulting modeled sound fields and model input on marine mammal and sea turtle movements (e.g., swim speeds, dive depths, dive duration, change in course, and total change in course per unit time) to simulate the four-dimensional movements of marine mammals and sea turtles through the model space and time. These simulated animals, or ‘animats’, were assumed to remain in the 1.75° longitude x 1.5° latitude model area box (approximately 20,000 square kilometers) surrounding the modeling site for the entire period of driving of a pile. The predicted sound received level as sampled by AIM every 30 seconds was used to create a sound exposure history for each animat over 24 hours of modeled operation. Each of these exposure histories were subsampled to create multiple estimates of sound exposure for each source-animal combination (for example, the monopile is projected to be driven in 2 hours, so twelve different two-hour exposure histories were extracted). The acoustic exposure history for each animat was analyzed to produce the metrics of maximum root- mean square sound pressure level, cumulative sound exposure level, and peak sound pressure level. These modeled exposure estimates were then scaled by the ratio of real-world density estimates to the modeled animat density. This results in the predicted number of exposures for each species or species group for each pile driven. The marine mammal and sea turtle densities used in this modeling effort were the best available.

The effect of applying mitigation methods (e.g., bubble curtains) to pile-driving scenarios was also explored, and the associated reductions in ranges to regulatory isopleths and the number of marine mammal and sea turtle acoustic exposures were determined. US Wind put forward a mitigation measure (COP Volume II Sections 1.5 and 9.3) committing to a 10 decibel (dB) reduction at the sound source.

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

°	degrees
ρ	density of a medium
λ	lambda
µPa	microPascal(s)
3D	three-dimensional
AIM	Acoustic Integration Model©
BOEM	Bureau of Ocean Energy Management
BW	beaked whales
c	speed of sound in a medium
C	Celsius (Centigrade)
CRM	Coastal Relief Model
dB	decibel(s)
dB re 1 µPa	decibel referenced to a pressure of 1 microPascal
dB re 1 µPa-m	decibel referenced to a pressure of 1 microPascal per meter
dB re 1 μPa^2s	decibel referenced to a pressure of 1 microPascal squared second
DP	Dynamic Positioning
DPS	distinct population segment
ESA	Endangered Species Act
F	Fahrenheit
FE	Finite Element
g	gram(s)
GARFO	Greater Atlantic Regional Fisheries Office (NOAA Fisheries)
GPa	gigaPascal(s)
h	hour(s)
HF	High Frequency
Hz	Hertz
ISO	Organization for International Standardization
kHz	kiloHertz
kJ	kiloJoule(s)
km	kilometer(s)
kph	kilometers per hour

kt	knot(s)
I	acoustic intensity
$L_{E,24h}$	cumulative sound exposure level over a 24-hour period
L_E(cum)	cumulative sound exposure level
L_E(1 sec)	1 second sound exposure level
L_E(ss)	single strike sound exposure level
L_P	root-mean-square sound pressure level
L_{pk}	peak sound pressure level
L_{pp}	peak to peak sound level for a given event
$I_{.}$	reference intensity level
λ	lambda (wavelength)
LF	Low Frequency
MAI	Marine Acoustics, Inc.
MF	Mid Frequency
MMPA	Marine Mammal Protection Act
MW	megawatt(s)
m^3	cubic meters
m	meter(s)
ms	millisecond(s)
N	Number of Samples (Sample Size)
NOAA	National Oceanic and Atmospheric Administration
NARW	North Atlantic right whale(s)
NMFS	National Marine Fisheries Service
NSPE	Navy Standard Parabolic Equation
OCS	outer continental shelf
OSS	offshore substation
OW	otariid pinnipeds in water
p	pressure
po	reference pressure
p(t)	squared sound pressure time series
PE	parabolic equation
pk-pk	peak to peak

PTS	permanent threshold shift
PW	phocid pinnipeds in water
RAM	range-dependent acoustic model
RL	received level
RMS	root-mean-square
s	second(s)
SD	standard deviation
SEL	sound exposure level
SL	source level
SPL	sound pressure level
spp.	species
ST	sea turtle
SVP	sound velocity profile
t	time
T	time interval
T_0	reference time interval of 1 second
T_{90}	90 percent of the sound level
T_{100}	time-integral of the squared pressure over the full event duration
the Project	US Wind Maryland Offshore Wind Project
TOL	third-octave level
TTS	temporary threshold shift
UNK	unknown
U.S.	United States of America
U.S.C.	U.S. Code
USGS	United States Geological Survey
v.	versus
WEA	wind energy areas
WTG	wind turbine generator

1 INTRODUCTION

US Wind proposes to construct and operate the Maryland Offshore Wind Project (the Project) to generate clean, renewable energy using available wind resources. The Project will be located within US Wind's Lease area (OCS Lease 0490), which is located approximately 10 nautical miles east of Maryland's Eastern Shore (Figure 1). The construction and operation of the Project has the potential to cause acoustic harassment to marine species, in particular marine mammals, sea turtles, and fish populations. Marine Acoustics, Inc. (MAI) was contracted to model and assess the sources of underwater noise generated during the construction and installation of the Project and the effect of sound attenuation methods as a means of mitigation. The objective of this modeling study was to predict the ranges to acoustic thresholds and resulting injury and behavioral acoustic exposures of marine mammals, sea turtles, and fish during construction of the Project.

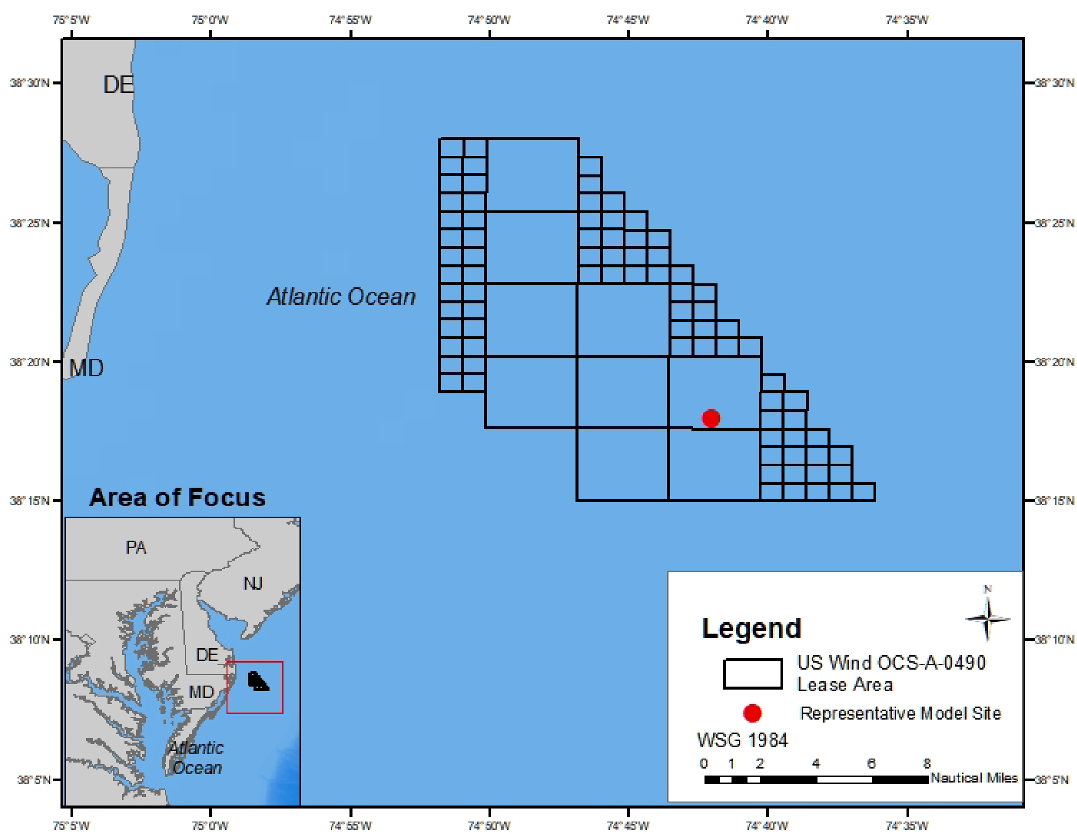

Figure 1. OCS-A-0490 lease area for US Wind Maryland Offshore Wind project.

1.1 Acoustic Modeling Scope

There are various activities that are expected to generate underwater sound during the construction of the proposed Project. These activities include impact pile driving of 11-m monopile foundations for wind turbine generators (WTGs), impact pile driving of 3-m post-piled skirt piles for the OSS jacket foundations, as well as impact pile driving of 1.8-m pin piles for a Meteorological tower. US Wind is not proposing vibratory pile driving of monopile foundations or drilling to break up obstacles because geotechnical surveys have not indicated hard bottom or boulder fields in the Project area. However, because vibratory pile driving was originally considered and modeled for the installation of 1.8-m piles, those model results are included herein even though US Wind will not be vibratory pile driving.

The impact pile driving activities were modeled to produce the resulting unweighted and frequency-weighted broadband underwater acoustic fields. The acoustic ranges to various physiological and behavioral auditory thresholds for marine mammals, fishes, and sea turtles were determined from these broadband sound fields. The appropriate regulatory thresholds described in Section 2 have been used.

1.2 Animat Modeling Scope

Animat modeling was conducted to determine acoustic exposures of marine mammals and sea turtles from the impact pile driving of monopile, skirt piles, and pin piles and the vibratory pile driving of pin piles. The potential acoustic exposures of protected marine mammals and sea turtles were estimated using the Acoustic Integration Model© (AIM). AIM is a Monte Carlo-based statistical model (Frankel *et al.* 2002) in which many repeated simulations provide the probability of an outcome. AIM simulations create realistic animal movement tracks that, collectively, provide a reasonable representation of the movements of the animals in a population. Animats are programmed with a range of values for movement parameters, such as minimum and maximum speed or dive depth (Table B-1; Appendix B).

The underlying statistical distribution for these parameters is uniform, except for speed. Speed can be specified with a truncated normal (eight standard deviations between the minimum and maximum speed) or a gamma distribution as best fits the data for that animat. The distribution used for each animat is specified in Appendix Table B-1. Multiple behavioral states can be included for each species or species group to best represent real animal movement. These simulated movements are integrated with the modeled acoustic fields produced by the impact and vibratory pile driving to estimate the animals’ exposure to the acoustic field. The AIM model simulated the four-dimensional (range, depth, bearing, and time) movements of marine mammals during impact and vibratory pile driving at the modeling location. Animats were distributed in a box from 37.5° to 39°N and 73.75° to 75.5°W (168 x 154 kilometers (km) centered on the modeling site (38.3°N, 74.7°W). Animats were further limited within this modeling box by the coastline and the minimum occurrence depth for each species, (Appendix B, Table B-1) based on the available scientific literature. These animat movements were convolved with the acoustic propagation modeling outputs to predict exposure histories for each simulated animal over a 24-hour period. Movements of marine mammal and sea turtle species potentially occurring in the US Wind Project area were modeled to predict their exposure to the sounds resulting from impact and vibratory pile driving.

2 REGULATORY CRITERIA AND SCIENTIFIC GUIDELINES

2.1 Underwater Acoustic Criteria for Marine Mammals

Under the Marine Mammal Protection Act (MMPA), the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) is allowed, upon request, to authorize the incidental, but not intentional, "taking" of small numbers of marine mammals by U.S. citizens or agencies who engage in a specified activity (other than commercial fishing) within a specified geographical region. The term "take," as defined in Section 3 (16 U.S. Code [U.S.C.] section 1362 (13)) of the MMPA, means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." "Harassment" was further defined in the 1994 amendments to the MMPA, with two levels of harassment: Level A and Level B. By definition, Level A harassment is any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock, while Level B harassment is any act of pursuit, torment, or annoyance that has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.

NMFS has provided guidance for assessing the physiological impacts (Level A) of anthropogenic sound on marine mammals under their regulatory jurisdiction, which includes whales, dolphins, seals, and sea lions (NMFS, 2018). The guidance specifically defines hearing groups, develops auditory weighting functions, and identifies the received levels or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity (permanent threshold shift [PTS] or temporary threshold shift [TTS]) for acute, incidental exposure to underwater sound. Southall *et al.* (2019) published consistent weighting functions and threshold levels for marine mammal species included in the NMFS (2018) guidance but included all marine mammal species (not just those under NMFS' jurisdiction) for all noise exposures (both under water and in air), as well as updating the hearing groups. The hearing groups are defined as:

- Low-frequency (LF) Cetaceans—this group consists of the mysticetes (baleen whales) with a collective generalized hearing range of 7 Hz to 35 kilohertz (kHz).
- Mid-frequency (MF) Cetaceans—includes most of the dolphins, all toothed whales except for *Kogia* spp., and all the beaked and bottlenose whales with a generalized hearing range of approximately 150 Hz to 160 kHz (renamed high-frequency cetaceans by Southall *et al.* (2019) because their best hearing sensitivity occurs at frequencies of several tens of kHz or higher).
- High-frequency (HF) Cetaceans—incorporates all the true porpoises, the river dolphins, plus *Kogia* spp., *Cephalorhynchus* spp. (genus in the dolphin family Delphinidae), and two species of *Lagenorhynchus* (Peale's and hourglass dolphins) with a generalized hearing range estimated from 275 Hz to 160 kHz (renamed very high-frequency

cetaceans by Southall *et al.* (2019) since some of these species have best hearing sensitivity at frequencies exceeding 100 kHz).

- Phocids Underwater (PW)—consists of true seals with a generalized underwater hearing range from 50 Hz to 86 kHz (renamed phocid carnivores in water by Southall *et al.* 2019).
- Otariids Underwater (OW)—includes sea lions and fur seals with a generalized underwater hearing range from 60 Hz to 39 kHz (termed other marine carnivores in water by Southall *et al.* (2019) and includes otariids, as well as walrus [Family Odobenidae], polar bear [*Ursus maritimus*], and sea and marine otters [Family Mustelidae]). It should be noted that otariids are not expected in the project area.

Within their generalized hearing ranges, the ability to hear sounds varies with frequency, as demonstrated by examining audiograms of hearing sensitivity (NMFS, 2018; Southall *et al.,* 2019). To reflect higher noise sensitivities at particular frequencies, auditory weighting functions were developed for each functional hearing group that reflected the best available data on hearing ability (composite audiograms), susceptibility to noise-induced hearing loss, impacts of noise on hearing, and data on equal latency (NMFS, 2018). These weighting functions are applied to individual sound received levels to reflect the susceptibility of each hearing group to noise-induced threshold shifts, which is not the same as the range of best hearing.

NMFS (2018) defined acoustic threshold levels at which PTS and TTS are predicted to occur for each marine mammal hearing group for impulsive and non-impulsive signals. Non-impulsive signals do not have the high peak pressure with rapid rise time and decay characteristic of impulsive sounds; instead, the pressure (i.e., intensity) of non-impulsive signals is more consistent throughout the signal. The PTS and TTS acoustic threshold levels are defined using metrics of the cumulative sound exposure level (SEL) over a 24-hr period and the peak sound pressure level. For the cumulative SEL, the appropriate frequency weighting for each hearing group is applied, which is reflected in the subscript of each threshold (e.g., the LF cetacean threshold is identified as $L_{E,LF,24h}$). The cumulative SEL metric considers both received level and duration of exposure over the duration of the activity within a 24-hr period. Impulsive sounds are assessed against the SEL and peak thresholds, whereas non-impulsive sounds are assessed only against an SEL threshold. The TTS SEL threshold is defined as 20 dB less than the PTS threshold for non-impulsive sources while the difference is 15 dB lower for impulsive sources. A summary of the acoustic thresholds for PTS is provided (Table 1).

The peak sound pressure level (Lpk) in these thresholds have a reference value of 1 µPa, and the cumulative sound exposure level (LE) has a reference value of 1 $\mu Pa^2 s$. The subscript “flat” indicates sound pressures are unweighted. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal (LF, MF, and HF cetaceans, and PW pinnipeds) auditory weighting function. The accumulation period for SEL thresholds is indicated in hours in the subscript.

Table 1. Acoustic threshold levels for marine mammal injurious harassment (MMPA Level A; NMFS, 2018) and behavioral harassment (NOAA, 2005).

Hearing Group	***Impulsive Sounds****			***Non-Impulsive Sounds***	***Continuous Sounds***
	PTS Onset		***Behavior (dB re 1μPa)***	***PTS Onset***	***Behavior (dB re 1 μPa)***
	SEL (dB re 1 μPa²-s)	***Peak (dB re 1μPa)***		***SEL (dB re 1 μPa²-s)***	
Low-frequency cetaceans (LF)	183 dB ($L_{E,LF,24h}$)	219 dB ($L_{pk,0-pk,flat}$)	160 dB (L_p)	199 dB ($L_{E,LF,24h}$)	120 dB (L_p)
Mid-frequency cetaceans (MF)	185 dB ($L_{E,MF,24h}$)	230 dB ($L_{pk,0-pk,flat}$)		198 dB ($L_{E,MF,24h}$)	
High-frequency cetaceans (HF)	155 dB ($L_{E,HF,24h}$)	202 dB ($L_{pk,0-pk,flat}$)		173 dB ($L_{E,HF,24h}$)	
Phocid pinnipeds underwater (PW)	185 dB ($L_{E,PW,24h}$)	218 dB ($L_{pk,0-pk,flat}$)		201 dB ($L_{E,PW,24h}$)	

*Dual metric thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds are recommended for consideration.

The behavioral threshold for marine mammals, which is part of MMPA Level B harassment along with TTS[1], is defined by NMFS as 120 dB re 1 µPa (LP) at a reference pressure of 1 microPascal squared (re 1 µPa) for continuous sources and 160 dB re 1 µPa (LP) for impulsive or intermittent sources, such as impact pile driving (NOAA, 2005) (Table 1). In the context of pile driving, NMFS applies the non-impulsive behavioral threshold to sounds produced during vibratory pile driving.

In a cooperative effort between federal and state agencies, interim criteria were developed to assess the potential for injury to fishes exposed to impact pile driving sounds. These noise injury thresholds have been established by the Fisheries Hydroacoustic Working Group, which was assembled by NMFS with thresholds subsequently adopted by NOAA Fisheries (FHWG, 2008). The NMFS Greater Atlantic Regional Fisheries Office (GARFO) has applied these standards for assessing the potential effects to fish species and sea turtles listed under the Endangered Species Act (ESA) that have been exposed to elevated levels of underwater sound

1 NMFS considers behavioral effects to be the onset of MMPA Level B harassment while TTS is upper Level B harassment.

produced during pile driving (GARFO 2019). These noise thresholds are based on sound levels that have the potential to produce injury or illicit behavioral responses from fishes (Table 2). Separate criteria are provided in GARFO (2019) for fishes weighing less than two grams and for fishes weighing more than two grams. Since fish of less than 2 grams are expected to occur in the waters of the Project for only a small percentage of the annual period, we have assessed only fish greater than 2 grams.

Table 2. Acoustic threshold levels for physiologic impacts to fishes (FHWG 2008, GARFO 2019, Popper et al. 2014).

Fish Group	***Impulsive Signals***			***Non-Impulsive Signals***	
	Injury		***TTS***	***Injury***	***TTS***
	SEL (dB re 1 μPa²-s) (Unweighted)	***Peak (dB re 1 μPa) (Unweighted)***	***SEL (dB re 1 μPa²-s) (Unweighted)***	***SPL (dB re 1 μPa) (Unweighted)***	***SPL (dB re 1 μPa) (Unweighted)***
Fishes without swim bladders**	> 216 dB ($L_{E,\ flat,\ 24h}$)	> 213 dB ($L_{pk,0\text{-}pk,flat}$)	> 186 dB ($L_{E,\ flat,\ 24h}$)		
Fishes with swim bladder not involved in hearing**	203 dB ($L_{E,\ flat,\ 24h}$)	> 207 dB ($L_{pk,0\text{-}pk,flat}$)	> 186 dB ($L_{E,\ flat,\ 24h}$)		
Fishes with swim bladder involved in hearing**	203 dB ($L_{E,\ flat,\ 24h}$)	> 207 dB ($L_{pk,0\text{-}pk,flat}$)	186 dB ($L_{E,\ flat,\ 24h}$)	170 dB ($L_{rms,\ flat}$)	158 dB ($L_{rms,\ flat}$)
All Fish (mass >2 g)* and +	187 dB ($L_{E,\ flat,\ 24h}$)	206 dB ($L_{pk,0\text{-}pk,flat}$)			
All Fish (mass <2 g)* and +	183 dB ($L_{E,\ flat,\ 24h}$)	206 dB ($L_{pk,0\text{-}pk,flat}$)			

*FHWG 2008; **Popper et al. 2014; + GARFO 2019 (for salmon and sturgeon)

For sea turtles, the *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)* technical report(DoN 2017) outlines both peak and cumulative SEL metrics to assess TTS and PTS injury (Table 3). The cumulative SEL metric is assessed with the appropriate frequency weighting for sea turtles (Figure 2). These injury criteria are incorporated into the guidance put forth by GARFO for sea turtles.

Table 3. Acoustic threshold levels for physiologic impacts to sea turtles (DoN 2017).

Species Group	***Impulsive Signals***				***Non-Impulsive Signals***	
	Injury		***TTS***		***Injury***	***TTS***
	SEL (dB re 1μPa²-s) (Weighted)	***Peak (dB re 1μPa) (Unweighted)***	***SEL (dB re 1μPa²-s) (Weighted)***	***Peak (dB re 1μPa) (Unweighted)***	***SEL (dB re 1μPa²-s) (Weighted)***	***SEL dB re (1μPa²-s) (Weighted)***
Sea turtles (TU)	204 dB ($L_{E,TU,\ 24h}$)	232 dB ($L_{pk,0\text{-}pk,flat}$)	189 dB ($L_{E,\ TU,\ 24\ h}$)	226 dB ($L_{pk,flat}$)	220 dB ($L_{E,\ TU,\ 24h}$)	200 dB ($L_{E,\ TU,\ 24h}$)

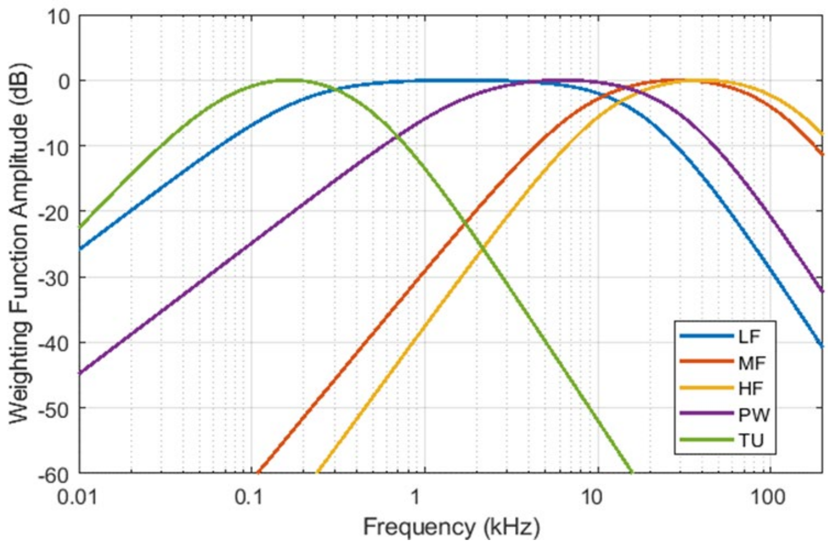

Figure 2. Auditory weighting functions for cetaceans (LF, MF, and HF species) and pinnipeds in water (PW) from NOAA Fisheries (2018d) and for sea turtles from DoN (2017).

A Working Group organized under the American National Standards Institute-Accredited Standards Committee S3, Subcommittee 1, Animal Bioacoustics, also developed a Technical Report on sound exposure guidelines for fish and sea turtles (Table 2; Popper et al. 2014). This working group identified three types of fish, depending on how they might be affected by underwater sound. The categories include fishes with no swim bladder or other gas chamber (e.g., dab and other flatfish); fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids); and fishes with a swim bladder that is involved in hearing (e.g., channel catfish). GARFO (2019) defined the behavioral impact threshold for fish while DoN (2017) defined the behavioral threshold for sea turtles (Table 4).

Table 4. Acoustic threshold levels for behavioral impacts to fishes (GARFO, 2019) and sea turtles (DoN 2017).

Group	***Behavioral threshold (dB re 1µPa, unweighted)***
Small fish (mass <2g)	150
Large Fish (mass >2 g)	150
Sea Turtles	175

2.2 Weighting Used for Marine Mammal Acoustic Analysis

To reflect higher noise sensitivities at particular frequencies, auditory weighting functions were developed for each of the functional marine mammal hearing groups and for sea turtles to reflect the best available data on hearing ability (composite audiograms), susceptibility to noise-induced hearing loss, impacts of noise on hearing, and data on equal latency (DoN 2017, NMFS 2018) (Figure 2).These weighting functions are applied to individual sound received levels to reflect the susceptibility of each hearing group to noise-induced threshold shifts, which is not the same as the range of best hearing. The cumulative SEL metric is assessed with the appropriate frequency weighting for marine mammals (by hearing group) and sea turtles for a 24-hour period ($L_{E,24h}$) (Figure 2).

3 PROTECTED MARINE MAMMAL AND SEA TURTLE SPECIES POTENTIALLY OCCURRING IN THE PROJECT AREA

Twenty-four species of marine mammals and four species of sea turtles may potentially occur in the waters of the Project area. However, nine of these species were considered as species groups rather than individual species for the modeling assessment since they occur in the same type of habitat, are difficult to differentiate at sea, and have similar dive and swim behaviors: pilot whales (inclusive of long-finned and short-finned pilot whales), *Kogia* spp. (inclusive of pygmy and dwarf sperm whales), the *Stenella* dolphins (Atlantic spotted, pantropical spotted, and striped dolphins) and seals (inclusive of harbor and gray seals) (Table 5). Additionally, other marine mammal species and all sea turtles were modeled and assessed as representative groups rather than individual species, due to the lack of available movement data for those species (e.g., all beaked whale species, inclusive of potentially occurring Blainville's, Cuvier's, Gervais', and True's, were modeled as the small beaked whale group and all sea turtles were modeled as the Turtle group) (Tables 5 and 6). Although modeling of the sea turtles was conducted for the entire *Turtle* group, the leatherback dive/swim information formed the basis for the movement parameters used in animat modeling, due to the wealth of dive and swim information available for this species compared to the other turtle species. However, individual species' seasonal densities were applied to the turtle modeling results to calculate individual's acoustic exposures by turtle species.

Descriptions of the protected, potentially occurring marine mammal and sea turtle species in the Project area, especially aspects of the behavior, movements, or hearing that are relevant to

Table 5. Potentially occurring marine mammals and their respective monthly (or annual) mean densities (Marine Geospatial Ecology Laboratory 2022) in the buffered Lease Area 0490 for the US Wind Maryland Offshore Wind project. The modeling group indicates when a species was modeled as a species group instead of as an individual species.

Marine Mammal Species	*Modeling Group**	*Monthly Seasonal Density (animals/km2)*											
		Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Atlantic spotted dolphin	*Stenella*	0.00003	0.00001	0.00002	0.00013	0.00046	0.00090	0.00396	0.01505	0.00475	0.00335	0.00243	0.00032
Blainville's beaked whale[1]	Small BW	0.00001											
Common bottlenose dolphin		0.03855	0.01316	0.01659	0.05668	0.15225	0.1592	0.18323	0.20608	0.1647	0.14689	0.1713	0.11705
Common minke whale		0.00069	0.00089	0.00114	0.00687	0.00750	0.00155	0.00050	0.00020	0.00010	0.00055	0.00025	0.00064
Cuvier's beaked whale[1]	Small BW	0.00000											
Dwarf sperm whale[1]	*Kogia* spp.	0.00000											
Fin whale		0.00214	0.00184	0.00154	0.00135	0.00094	0.00111	0.00041	0.00028	0.00040	0.00037	0.00045	0.00151
Gervais' beaked whale[1]	Small BW	0.00001											
Gray sea[2]	Seals	0.05234	0.03722	0.02331	0.03659	0.03032	0.00335	0.00126	0.00073	0.00125	0.00665	0.00992	0.04848
Harbor porpoise		0.03653	0.03336	0.02586	0.03191	0.00615	0.00002	0.00001	0.00001	0.00000	0.00000	0.00002	0.02025
Harbor seal[2]	Seals	0.11759	0.08362	0.05238	0.08220	0.06811	0.00752	0.00282	0.00163	0.00280	0.01493	0.02230	0.10893
Humpback whale		0.00091	0.00062	0.00083	0.00187	0.00142	0.00102	0.00020	0.00011	0.00027	0.00112	0.00143	0.00088
Killer whale[1]		0.00002											
Long-finned pilot whale[1, 2]	Pilot Whales	0.00022											
North Atlantic right whale		0.00075	0.00076	0.00063	0.00045	0.00008	0.00003	0.00001	0.00001	0.00002	0.00004	0.00011	0.00036
Pantropical spotted dolphin[1]	*Stenella*	0.00004											

Table 5. Potentially occurring marine mammals and their respective monthly (or annual) mean densities (Marine Geospatial Ecology Laboratory 2022) in the buffered Lease Area 0490 for the US Wind Maryland Offshore Wind project. The modeling group indicates when a species was modeled as a species group instead of as an individual species.

Marine Mammal Species	***Modeling Group****	***Monthly Seasonal Density (animals/km2)***											
		Jan	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Pygmy sperm whale[1]	*Kogia* spp.	0.00000											
Risso's dolphin		0.00045	0.00006	0.00006	0.00056	0.00051	0.00018	0.00017	0.00018	0.00010	0.00023	0.00092	0.00169
Rough-toothed dolphin[1]		0.00002											
Sei whale		0.00029	0.00021	0.00034	0.00061	0.00020	0.00005	0.00001	0.00000	0.00001	0.00006	0.00017	0.00046
Short-beaked common dolphin		0.04298	0.01869	0.01972	0.03268	0.03289	0.01471	0.01301	0.00501	0.00044	0.00765	0.05746	0.07939
Short-finned pilot whale[1, 2]	Pilot Whales	0.00017											
Sperm whale		0.00004	0.00001	0.00001	0.00004	0.00006	0.00002	0.00002	0.00000	0.00000	0.00000	0.00001	0.00003
Striped dolphin[1]	*Stenella*	0.00004											
True's beaked whale[1]	Small BW	0.00001											

* Modeling group indicates those species that were modeled as a representative group rather than as individual species. BW=beaked whales

1 Only annual densities for these species/species groups available in the MGEL 2022 dataset as insufficient sighting data exist to derive monthly density estimates

2 Densities are only available for the combined seal and pilot whale groups in the MGEL 2022 dataset; to derive species-specific densities for take calculations, the annual or monthly group densities were scaled by the relevant species' abundances

3 Two stocks of common bottlenose dolphins may occur in the Project area but due to the difficulty differentiating the stocks, the species is presented in its entirety herein

4 Densities are only available for the combined seal and pilot whale groups in the MGEL 2022 dataset; to derive species-specific densities for take calculations, the annual or monthly group densities were scaled by the relevant species' abundances

Table 6. Potentially occurring sea turtle species and their respective seasonal densities (DoN 2007, Barco et al. 2018) in the buffered lease area 0490 for the US Wind Maryland Offshore Wind project. The modeling group indicates that all sea turtles were modeled as a group instead of as an individual species.

Turtle Species	***Modeling Group***	***Densities (animals per km²)***			
		Spring (March to May)	***Summer (June to August)***	***Fall (September to November)***	***Winter (December to February)***
Green turtle (Hardshelled guild)	Turtle	0.03802	0.05041	0.03802	0.03802
Kemp's ridley turtle	Turtle	0.00220	0.00226	0.00220	0.00220
Leatherback turtle	Turtle	0.02040	0.02706	0.02040	0.02040
Loggerhead turtle (DoN 2007)	Turtle	0.05858	0.07848	0.05712	0.05843
		Spring (May to June)	***Summer (July to August)***	***Fall (September to October)***	
Loggerhead turtle (Barco et al. 2018)	Turtle	3.319	1.385	1.488	

animat modeling, are included herein. Appendix B, Table B-1 provides movement parameters for each species or species group modeled.

3.1 Marine Mammal and Sea Turtle Modeling and Density Derivation

Population estimates are a necessary part of the analysis process to estimate the effect that acoustic exposure has on the potentially occurring protected marine mammals and sea turtles in an area. Density estimates for each marine mammal species (or species group) were derived for each month (or annually for some species) while sea turtle density estimates were only available by season. Marine mammal and sea turtle densities were estimated for the buffered US Wind Lease Area OCS-A-0490. The buffer distance applied to the perimeter of Lease Area 0490 was the largest range to a regulatory threshold for the pile driving hammer sources proposed for use in the project, which was 5.25 km. This distance of 5.25 km was buffered (added) onto the outer lease area boundary (Figure 3), and marine mammal and sea turtle densities and takes were derived for all impact pile driving construction activities within this buffered area.

Marine mammal and turtle animats populated the model area with representative nominal densities. In some cases, the modeled animat density was higher than the real-world density estimates for a given marine mammal or sea turtle species. This “over population” ensured that the result of the animat model simulation was not unduly influenced by the initial animat placement and provided statistical robustness. To obtain final exposure estimates, the modeled results were normalized by the ratio of the modeled animat density to the real-world marine mammal or sea turtle seasonal density estimates (Tables 5 and 6).

3.2 Marine Mammals

The Marine Geospatial Ecology Laboratory (MGEL) (2022) marine mammal density estimates represent the best available marine mammal data for the Project area; the methodology by which the MGEL densities were derived is described in Roberts et al. (2016). MGEL monthly (or annual for some species) density data are delineated in 5-km square grid cells in U.S. Atlantic waters and by species or species groups with discrete density designated for each monthly (or annual) grid cell within the MGEL datasets. To determine the marine mammal densities for the US Wind Project area, the perimeter of Lease Area 0490 was buffered by the largest range to a regulatory threshold for the pile driving hammer sources proposed for use in the project, which was 5.25 km. This distance of 5.25 km was buffered (or added) onto the outer Lease Area 0490 boundary (Figure 3), and marine mammal densities were compiled for this buffered area for all pile driving activities. The MGEL grid cell densities within the buffered lease area were averaged for each month to provide mean monthly densities for each marine mammal species/species group (or an annual density for some species or species groups); only grid cells whose centroid fell within the boundary of the buffered lease area were included in the density estimate (Figure 3). For some species, however, like pantropical spotted, rough-toothed, and stiped dolphins, all beaked whales, killer whales, and both species of *Kogia* and pilot whales, only annual density estimates were available in MGEL (2022), as insufficient information on their populations are available to derive seasonal estimates (Table 5). For these species, the annual mean density estimates were used as an input for each month of the year.

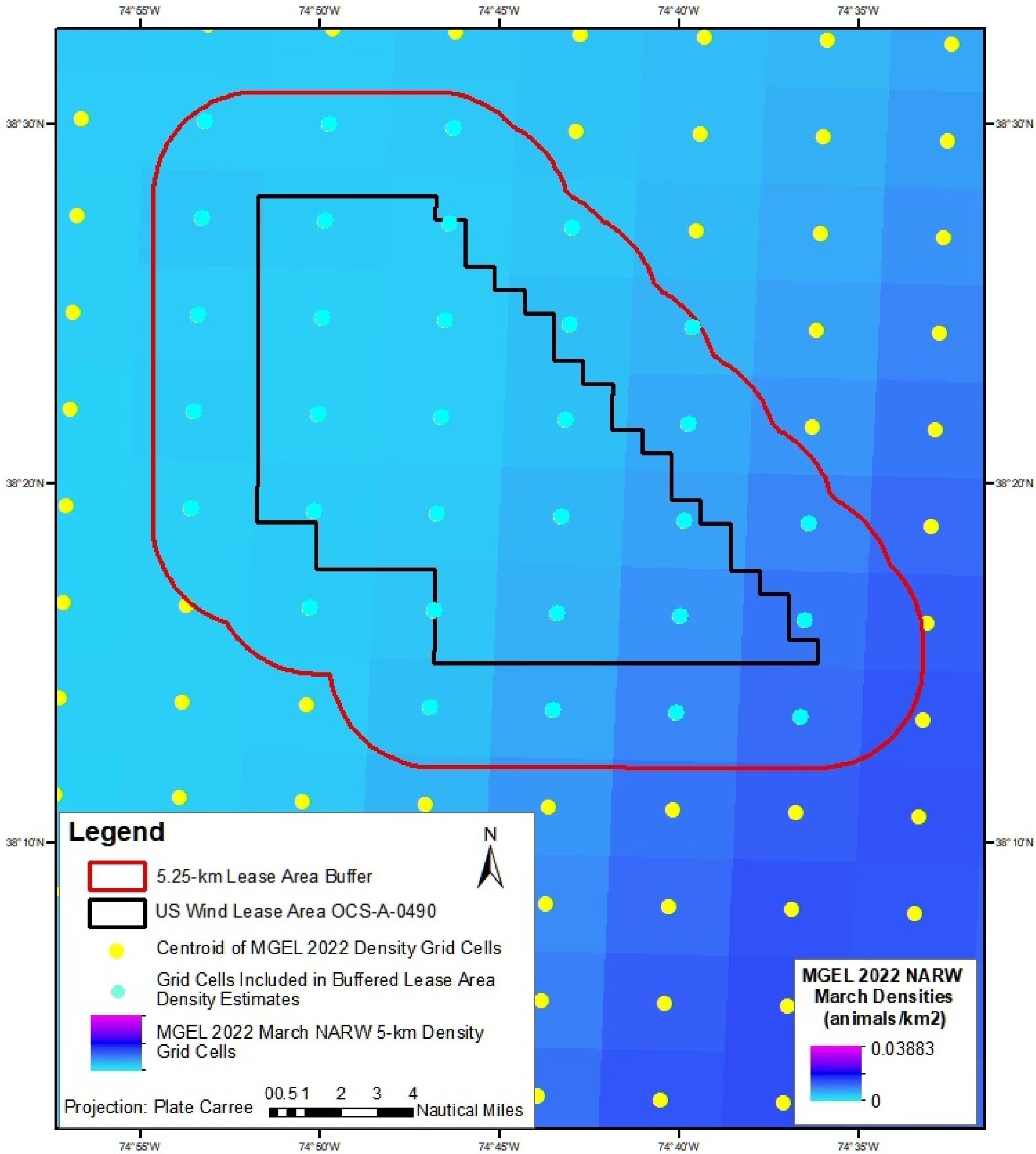

Figure 3. MGEL (2022) North Atlantic right whale density surface and grid cells in March, showing the MGEL grid cells within the buffered Lease Area OCS-A-0490 for US Wind that were averaged to determine the monthly density; only the 32 grid cells within the buffered lease (turquoise dots) are included in the monthly mean density estimates.

Additionally, for some species like the harbor and gray seals and short-finned and long-finned pilot whales, MGEL densities are only available for the generalized groups of seals and pilot whales rather than for the individual species. To obtain the density estimates for each of these individual species that were treated as a group in the MGEL 2022 database, the MGEL (2022) group density was scaled by the abundances of each of the individual species (Hayes et al. 2023), using the following equation with the harbor seal as an example:

$$d_{\text{harbor seal}} = d_{\text{MGEL(both)}} * (a_{\text{harbor seal}} / (a_{\text{harbor seal}} + a_{\text{gray seal}}))$$

where d represents density and a represents abundance. These abundance-scaled densities were used in this modeling analysis (Table 5).

Two stocks of common bottlenose dolphin (Northern Migratory Coastal and Offshore) are present within the Maryland Offshore Wind Project area, but density estimates are only available in the MGEL density data for the bottlenose species in its entirety. The density of the bottlenose species from MGEL (2022) was used to represent the bottlenose dolphin.

3.2.1 Sea Turtles

Few at-sea density data are available for sea turtles. For the Project area, two sources of sea turtle densities represent the best available at-sea density data for sea turtles: DoN (2007) and Barco *et al.* (2018) (Table 6). The DoN (2007) density estimates were prepared for the Navy's U.S. Atlantic operating areas; the Project area lies within one of the Navy's operating areas. However, densities of sea turtles are available only by season and not by month from the DoN (2007) data (Table 6). Like the MGEL marine mammal density data, the DoN (2007) densities are based on grid cells for the U.S. Atlantic. Only DoN (2007) grid cells that fell within the buffered lease area were included in the seasonal density estimates for each potentially occurring turtle species (Table 6).

More recent loggerhead turtle density estimates for the Project area are available in Barco et al. (2018). These more recent loggerhead densities presented in Barco et al. (2018) are much higher than the older DoN (2007) estimates for the loggerhead turtle. Additionally, Barco et al. (2018) included a seasonal availability correction factor. Instead of selecting one of these loggerhead density estimates for the calculation of acoustic exposure to loggerheads, both the DoN (2007) and Barco et al. (2018) loggerhead turtle density estimates have been included (Table 6).

Although green turtles may occur seasonally in the Project area, no at-sea density estimates are available for this more rarely occurring species. Since available occurrence data for the green turtle were included in the "Hardshelled Guild" in the DoN (2007) density dataset, the seasonal density estimate from this guild was used as a surrogate density for the green turtle. The U.S. Navy set the precedent for using the hard-shelled guild's density estimates to represent the green turtle (DoN 2017a)

3.3 Potentially Occurring Marine Mammals

3.3.1 Common Minke Whale (Balaenoptera acutorostrata)

Common minke whales are smaller baleen whales that are about 11 m in length. Minke whales occur most often in tropical to polar coastal/neritic and inshore waters of the Atlantic, Pacific, and Indian oceans but infrequently also occur in pelagic waters. Common minke whales are considered rare in the northern Indian Ocean, Gulf of Mexico, and Mediterranean Sea (Jefferson *et al.* 2015). Common minke whales are thought to be migratory, at least in some areas, but migratory pathways are not well known and populations in some area remain resident year-round (Cooke 2018). Minke whales opportunistically feed on a wide variety, including crustaceans, plankton, and small schooling fish.

Although the hearing sensitivity of minke whales has not been directly measured (Ketten 2000) models of their middle ears predicts their best hearing overlaps with their vocalization frequency range (Tubelli *et al.* 2012). Minke whales produce a variety of sounds, primarily moans, clicks, downsweeps, ratchets, thump trains, grunts, and “boings” in the 80 Hz to 20 kHz range, and the signal features of their vocalizations consistently include LF, short-duration downsweeps from 250 to 50 Hz (Edds-Walton 2000, Mellinger *et al.* 2000, Risch *et al.* 2014).

3.3.2 Fin Whale (Balaenoptera physalus)

Fin whales are the second largest whale species, with males reaching 25 and females reaching 26 m in length. Fin whales are a cosmopolitan species, only avoiding ice covered or tropical waters. Northern fin whales prefer to feed on krill, although they will eat other crustacean species and small fish as well. Southern hemisphere fin whales have a well-defined seasonal latitudinal migration, as is typical in many baleen whales. Migratory patterns of the fin whale in the northern hemisphere are not well understood. In the North Atlantic, some individual fin whales are known to remain at high latitudes, while others remain at low latitudes throughout the year. It may be that prey distributions are driving the movements of the whales. Other potential drivers of this difference in distributions could be due to coastal feeding in the summer and movement into deeper water in the winter.

No direct measurement of fin whale hearing sensitivity has been made. Cranford and Krysl (2015) generated synthetic audiograms of a small fin whale and suggested that the fin whale hears sound through bone conduction via its skull; they suggested that sound waves interact in the skull to produce deformations that induce motion in the ear complex, which results in best hearing in the low frequency range. Fin whales produce a variety of LF sounds that range in frequency from 10 to 200 Hz (Edds 1988, Watkins 1981, Watkins *et al.* 1987, Cranford and Krysl 2015). Fin whales produce well-known “20 Hz pulses” and most of their vocalizations are below 100 Hz (Watkins *et al.* 1987). Males can produce these pulses in a repeated pattern that functions as song, a presumed reproductive display (Morano *et al.* 2012). Fin whales are known to respond to anthropogenic noise such as shipping vessel noise, airguns, and small vessel noise (Jahoda *et al.* 2003, Castellote *et al.* 2012).

3.3.3 Humpback Whale (*Megaptera novaeangliae*)

Humpback whales are a medium sized baleen whale, with typical adult sizes of 15 to 16 m. They are a cosmopolitan species found in all ocean basins. All populations, except that of the Arabian Sea, migrate seasonally between high latitude feeding grounds and low latitude reproductive areas, where calving is known to occur. Given their 11.5 month long reproductive cycle, mating is presumed to occur in low latitude areas as well, but it remains unobserved. Northwest Atlantic humpbacks migrate from their summer grounds off northeastern U.S. and Canada to the Caribbean in the winter. Humpbacks are catholic feeders, able to take prey ranging from krill to small fish including sandlance, herring, spot, drum, and capelin.

Hearing has not been measured in humpback whales, but they were the first whale known to produce songs. Vocalizations span from 10 Hz to more than 24 kHz (Frankel *et al.* 1995, Au *et al.* 2006, Zoidis *et al.* 2008) but most of the energy is concentrated below 2 kHz. Humpback whales are known to react to anthropogenic sound (Frankel & Clark 2000, Fristrup *et al.* 2003, Dunlop *et al.* 2018). Like some other whale species, they have shown the ability to at least partially compensate for increases in masking noise by increasing their source level (Dunlop *et al.* 2014).

3.3.4 North Atlantic Right Whale (*Eubalaena glacialis*)

North Atlantic Right Whales (NARW) are a large slow-moving whale that typically grows to a length of 13 to 16 m. They are migratory between high latitude waters in the summer and lower latitude waters in the winter. Historically, NARW ranged between Florida, northwest Africa, Labrador, south Greenland, Iceland, and Norway. Commercial whaling decimated their numbers, and a remnant population now migrates between the southeast United States (U.S) (primarily eastern Florida and Georgia) and Canada.

Right whales are obligate predators on zooplankton, notably calanoid copepods, feeding in the spring, summer, and fall on their high latitude summer grounds. Feeding can occur at the surface and at depth, making them vulnerable to ship strikes and entanglement in fishing gear. They have been found to shift their feeding grounds in response to changing sea surface temperatures (Keller *et al.* 2006), likely a response to shifts in the distribution of their prey (Meyer-Gutbrod & Greene 2014).

NARWs migrate to calve in the southeast U.S. waters in the winter. They show strong preferences for waters that are 13 to 19 m in depth and between 13 to 16°C (Winn *et al.* 1986, Kraus & Rolland 2007). The breeding grounds are unknown and NARW typically have a three-year reproductive cycle.

NARW are low-frequency hearing specialists. Their predicted hearing ranges from 10 to 22,000 Hz (Parks *et al.* 2007b). Their vocalizations have most of their energy below 2,000 Hz (Parks *et al.*, 2011). The characteristics of NARW vocalizations have been shown to change in response to increased noise (Parks *et al.* 2011, Parks *et al.* 2007a).

3.3.5 Atlantic Spotted Dolphin (*Stenella frontalis*)

Atlantic spotted dolphins are about 1.5 to 2.3 m in length and are found only in the tropical and warm-temperate waters of the Atlantic Ocean and associated seas and occur commonly along the southeastern U.S. and the Gulf coasts, in the Caribbean, and off West Africa. They inhabit waters usually about 200 m in depth but may occasionally swim closer to shore to feed. These dolphins eat small fish, invertebrates, and cephalopods (such as squid and octopi).

There are no current hearing data on Atlantic spotted dolphins. Atlantic spotted dolphins produce a variety of sounds, including whistles, whistle-squawks, buzzes, burst-pulses, synch pulses, barks, screams, squawks, tail slaps, and echolocation clicks. Like other odontocetes, they produce broadband, short duration echolocation signals. Their broadband clicks have peak frequencies between 60 and 120 kHz. Dolphins produce whistles with a frequency range of 1 to 23 kHz.

3.3.6 Blainville's Beaked Whale (Mesoplodon densirostris)

Blainville's beaked whale is the most cosmopolitan of the *Mesoplodon* beaked whales, having a continuous distribution throughout tropical, sub-tropical, and warm-temperate waters of the world's oceans (MacLeod *et al.* 2006).

The hearing sensitivity of a stranded Blainville's beaked whale was reported between 5.6 and 160 kHz, with the best hearing response between 40 and 50 kHz and thresholds less than 50 dB re 1 mPa (Pacini *et al.* 2011). Johnson *et al.* (2006) investigated the clicks of Blainville's beaked whales and discovered they have a distinct search click with an FM upsweep with a minus 10 dB bandwidth from 26 to 51 kHz; they also produce a buzz click that is used during the final stage of prey capture.

3.3.7 Common Bottlenose Dolphin (Tursiops truncatus)

The common bottlenose dolphin is typically 2 *to* 3.9 m in length. Common bottlenose dolphins are distributed worldwide in temperate to tropical waters. In North American waters, this species inhabits waters with temperatures ranging from 50 to 89°F (10 to 32°C) (Wells & Scott 2009). Common bottlenose dolphins are primarily found in coastal or shallower waters, but they also occur in diverse habitats ranging from rivers and protected bays to oceanic islands and the open ocean (Scott & Chivers 1990, Sudara & Mahakunayanakul 1998, Wells & Scott 2009). Common bottlenose dolphins in the U.S. Atlantic waters are divided into multiple offshore, estuarine, and coastal stocks. Seasonal movements vary between inshore and offshore locations and year-round home ranges (Croll *et al.* 1999, Wells & Scott 2009). Bottlenose dolphins can thrive in many environments and feed on a variety of prey, such as fish, squid, and crustaceans (e.g., crabs and shrimp). They use different techniques to pursue and capture prey, searching for food individually or cooperatively.

Bottlenose dolphins hear underwater sounds in the range of 150 Hz to 135 kHz (Johnson 1967, Ljungblad *et al.* 1982). Their best underwater hearing occurs between 15 and 110 kHz, with the threshold level range is 42 to 52 dB RL (Au 1993). Nachtigall *et al.* (2000) more recently measured the range of highest sensitivity as between 25 and 70 kHz, with peaks in sensitivity at 25 and 50 kHz. Bottlenose dolphins produce a variety of whistles, echolocation clicks, low-frequency narrow, "bray" and burst-pulse sounds with frequencies as low as 50 Hz and as high as 150 kHz with dominant frequencies at 0.3 to 14.5 kHz, 25 to 30 kHz, and 95 to 130 kHz (Janik 2000).

3.3.8 Short-beaked Common Dolphin (Delphinus delphis)

The common dolphin is one of the most abundant dolphins in the world. It reaches lengths of about 1.8 m. Common dolphins are distributed worldwide in temperate, tropical, and subtropical oceans, primarily along continental shelf and steep bank regions where upwelling occurs (Jefferson et al. 2015). Short-beaked common dolphins seem to be most common north of 50°N in the Atlantic Ocean (Croll *et al.* 1999). Common dolphins usually rest during the day and feed at night. They typically dive to about 30 m to feed on schooling fish and cephalopods (e.g., squid) that migrate towards the surface at night.

Little is known about hearing in the common dolphin. The hearing threshold of a common dolphin was measured with an auditory range from 10 to 150 kHz, with greatest sensitivity between 60 and 70 kHz (Popov and Klishin 1998). Common dolphins produce sounds as low as 0.2 kHz and as high as 150 kHz, with dominant frequencies at 0.5 to 18 kHz and 30 to 60 kHz (Au 1993, Moore & Ridgway 1995). Signal types consist of clicks, squeals, whistles, and creaks (Evans 1994). The whistles of common dolphins range between 3.5 and 23.5 kHz (Ansmann *et al*. 2007). Most of the energy of echolocation clicks is concentrated between 15 and 100 kHz (Croll *et al*. 1999). In the North Atlantic, the mean SL of common dolphin whistles was approximately 143 dB with a maximum of 154 (Croll *et al*. 1999).

3.3.9 Cuvier's Beaked Whale (Ziphius cavirostris)

Cuvier's beaked whale can reach lengths of 4.6 to 7 m. They are the most cosmopolitan of all beaked whale species, with a wide distribution in oceanic tropical to polar waters of all oceans except the high polar regions. Cuvier's beaked whales prefer the deeper waters of the continental slope and areas around steep underwater geologic features like seamounts and submarine canyons.

The hearing sensitivity of Cuvier's beaked whales has not been measured (Ketten 2000). Cuvier's beaked whales have been recorded producing clicks between about 12 to 40 kHz with associated SLs of 200 to 220 dB re 1 μPa-m (pk-to-pk). Johnson *et al.* (2004) also found that Cuvier's beaked whales do not vocalize when within 200 m of the surface and only started clicking at an average depth of 475 m and stopped clicking on the ascent at an average depth of 850 m.

3.3.10 Gervais' Beaked Whale (Mesoplodon europaeus)

Gervais' beaked whales are about the same size as Cuvier's beaked whale, with lengths ranging from 4.7 to 5 m. Gervais' beaked whales occur in deep tropical, subtropical, and warm temperate waters of the Atlantic Ocean, ranging from Ireland to Brazil and the Gulf of Mexico, but are occasionally found in colder temperate seas. While diving, they use suction to feed mainly on cephalopods (e.g., squid), mysid shrimp, and small fish in deep water.

Few data are available on the auditory abilities of *Mesoplodon* beaked whales. A stranded Gervais' beaked whale had an upper limit for effective hearing at 80 to 90 kHz (Finneran *et al.* 2009).

3.3.11 Harbor Porpoise (Phocoena phocoena)

Harbor porpoises are small, coastal odontocetes that are common in the waters of the northern hemisphere. They reach a maximum size of about 1.5 m and are typically difficult to spot at the sea surface due to their small size and very short surface durations. Harbor porpoise feed primarily on small fish.

Harbor porpoises are classified as HF hearing specialists and produce narrowband high-frequency echolocation clicks (Madsen *et al.* 2005). Despite their HF hearing, harbor porpoises are well known for sometimes strong behavioral reactions to LF sound (Tougaard et al. 2009, Kastelein 2013, Kastelein et al. 2017, Graham et al. 2019, Graham et al. 2017).

3.3.12 Killer Whale (Orcinus orca)

Killer whales range from 8.5 to nearly 10 m in length, for females and males, respectively. This largest member of the dolphin family has a distinctive and easily identifiable appearance and is perhaps the most cosmopolitan of all marine mammals. Killer whales occur in all the world's oceans from about 80°N to 77°S and are especially common in high productivity and high-latitude (cold-temperate to subpolar) neritic waters (Ford 2009, Forney and Wade 2006, Leatherwood and Dahlheim 1978). Killer whales have a widely varied diet, feeding on nearly every group of large marine animals and even some marine birds. Killer whales can be divided into ecotypes depending upon their geography and the prey type upon which they feed. In the Atlantic Ocean, killer whales have been generally categorized as two ecotypes, Type 1, which are smaller and fish-eating, and Type 2, larger whales that feed on cetaceans (Jefferson et al. 2015).

Killer whales hear underwater sounds in the range of <500 Hz to 120 kHz (Bain *et al.* 1993, Szymanski *et al.* 1999). Their best underwater hearing occurs between 15 and 42 kHz (Hall and Johnson 1972, Szymanski *et al.* 1999). Killer whales produce sounds as low as 80 Hz and as high as 85 kHz with dominant frequencies at 1 to 20 kHz (Awbrey 1982, Ford and Fisher 1982, Miller and Bain 2000, Schevill and Watkins 1966). An average of 12 different call types (range 7 to 17)—mostly repetitive discrete calls—exist for some pods of killer whales (Ford 2009). Vocalizations include pulsed calls, whistles, and echolocation clicks. While the basic structure of killer whale vocalizations is similar within all populations, geographic variation between populations does exist (Samarra *et al.* 2015).

3.3.13 Kogia spp. (Dwarf and Pygmy Sperm Whales)

The two *Kogia* species, pygmy and dwarf sperm whales, are very difficult to differentiate at sea due to their small body size and cryptic nature, so most records of these species are only identified to genus (*Kogia* spp.). Thus, little detailed information is available for either species. Pygmy and dwarf sperm whales are distributed worldwide, primarily in temperate to tropical deep waters, and are especially common in waters along continental shelf breaks (Evans 1987, Jefferson *et al.* 2015). Dwarf sperm whales appear to prefer warmer water than the pygmy sperm whale (Caldwell and Caldwell 1989). Little evidence exists for seasonal movements in either species (Mcalpine 2009). Both *Kogia* species feed on deep water cephalopods but also feed on fishes and shrimps (Jefferson *et al.* 2015).

Sparse data exist on the hearing sensitivity of pygmy sperm whales and no data are known on the hearing sensitivity of the dwarf sperm whale have been measured. The hearing of a rehabilitating pygmy sperm whale was measured, with greatest hearing sensitivity between 90 and 150 kHz (Carder *et al.* 1995, Ridgway and Carder 2001). Recordings of captive pygmy sperm whales show they produce sounds between 60 and 200 kHz with peak frequencies at 120 to 130 kHz (Carder et al. 1995, Ridgway & Carder 2001, Santoro *et al.* 1989). Echolocation pulses of pygmy sperm whales were documented with peak frequencies at 125 to 130 kHz (Ridgway and Carder 2001). Merkens *et al.* (2018) recently reported that the sounds produced by captive and free-ranging dwarf sperm whales were very similar to those of pygmy sperm whales, and were characterized as narrow-band, HF clicks with mean frequencies from 127 to 129 kHz.

3.3.14 Pantropical Spotted Dolphin (Stenella attenuata)

Pantropical dolphins are relatively small dolphins that range in size from 1.8 to 2.1 m. These dolphins occur throughout tropical and sub-tropical waters of the world from roughly 40°N to 40°S (Jefferson *et al*. 2015). Typically, oceanic, pantropical spotted dolphins can be found close to shore in areas where deep water approaches the coast. Pantropical spotted dolphins spend most of daylight hours in waters between 91 and 305 m deep, but at night, they dive into deeper waters to search for prey and feed primarily on mesopelagic cephalopods and fishes.

There are no direct hearing measurements for the pantropical spotted dolphin. Pantropical spotted dolphins produce whistles with a frequency range of 3.1 to 21.4 kHz (Richardson *et al.* 1995). They also produce click sounds that are typically bimodal in frequency with peaks at 40 to 60 kHz and 120 to 140 kHz with source levels up to 220 dB re 1 µPa at 1m (Schotten *et al.* 2004).

3.3.15 Long-finned and Short-finned Pilot Whales (Globicephala melas melas and macrorhynchus, respectively)

Both the short- and long-finned pilot whales occur in the North Atlantic Ocean. Adult pilot whales reach lengths of about 6.5 m. Sightings of pilot whales in the western North Atlantic occur primarily near the continental shelf break from Florida to the Nova Scotian Shelf (Mullin and Fulling 2003). Pilot whales tend to concentrate in areas of high bathymetric relief or strong thermal fronts and are typically found almost exclusively along the continental shelf edge and slope regions (Hamazaki 2002). In the North Atlantic Ocean, long-finned pilot whales occur from Iceland, Greenland, and the Barents Sea south to North Carolina and North Africa, while short-finned pilot whales have a more tropical and subtropical distribution, ranging from North Carolina through the wider Caribbean Sea and Gulf of Mexico(Hayes et al. 2022); the species' ranges overlap in mid-Atlantic waters. Pilot whales feed mainly on squid, but they may also feed on octopuses and fish, all from moderately deep water of 305 m or more.

The best hearing sensitivity for a captive pilot whale was measured between 40 and 56 kHz with the upper limit of functional hearing between 80 and 100 kHz. Pilot whales echolocate with a precision similar to bottlenose dolphins. Short-finned pilot whales produce sounds as low as 280 Hz and as high as 100 kHz, with dominant frequencies between 2 to 14 kHz and 30 to 60 kHz (Caldwell and Caldwell 1969, Fish and Turl 1976, Scheer *et al.* 1998). The mean frequency of calls produced by short-finned pilot whales is 7,870 Hz, much higher than the mean frequency of calls produced by long-finned pilot whales (Rendell *et al.* 1999). Echolocation abilities have been demonstrated during click production (Evans 1973). SLs of clicks have been measured as high as 180 dB (Fish and Turl 1976).

3.3.16 Risso's Dolphin (Grampus griseus)

Risso's dolphin's range in length from 2.6 to 3.9 m. These dolphins inhabit deep oceanic and continental slope waters worldwide, from tropical to temperate waters of both hemispheres (Leatherwood *et al.* 1980, Baird 2009). They appear, however, to have a strong preference for temperate waters between 30° and 45° in latitude (Jefferson et al., 2015). Little to nothing is known about the movement or migration patterns of Risso's dolphins. Although Risso's dolphins consume cephalopods and crustaceans, they prefer squid and octopus (Jefferson et al. 2015).

Audiograms for Risso's dolphins indicate that their hearing ranges in frequency from 1.6 to 110 kHz, with optimal hearing occurring between 4 and 80 kHz (Nachtigall *et al.* 1995). Risso's dolphins produce sounds as low as 0.1 kHz and as high as 65 kHz. Their dominant vocalizing frequencies are between 2 to 5 kHz and 65 kHz (Corkeron and Van Parijs 2001, Watkins 1967, Au 1993). Risso's dolphins produce tonal whistles, burst-pulse sounds, echolocation clicks, and a hybrid burst-pulse tonal signal (Corkeron and Van Parijs 2001).

3.3.17 Rough-toothed Dolphin (Steno bredanensis)

Rough-toothed dolphins reach lengths of about 2.6 m and occur in oceanic tropical and warm-temperate waters around the world. Although they appear to be relatively abundant in certain areas; these dolphins are typically found in continental shelf waters in some locations, such as Brazil. In the western Atlantic Ocean, they are found from the southeastern U.S. to southern Brazil, including the Gulf of Mexico and Caribbean Sea. Prey that rough-toothed dolphins feed upon include squids and different types of fish.

Very little information is available on the hearing sensitivity of rough-toothed dolphins. Rough-toothed dolphins are likely capable of detecting frequencies much higher than 80 kHz and as low as 5 kHz (Cook *et al.* 2005). Rough-toothed dolphins produce clicks and whistles ranging from 0.1 kHz to 200 kHz (Miyazaki and Perrin 1994, Popper 1980, Thomson and Richardson 1995).

3.3.18 Sperm Whale (Physeter macrocephalus)

The sperm whale is the largest toothed whale, with males averaging 16 m and females only about 12 m in length. Sperm whales are primarily found in deeper (1000 m) ocean waters and distributed in polar, temperate, and tropical waters of the world's oceans. In the waters of the U.S. Atlantic, sperm whales are distributed from the continental shelf edge and slope to open ocean waters and are often associated with the Gulf Stream and its features. Sperm whales dive deeply for their prey, which consists of species such as squid, sharks, skates, and fishes.

The measured hearing of a stranded sperm whale calf suggested an auditory range of 2.5 to 60 kHz, with best hearing sensitivity between 5 and 20 kHz (Ridgway and Carder 2001). Ketten (2000) predicted a lower limit of hearing, near 100 Hz. Sperm whales produce broadband clicks with energy from less than 100 Hz to 30 kHz. Regular click trains and creaks have been recorded from foraging sperm whales and may be produced as a function of echolocation. A series of short clicks, termed “codas,” have been associated with social interactions and are thought to play a role in communication.

3.3.19 Striped Dolphin (Stenella coeruleoalba)

Striped dolphins are one of the most abundant and commonly occurring dolphins in the world. They reach about 2.7 m in length and are common in tropical and warm-temperate oceanic waters of the Atlantic, Pacific, and Indian oceans and adjacent seas between roughly 50° N and 40° S (Jefferson et al. 2015) and are often linked to upwelling areas and convergence zones.

The behavioral audiogram developed by Kastelein *et al.* (2003) for the striped dolphin shows hearing capabilities from 0.5 to 160 kHz. The best underwater hearing of the species appears to be at from 29 to 123 kHz (Kastelein *et al*. 2003). Striped dolphins produce whistle vocalizations lasting up to three seconds, with frequencies ranging from 1.5 to >24 kHz, with peak frequencies ranging from 8 to 12.5 kHz.

3.3.20 True’s Beaked Whale (Mesoplodon mirus)

True’s beaked whales are medium sized beaked whales, ranging from 4.7 to 5.3 m in length. This beaked whale species occurs in the deep, warm, temperate waters of the North Atlantic Ocean as well as at least two other areas in the Southern Hemisphere. In the western North Atlantic Ocean, True’s beaked whales range from Nova Scotia to Brazil. While diving, these beaked whales use suction to feed on small fish and cephalopods (e.g., squid) in deep waters, normally about 870 m in depth.

Few data are available on the auditory abilities of *Mesoplodon* beaked whales. Scientists recently discovered that True’s beaked whales emit ultrasonic[2] vocalizations, such as clicks, during foraging dives. DeAngelis *et al.* (2018) described the frequency modulated clicks of True’s beaked whales as similar to those of Gervais’s beaked whales. The median peak frequencies of True’s beaked whale clicks recorded in 2016 and 2017 were 43.1 and 43.5 kHz, respectively. Median inter-click intervals were 0.17s and 0.19 s.

3.3.21 *Gray Seal* (*Halichoerus grypus atlantica*)

Gray seals are between 2 to 3 m in length and occur in coastal temperate to sub-polar waters of the North Atlantic Ocean and Baltic Sea (Jefferson et al. 2015). In the northwestern Atlantic, gray seals occur principally in coastal waters of eastern Canada (Labrador) to the northeastern U.S. (New Jersey) but may occasionally occur extralimitally further south (Hayes et al. 2020).

Gray seals’ underwater hearing range has been measured from 2 kHz to 90 kHz, with best hearing between 20 kHz and 50 to 60 kHz (Ridgway and Joyce, 1975). Gray seals produce in-air sounds at 100 Hz to 16 kHz, with predominant frequencies between 100 Hz and 4 kHz for seven characterized call types, and up to 10 kHz for “knock” calls (Asselin et al., 1993). Oliver (1978) has reported sound frequencies as high as 30 and 40 kHz for these seals.

2 Ultrasonic=frequencies >20 kHz

3.3.22 Harbor Seal (Phoca vitulina)

Harbor seals are also known as common seals and are one of the most widely distributed pinnipeds in the world and the most common seal in U.S. Atlantic waters. They are typically less than 2 m in length and occur principally in temperate to polar coastal waters of North America, Europe, and eastern Asia. In the northwestern Atlantic Ocean, harbor seals occur from eastern Canada through the U.S. mid-Atlantic.

The harbor seal can hear sounds in the range of 75 Hz to a maximum of 180 kHz (Kastak and Schusterman, 1998; Terhune, 1991). Underwater hearing thresholds are ~ 53 dB @ 4 kHz (Kastelein *et al.* 2010). Harbor seals produce a variety of sounds including clicks, groans, grunts, and creaks that range in frequency from 0.1 to 7 kHz, although clicks can range from 8 to more than 150 kHz, with dominant frequencies between 12 and 40 kHz (Hanggi and Schusterman 1994), Richardson *et al.* 1995).

3.4 Potentially Occurring Sea Turtles

3.4.1 Green Turtle (Chelonia mydas)

Eleven distinct population segments (DPSs) for the green turtle have been designated worldwide as either threatened or endangered under the ESA (NOAA 2016). Green turtles potentially occurring in the project area are part of the North Atlantic DPS, which is listed as threatened. The ESA critical habitat in the coastal waters around Culebra Island, Puerto Rico and its outlying keys established in 1998 remains in effect for the North Atlantic DPS. The global population of the green turtle is estimated as 570,926 turtles while the North Atlantic DPS has an estimated population of 167,424 individuals (NOAA 2016).

Green turtles are widespread throughout tropical, subtropical, and warm-temperate waters of the Atlantic, Pacific, and Indian oceans and Mediterranean Sea between 30° N and 30°S (Lazell, 1980). Except during the juvenile lifestage and adult migrations when green turtles are found in the oceanic environment, green turtles principally inhabit the neritic zone, typically occurring in nearshore and inshore waters where they forage primarily on sea grasses and algae (Mortimer, 1982). Nesting of green turtles occurs on nearly 1,800 nesting beaches worldwide in over 80 countries (Hirth 1997, Pike 2013).

Green turtles typically make shallow and short-duration dives to no more than 30 m for <23 min but dives more than 138 m and for durations of 307 min have been recorded, with these deeper dives usually occurring during winter (Blanco et al. 2013, Hays et al. 2000, Hochscheid *et al.* 1999, Rice and Balazs 2008). Godley et al. (2002) reported travel speeds for green turtles ranging from 0.6 to 2.8 kph, with faster swim speeds associated with traverse across deeper, open waters. Song et al. (2002) reported average swimming speeds ranging from 1.4 to 3 kph for migrating green turtles.

Juvenile green sea turtles have a narrow range of low frequency underwater hearing, from 50 to 1,600 Hz, with the best sensitivity between 200 and 400 Hz and an averaged threshold of 95 to 96 dB re 1 µPa (rms) (Piniak *et al.* 2016). Ketten and Bartol (2006) found that juvenile green turtles exhibited a somewhat broader hearing range than sub-adult green turtles, whose hearing was measured at 100 to 500 Hz. Charrier *et al.* (2022) observed that juvenile green turtles produce 10 different types of sound that can be classified as pulses, calls, squeaks, and frequency modulated sounds, with the frequency characteristics of the generated sounds in the range of their measured hearing.

3.4.2 Kemp's Ridley Turtle (Lepidochelys kempii)

The Kemp's ridley turtle is the rarest sea turtle worldwide and has the most restricted distribution. The Kemp's ridley turtle is listed as endangered throughout their range under the ESA with no designated critical habitat. Although abundance information for the Kemp's ridley turtle is sparse, the 2012 estimated population of female Kemp's ridley turtles 2 years and older was 248,307 turtles with 10,987 nests reported in 2014 (NMFS and USFWS 2015).

Kemp's ridley turtles are found primarily in the neritic waters along the U.S. and Mexico coasts of the Gulf of Mexico and western North Atlantic Ocean (Byles and Plotkin 1994, Marquez-M. 1994, Plotkin 2003). Adult females make relatively short annual migrations from their feeding grounds in the western Atlantic and Gulf of Mexico to their principal nesting beach at Rancho Nuevo, Mexico. Unique among sea turtles, adult males are non-migratory, remaining resident in coastal waters near Rancho Nuevo year-round. In contrast, juvenile Kemp's ridleys make longer migrations between their winter-feeding grounds in the Gulf of Mexico and Florida to their summer feeding grounds in coastal waters and embayments of the U.S. East Coast. Kemp's ridley turtles participate in arribada nesting, with the major arribada nesting site at Rancho Nuevo; however, solitary nesting has been recorded at 10 beaches along 120 mi (193 km) of Mexican shoreline in Tamaulipas and another 32 km in Veracruz, Mexico.

Kemp's ridleys make shallow dives <50 m) of short duration (12 to 18 min) (Lutcavage and Lutz 1997). Renaud (1995) reported the mean dive duration as 33.7 min, with 84 percent of the submergences <60 min. Mean swimming speeds were reported to range from 0.7 to 1.3 kph, with over 95% of the actual velocity values <5 kph (Renaud 1995).

Kemp ridley turtles appear to have the most restricted hearing range (100 to 500 Hz) with their best hearing sensitivity between 100 and 200 Hz(Ketten and Bartol 2006). Ferrara *et al.* (2019) found that Kemp's ridley hatchlings produced underwater sounds, most of which showed peak frequencies between 560 and 750 Hz, which is above the hearing range measured by Ketten and Bartol (2006).

3.4.3 Leatherback Turtle (Dermochelys coriacea)

The leatherback turtle is the largest turtle in the world and one of the largest living reptiles. As a species, the leatherback is listed endangered throughout its range under the ESA. Critical habitat for the leatherback turtle has been designated in the Caribbean Sea waters adjacent to Sandy Point Beach, St. Croix, U.S. Virgin Islands, as well as in the northeast Pacific Ocean waters from California to Washington (NOAA 1979b, 2012b). Nel (2012) reported the worldwide leatherback abundance as 57,147 to 61,256 nests annually. The subpopulation of leatherback turtles in the northwest Atlantic Ocean is the largest in the world, with an estimated 34,000 to

94,000 individuals (The Turtle Expert Working Group 2007) and 50,842 nests per year (Wallace et al. 2013).

Leatherbacks are the most pelagic and most widely distributed of any sea turtle and can be found circumglobally in temperate and tropical oceans (Spotila 2004). The largest Atlantic nesting sites are located in Gabon, Africa and Trinidad, Caribbean Sea (Wallace *et al.* 2013). Highly migratory, leatherbacks in the western Atlantic travel north in the spring, following the Gulf Stream and feeding opportunistically, arriving in continental shelf and coastal waters off New England and Atlantic Canada where they remain through October. In the fall, some leatherbacks head south essentially retracing their offshore migratory route while others cross the Atlantic to Great Britain and migrate south along the eastern Atlantic (James *et al.* 2005).

Leatherback turtles make the deepest dives of any sea turtle, with the deepest dive recorded at 1,280 m (Doyle *et al.* 2008). Their longest duration dive was 86.5 min, but most dives are no more than 40 min (Byrne *et al.* 2009, López-Mendilaharsua et al. 2009, Sale *et al.* 2006). Hougthon *et al.* (2008) found that 99.6 percent of leatherback dives were to water depths less than 300 m while only a 0.4 percent were to deeper water depths, with the dives to waters >300 m occurring principally during the day and during migrational transit. In the Atlantic, Hays *et al.* (2004) determined that migrating and foraging adult leatherbacks spent 71 to 94 percent of their diving time at depths from 70 to 110 m. The modal speeds of swimming leatherback turtles ranged between 2 to 3 kph with absolute maximum speeds in the range of 6.5 to 10 kph (Eckert 2002). Inter-nesting leatherback turtles swam at speeds ranging from 1.25 to 2.5 kph (Byrne *et al.* 2009).

Leatherback hatchlings can hear both underwater and in air, and were found to detect sound from 50 to 1,200 Hz underwater, with best hearing sensitivty was between 100 and 400 Hz with a threshold of 84 dB re 1µPa at 300 Hz (Dow Piniak *et al.* 2012). Cook and Forest (2005) noted that female leatherbacks make broadband sounds when ashore during nesting, including breath noises, grunts, and gular pumps that ranged in frequency from 300 to 500 Hz. Hatchlings also produce sounds when in their nests but no underwater sound production by any lifestage of leatherbacks has been documented Ferrara *et al.* (2014).

3.4.4 Loggerhead Turtle (Caretta caretta)

Five loggerhead DPS are listed as endangered under the ESA while four DPS are listed as threatened (NOAA and USFWS 2011). Only members of the threatened Northwest Atlantic Ocean DPS occur in the project area. In 2014, critical habitat was designated for the Northwest Atlantic Ocean DPS in the northwestern Atlantic Ocean and the Gulf of Mexico that includes nearshore reproductive habitat, winter habitat, breeding areas, constricted migratory corridors, and *Sargassum* habitat (NOAA 2014). Critical habitat for the Northwest Atlantic Ocean DPS additionally includes 38 marine areas along the coastlines and offshore of North Carolina, South Carolina, Georgia, Florida, Alabama, Louisiana, and Texas (DoI 2014). Casale and Tucker (2017) estimated the minimum global population of loggerhead turtles as 200,246 individuals. One of the two major global populations occurs in southeastern U.S. and northern Gulf of Mexico waters, with the number of U.S. nests estimated at approximately 68,000 to 90,000 nests per year. The largest concentration of loggerhead female turtles in the Northwest Atlantic DPS nest along the coast of Florida, where in 2016, 65,807 nesting females were reported (FFWCC 2018).

Loggerhead turtles are found in coastal to oceanic temperate, tropical, and subtropical waters of the Atlantic, Pacific, and Indian oceans and the Mediterranean Sea (Dodd 1988). Although loggerhead turtles are highly migratory, no movements across the equator are known, and loggerheads migrate hundreds to thousands of miles between feeding and nesting grounds.

Howell et al. (2010) found that more than 80 percent the time, loggerheads in the North Pacific Ocean dove to water depths <5 m, but 90 percent of their time was spent diving to depths <15 m. Even as larger juveniles and adults, loggerheads' routine dives are only to 9 to 22 m (Lutcavage and Lutz 1997). Migrating male loggerheads along the U.S. East Coast dove to water depths of 20 to 40 m (Arendt *et al.* 2012). An adult loggerhead made the deepest recorded dive to 233 m, staying submerged for 8 min (Sakamoto *et al.* 1990). The longest duration dive by a loggerhead turtle was 614 min during deep-bottom resting dives (Broderick *et al.* 2007). Sakamoto *et al*. (1990) reported loggerhead diving speeds ranging from 0.75 to 3.5 kph, while migrating females swam at minimum speeds of 0.75 to 1.7 kph (Godley *et al.* 2003).

The underwater hearing of a single adult loggerhead was measured from 50 to 3200 Hz using auditory evoked potential methods and from 50 to 1131 Hz using behavioral methods (Martin *et al.* 2012). Bartol and Bartol (2011) found that the hearing range using both auditory evoked potential and behavioral methods was the same, 50 to 1,200 Hz, in both post-hatchling and juvenile loggerhead turtles.

4 ACOUSTIC MODELING

4.1 Acoustic Modeling Inputs

The scenarios modeled and discussed in this report are based on expected locations, schedules, and activities for the Project. The environmental inputs used in the acoustic environment and the construction scenarios assessed are described in this section.

4.1.1 Modeling Area

A single representative location (38.3°N, 74.7°W) was selected for the underwater acoustic modeling analysis (Figure 4). This site has a depth of 27 m, which is an intermediate depth over the water depth range (13 to 42 m) of the Project area. A sensitivity study was conducted to assess the differences in acoustic propagation at the selected intermediate-depth model location (27 m) as well as at the deepest (42 m) and shallowest (13 m) locations within the Project area (Figure 5). The results of this sensitivity study indicated that although acoustic propagation was not significantly different between the sites, the modeling predicted lower received levels at the shallowest and deepest locations relative to the selected intermediate depth modeling location. Therefore, of the three considered modeling locations, the intermediate depth (27 m) location was selected to provide the most conservative and representative modeling results.

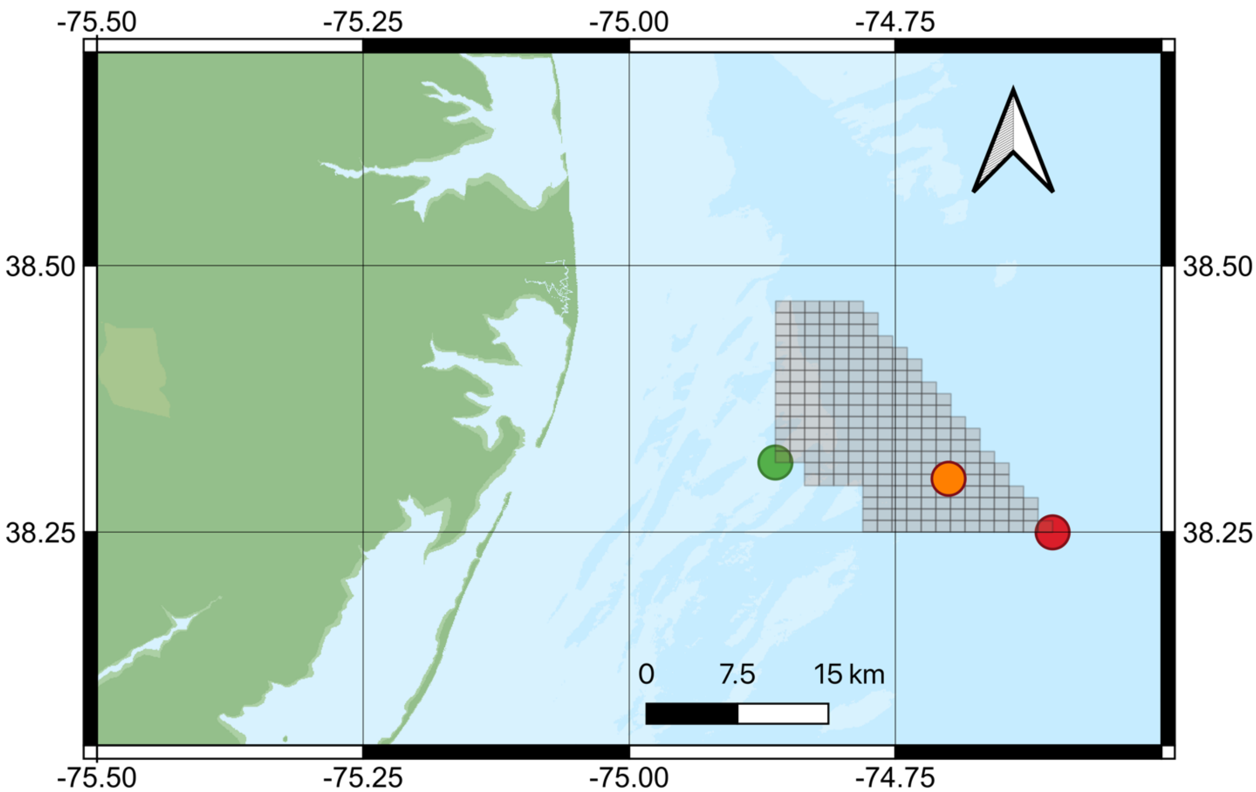

Figure 4. The modeling site (orange) selected as representative of the Project lease area; the shallowest (green) and deepest (red) water depth locations within the lease area were also considered but environmental conditions were so similar that the intermediate water depth site was selected for modeling.

4.1.2 Environmental Inputs

A description of the physical and acoustic environment of the modeling area is provided in the following sections. This includes a description of the local ambient noise environment.

4.1.3 Bathymetry

Bathymetric data for the Project area were obtained from the Coastal Relief Model (NOAA-NGDC 2013) with a spatial resolution of 3 arc-seconds (approximately 90 m). The bathymetry was extracted along radials in 10° increments emanating from the source location to the maximum modeled range. The data were extracted in range intervals of 25 m.

4.1.4 Sediment Characteristics and Geoacoustic Model

The geoacoustic model (Table 7) was based on the geological description presented in Fugro USA Marine (2020). This document provided measurements of compressional and shear wave speeds and densities for the different sediment layers in the Project area. Compressional and shear wave attenuation values were calculated using the model presented in Buckingham (2005).

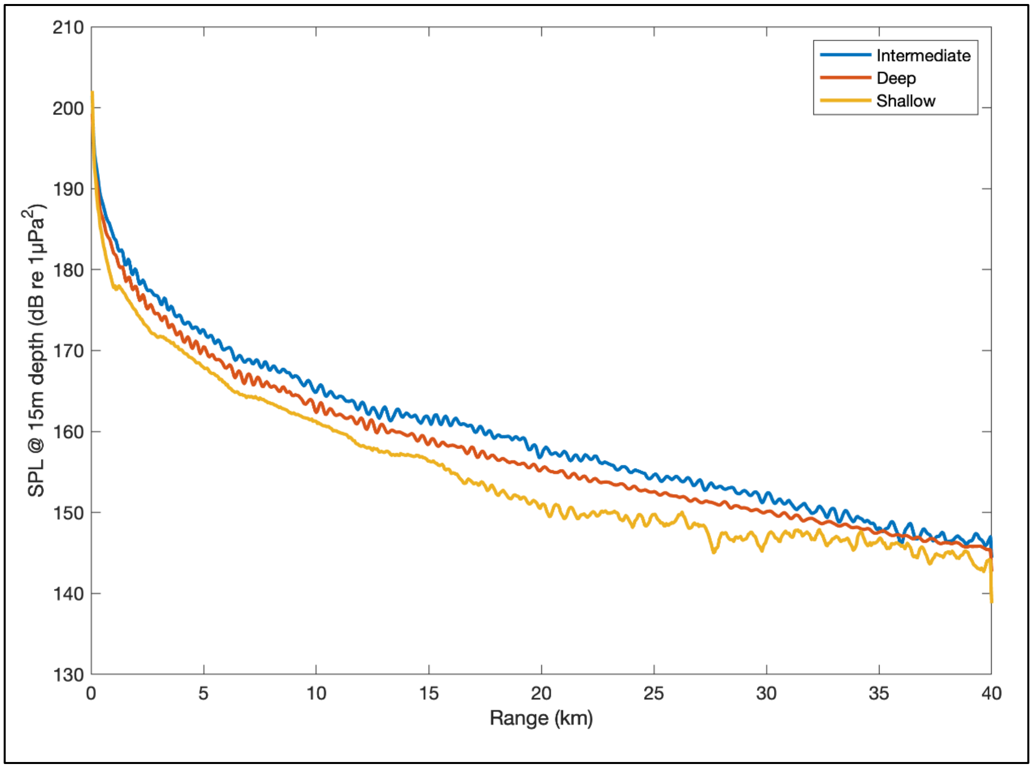

Figure 5. Predicted broadband received levels as a function of range for a source at a depth of 15 m in water depths of 27m (intermediate), 42 m (deep), and 13 m (shallow) at a bearing of 90° within the lease area. The differences in propagation between the sites are small, but the intermediate site provides the most conservative results with the largest received levels.

4.1.5 Sound Velocity Profile

Sound velocity profiles for the modeling site were extracted from the GDEM-V 3.0 database (Carnes 2009) (Figure 6). A single representative month was modeled to represent the entire proposed construction period (May to September). The average profile from May was used in the acoustic propagation modeling.

4.1.6 Ambient Noise

A dedicated passive acoustic study (Bailey *et al.*, 2018) in the Project area described the ambient noise environment. Bailey *et al.* (2018) deployed acoustic recorders throughout the Maryland Wind Energy Area (WEA) as well as offshore and inshore of the WEA to monitor baleen whales. They deployed a series of long-term recorders that monitored LF noise (1 to 1,000 Hz). The measured ambient noise levels were affected by the proximity of the shipping lanes into the Philadelphia area (white rectangles in Figure 7). Ambient noise levels were increased at sites A-4M, A-7M and T-2M that adjoin or are in line with the shipping lanes (Table 8). Although these elevated ambient noise levels have no impact on the definition of regulatory acoustic exposures, the raised ambient noise level reduced the signal excess of any pile driving sound.

Table 7. Geoacoustic model information that was used to represent the modeling locations in the Project area (Buckingham 2005, Fugro USA Marine 2020).

Depth below Seafloor (m)	Substrate Material	Density (g/cc)	Compressional Wave		Shear Wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0 to 12.5	Dense to very dense silty fine to medium sand with few stratifications of gravel	2.18	2,112	1.20	609	3.65
12.5 to 20.2	Dense to very dense silty fine to medium sand	1.58	1,831	1.28	467	
20.2 to 23.3	Very loose to loose sandy silt	1.14	1,638	0.59	178	
23.3 to 26.5	Very stiff to hard clay with fine sand	1.12	1,627	0.53	158	
26.5 to 44.0	Very stiff to hard sandy clay	1.12	1,607	0.46	134	
44.0 to 50.8	Dense to very dense silty fine sand	1.24	1,784	1.14	376	
50.8 to 64.9	Dense clayey fine to medium sand	1.21	1,770	1.08	353	

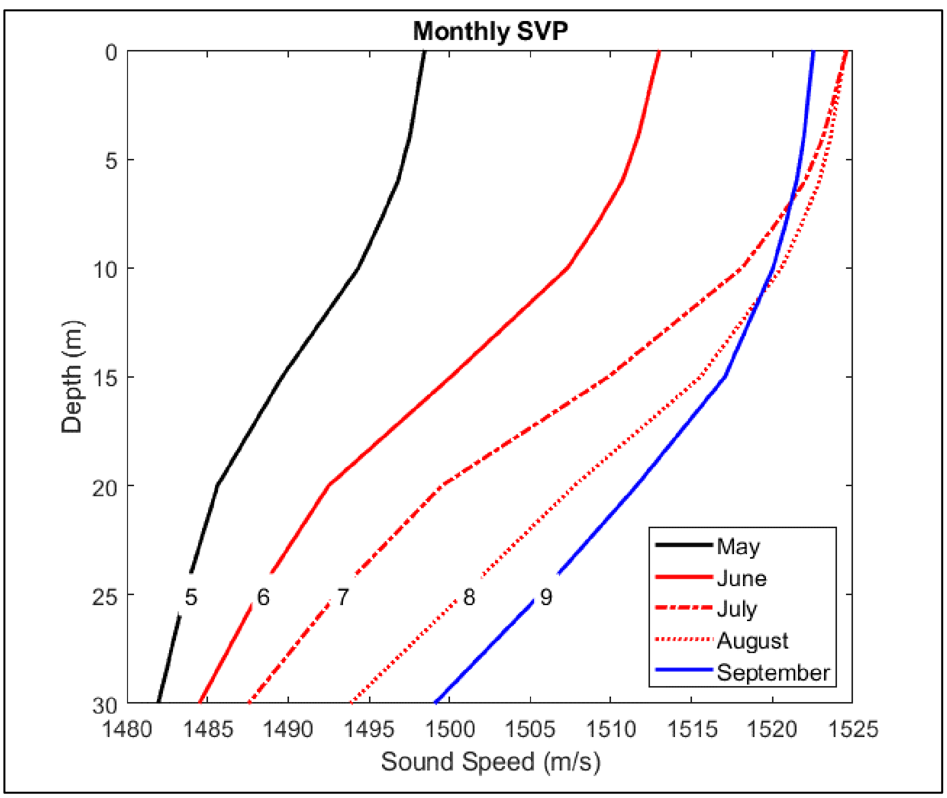

Figure 6. Modeling site monthly sound velocity profiles extracted from the GDEM-V 3.0 database (Carnes 2009).

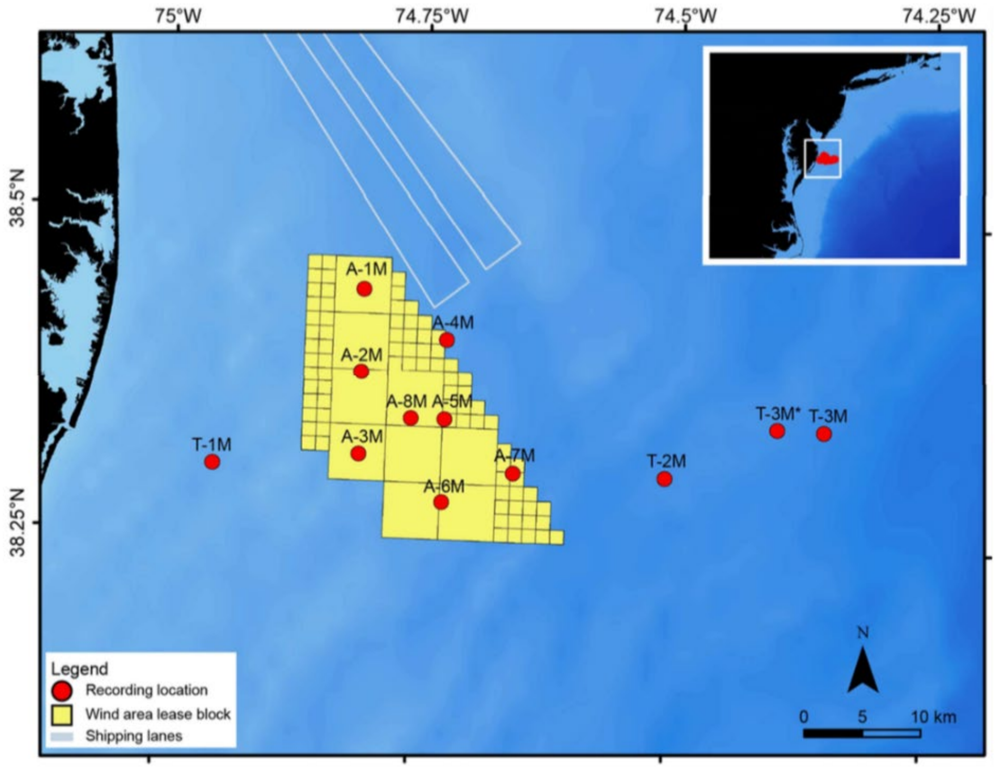

Figure 7. Location of recorders in the Bailey et al (2018) passive acoustic study with the shipping lanes into the Philadelphia area shown as white lines.

Table 8. Summary broadband (1 to 1,000 Hz) ambient noise levels reported by Bailey et al. (2018) in the Project area.

Site	***Average dB Year 1***	***Average dB Year 2***	***Average dB Year 3***	***Median dB***
T-1M	109.8	108.7	108.2	107.2
A-1M	111.7	110.7	111.3	110.5
A-2M	110.1	109.8	109.8	108.5
A-3M	110.7	109.1	109	108.1
A-4M	116.3	116	116.1	115.6
A-5M	114.9	113.5	114.4	113.8
A-6M	113.2	113.3	112.4	112.1
A-7M	116.9	116.3	116.7	116.1
A-8M	112.4	113	NA	111.4
T-2M	115.4	115.8	115	115.3
T-3*M	NA	118.3	114.2	113.8
T-3M	113.8	112	NA	112

NA=not applicable

4.2 Acoustic Modeling Scenarios

Although US Wind ultimately decided not to utilize vibratory pile driving during construction of the Maryland Offshore Wind Project, vibratory modeling was initially considered and modeled. US Wind decided to use impact pile driving to install the piles for the Meteorological (Met) Tower that was originally considered for vibratory piling. Since the vibratory piling was modeled for the 1.8-m Met Tower piles, that information is included in this report, even though US Wind will not utilize the model results.

Three installation scenarios were selected to represent the scope of the pile driving operations for the Project, representing three types of foundation installations (Table 9). The WTGs were modeled as 11-m diameter monopiles to be impact driven at a maximum strike energy of 4,400 kJ for a 2-hour duration. The offshore substation (OSS) jacket foundations were modeled as being comprised of four 3-m post-piled skirt piles that will be impact driven at a maximum strike energy of 1,500 kJ and a duration of 2 hours per pile. The installation of one 11-m monopile per day (24-hour period) and one jacket foundation per day (comprised of four 3-m post-piled skirt piles) was considered. The Met Tower foundation was originally modeled as three 1.8-m diameter piles to be vibratory driven, but this was subsequently changed to impact pile driving.

4.2.1 Pile Progression

To allow for operational flexibility during the piling of the 11-m monopiles, the acoustic modeling was performed at the maximum hammer energy of 4,400 kJ, and the modeled sound fields were then adjusted by a broadband sound reduction to represent the lower strike energy levels of 1100, 2200, and 3300 kJ that US Wind will likely use for impact piling of the monopiles (Table 10). To account for the differences in hammer energies between what US Wind expects to use in the installation of the 11-m monopiles (i.e., 1100, 2200, and 3300 kJ) and the modeled maximum hammer energy of 4400 kJ, the modeled sound levels for the 4400-kJ hammer were scaled down by 10*log10(E1/E2) (where E1 is the lower strike energy level and E2 is the modeled energy level) to represent each of the lower proposed hammer energies (von Pein et al. 2022). This resulted in the application of scaling factors of -6, -3, and -1 dB to represent the 1100, 2200, and 3300 kJ hammer energies, respectively. This difference in hammer energy is accounted for when calculating the cumulative SEL over the installation of each pile using the number of strikes at each energy level (Table 10). The broadband dB scaling factor (i.e., energy-based reduction) was subtracted from the modeled received levels for the indicated number of strikes before the cumulative SEL was calculated. The calculation of the broadband scaling factor is described in more detail in Section 4.4.1. It was assumed that a single 11-m monopile was installed each day.

For the 3-m skirt pile scenario, the hammer energy was assumed to be 1,500 kJ for the duration of installation. Each pile is estimated to take 120 minutes and 4,800 hammer strikes at a rate of 40 strikes per minute, which results in 480 minutes and 19,200 hammer strikes to install the four piles in each jacket foundation (Table 10). The acoustic ranges and exposures were calculated assuming four 3-m skirt piles were installed each day.

Table 9. Overview of modeling scenarios for the US Wind Maryland Offshore Project

Scenario	***Source***	***Pile Diameter (meters)***	***Hammer Type***	***Modeled Maximum Hammer Energy (kJ)***	***Representative Hammer Make/Model***	***Representative Modeling Location***
Scenario 1: Monopile - 1 Pile Per Day	Monopile	11	Impact	4400 kJ	MHU 4400	38.3°N, 74.7°W
Scenario 2: OSS Jacket Pile - 4 Piles Per Day	Post-piled Skirt Pile	3	Impact	1500 kJ	MHU 1900	
Scenario 3: Met Tower Pile - 1 Pile Per Day	Vibratory*	1.8	Vibratory	800 kJ	CAPE VLT 640	
Scenario 3: Met Tower Pile - 3 Piles Per Day (Revised)	Pre-piled pin Pile	1.8	Impact	500 kJ	MHU 1900 (Undecided)	

*Vibratory piling for the Met Tower was originally planned and modeled, hence its inclusion here, although US Wind ultimately decided to use impact pile driving to install the 1.8-m pin piles.

For the revised 1.8-m pin pile scenario with installation by impact pile driving, the impact hammer energy was assumed to be 500 kJ for the duration of installation. Each pile was estimated to take 120 minutes and 1,000 hammer strikes, which resulted in 360 minutes and 2,988 hammer strikes to install the three piles in the Met Tower foundation (Table 10). The acoustic ranges and exposures were calculated assuming three 1.8-m pin piles were installed each day.

4.2.2 Annual Installation Schedule

The installation of the WTGs, OSSs, and Met Tower will span a three-year period (Table 11). In Year 1, US Wind estimates that a total of 21 11-m monopiles and 1 OSS jacket (four 3-m skirt piles) will be installed. In Year 2, the estimate is that a total of 55 11-m monopiles, 2 OSS jackets (eight 3-m skirt piles), and 1 Met tower (three 1.8-m pin piles) will be installed. In Year 3, the remainder of the monopiles and skirt piles are planned to be installed, for a total of 38 11-m monopiles and 1 OSS jacket (four 3-m skirt piles) to be installed. Installation will span the period between June and September in Year 1, between May and August in Year 2, and between June and August in Year 3.

Table 10. US Wind's planned hammer strike energy progression and installation duration for the impact and vibratory pile driving modeling scenarios.

Pile Type	*Hammer Type*	*Hammer Energy (kJ)*	*Duration at Energy Level (minutes)*	*Blows per minute*	*Number of Hammer Blows per Pile*	*Scaling Factor (dB) to Lower Hammer Energy*	*Total Duration for Pile Install per Day (minutes)*	*Total Number of Blows for Pile(s) Installed per Day*
Scenario 1: 11-m Monopile (1 pile per day)	Impact	1100	30	20	600	-6	120	4800
		2200	60	40	2400	-3		
		3300**	30	60	1800	-1		
Scenario 2: 3-m Skirt Pile (4 piles per day)	Impact	1500	480	40	19200	0	480	19200
Scenario 3: 1.8 m Pin Pile (1 pile per day)*	Vibratory						60	
Scenario 3: 1.8-m Pin Pile (3 piles per day) (revised)	Impact	500	360	8.3+	2988	0	360	2988

*Vibratory piling for the Met Tower was originally planned and modeled, hence its inclusion here although US Wind ultimately decided to use impact pile driving to install the 1.8-m pin piles.
+ Although the fractional number of 8.3 hammer per minute is unlikely to be accomplished during installation, this number instead of the rounded more realistic value of 8 blows per minute is included as it results in a higher number of total hammer blows than if the rounded blows per minute value were used.

4.3 Acoustic Modeling Approach

4.3.1 Impact Pile Driving

The primary source of underwater sound due to impact pile driving is a result of the compression of the pile during each hammer strike. The hammer strike produces a compressional wave in the pile that results in the pile wall deforming. The pile is compressed in the vertical dimension and expands in the horizontal dimension. This deformation or "bulge" travels down the pile at a speed close to the compressional wave speed in steel and behaves as the sound source. Since the pile is surrounded by water, and the speed of sound in water is less than that in steel, the resulting acoustic field is in the shape of a Mach cone.

Table 11. Proposed annual installation schedule of the US Wind Project, spanning a three-year period with 22 foundations being installed in Year 1, 58 in Year 2, and 39 in Year 3.

Annual Construction Period	*Scenario 1: Monopile (11 m pile)*	*Scenario 2: OSS Foundation (4 3-m piles)*	*Scenario 3: Met Tower (3 1.8-m piles)*
Year 1			
May			
June	8		
July		1	
August			
September	13		
Year 2			
May	16		
June	16		1
July	16	2	
August	7		
September			
Year 3			
May			
June	15		
July	10	1	
August	13		

Vertical directionality of the propagating Mach wave is included in the model by specifying a beam-pattern from which the starting field for the parabolic equation is calculated; this starting field consists of a summation over the product of modes that solves an associated homogeneous waveguide problem (i.e., sine functions) and amplitudes given by the angular dependence of the beam-pattern. In the modeling described in this report, the pile is represented as a vertical line array. The pile beampattern was created from a vertical line array of elements with one meter spacing from the surface to the seafloor. This representative array was used to compute a frequency-specific beam-pattern, steered at an angle equal to the Mach cone angle, which was input to the Navy Standard Parabolic Equation (NSPE). The NSPE is an implementation of the RAM PE model (Collins 1993) and includes the option to compute a starting field from an input beam-pattern, as described above.

This process was followed for each third octave center frequency in the bands from 10 Hz to 25 kHz. Radials were run at 10° intervals to a range of 50 km. The process for deriving the appropriate source levels from available source spectra is described in detail in Section 4.4. The third-octave band source levels were added to each transmission loss value to produce a received level value at each range, depth, and bearing point.

Finally, the combined sound fields for each frequency were summed to generate a representative broadband sound field. This process was followed for each radial around the source to produce an N x 2-D grid of received sound levels in range, depth and bearing. The resulting predicted acoustic SEL field was weighted using the LF, MF, HF, PW, and ST weighting functions (NMFS 2018). The peak and SPL sound fields were derived using the methods described in Section 4.4.4.

4.3.2 Vibratory Pile Driving

Even though US Wind ultimately decided not to utilize vibratory pile driving during construction of the Maryland Offshore Wind Project, vibratory modeling had been considered and modeled. As such, this information is included in this modeling report. This section describes the approach for that modeling.

To model vibratory pile driving operations, an omnidirectional source was placed at a depth of 5 m from the surface. This approach for the modeling of the vibratory hammer source was used because vibratory pile driving lacks Mach cone directionality. Propagation predictions were calculated using the RAM PE model (Collins 1993).

This process was followed for each third-octave center frequency in the bands from 63 Hz to 2 kHz, which is the extent of the measured vibratory source spectrum; at the 2 kHz extent, the source level is reduced by ~20 dB. Radials were run at 10° intervals out to a range of 25 km.

The representative sound fields for vibratory driving were generated in the same manner as the impact pile driving analysis. The sound fields for each frequency were summed to generate a representative broadband sound field. This process was followed for each radial around the source to yield a transmission loss grid in range, depth, and bearing. The resulting predicted acoustic SEL field was weighted using the LF, MF, HF, PW, and ST weighting functions (NMFS 2018).

4.4 Source Characterization

The derivation of the source levels and source spectra resulting from the pile driving of the 11-m, 3-m, and 1.8-m piles planned for installation in the US Wind Project is described in this section.

4.4.1 Impact Driving of 11-m Monopiles (Scenario 1)

MAI used the predicted spectrum of an 11-m diameter monopile developed for the South Fork Wind Farm (Denes *et al.* 2021) as a surrogate source signature in the modeling of the 11-m monopile for the US Wind Project (Figure 8). This surrogate spectrum was predicted for the impact pile driving of an 11-m monopile using an IHC S-4000 hammer at a strike energy of 4,000 kJ. This spectrum was used to represent the impact pile driving of the 11-m monopile in the Project area with a strike energy of 4,400 kJ. The expected difference in sound level between 4,000 and 4,400 kJ was determined to be minimal at 0.4 dB, which resulted in the Denes et al. (2021) spectrum being used. The spectral levels that were shown in Denes et al. (2021) did not include levels for frequencies above 16 kHz. The levels were linear in log-frequency for 200 Hz and greater, so a least-squares linear fit on the levels from 200 Hz to 16 kHz was used to extrapolate to the 20 kHz and 25 kHz band centers. The expected difference of 0.4 dB was

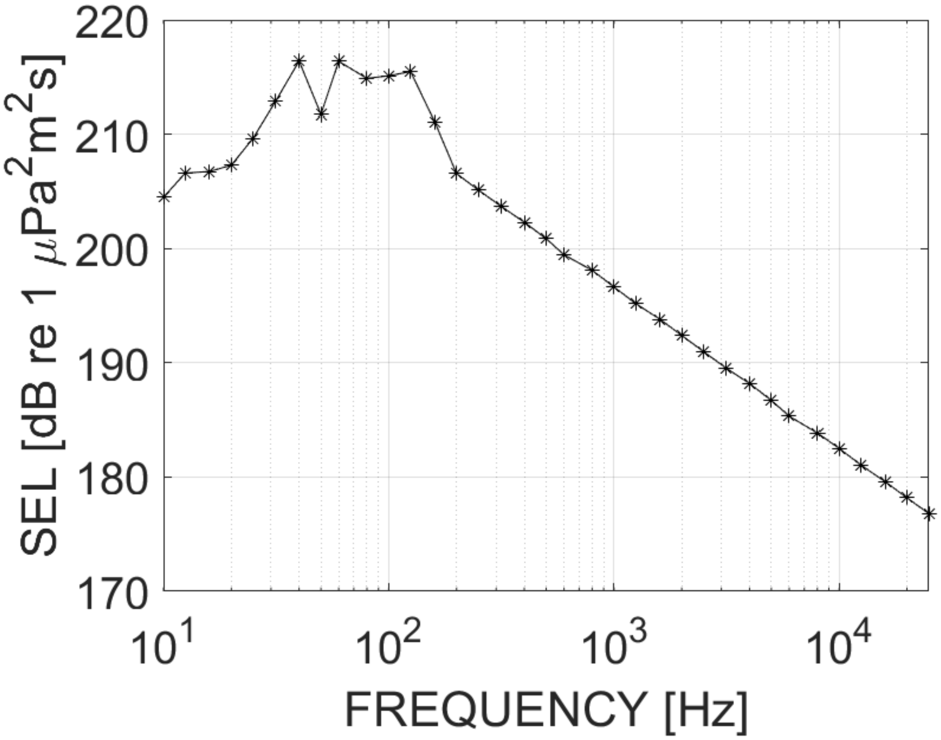

Figure 8. Acoustic Source Spectrum in Third Octave Bands Used to Model the Impact Piling of the 11-m Diameter Monopile for the US Wind Project Based on the 4000 kJ Hammer Spectra in Denes et al. (2021).

estimated using the scaling relationship presented in von Pein *et al.* (2022), which states that, during impact pile driving, the measured sound exposure level of an impact hammer strike increases with increasing hammer strike energy according to $SEL_2 = SEL_1 + 10 \times \log_{10}(E_2/E_1)$. To account for the lower strike energies being proposed in the pile installation, the spectrum was scaled using this relationship.

The broadband source level was calculated by converting each band level to intensity and converting their sum back to a decibel value. The resulting broadband SEL source level at 4,400 kJ was 224 dB re 1µPa^2-m^2-s. The broadband source levels for the hammer energies US Wind proposes to use to install the 11-m monopile were determined using the scaling factor reduction of 6, 3, and 1 dB (Table 12). These sound level offsets were used when calculating the cumulative SEL sound field to assess against the acoustic guidance.

4.4.2 Impact Driving of 3-m Skirt Pin Piles (Scenario 2)

The 3-m skirt pile source spectrum using in the modeling (Figure 9) was based on the measured spectra of a 6-m pile reported by Bruns et al. (2014) and a 3.5-m FINO2 pile reported by Matuschek and Betke (2009), which were the best available sources of information. However, the hammer energy used during measurement of the spectrum was not specified in either Matuschek and Betke (2009) nor in Bruns *et al*. (2014).

Table 12. Broadband SEL source levels for the 11-m monopile at varying strike energies and the associated sound level offset from the modeled hammer energy.

Hammer Energy (kJ)	*Broadband SL (dB re 1µPa^2-m^2-s)*	*Scaling Factor (dB) from Modeled Energy*
1100	218	-6
2200	221	-3
3300	223	-1
4400	224	0

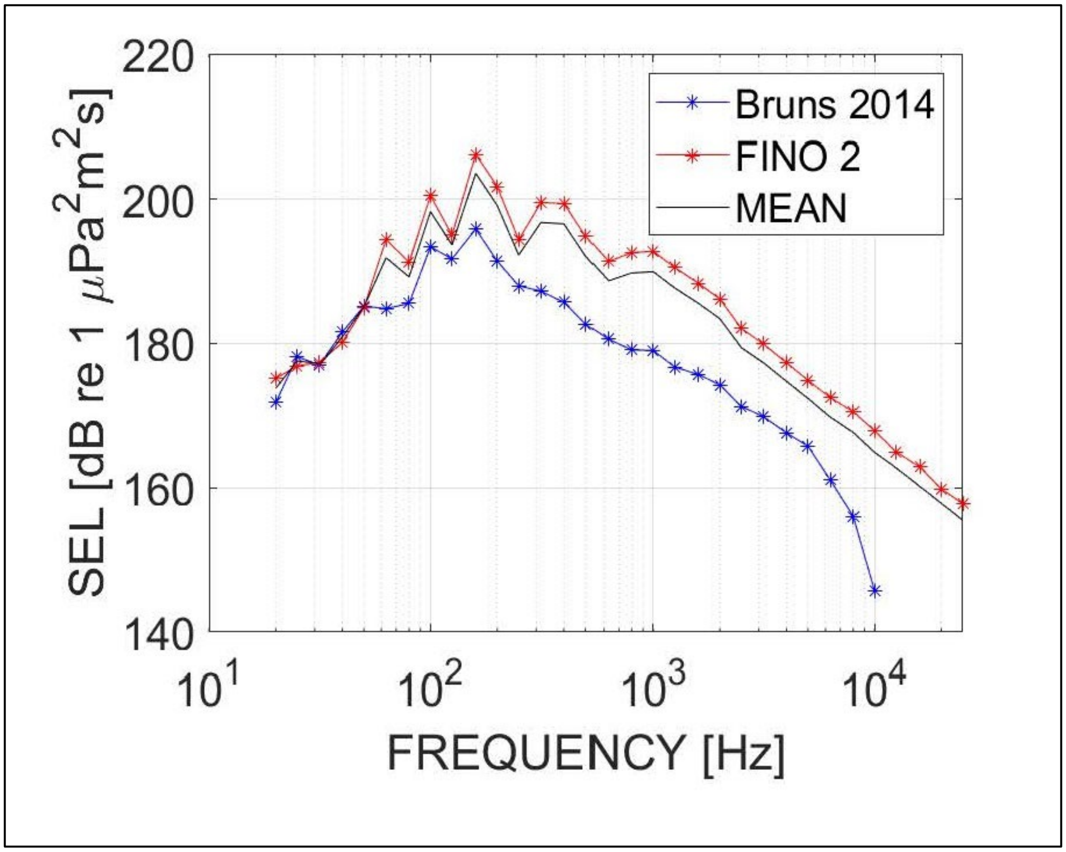

Figure 9. Measured and scaled spectra of a 6-m pin pile (Bruns et al. 2014) (measured at distance of 15 m) and a 3.5-m FINO2 pin pile (Matuschek and Betke 2009) (measured at 500 m) and the extrapolated mean of the two spectra, which was used as the representative spectrum for the 3-m skirt pile the Project.

The spectrum for the 6-m pile reported by Bruns *et al.* (2014) was recorded at 15 m, and a hybrid spherical/cylindrical spreading model (i.e., 15 x $\log_{10}$ (range)) was used to adjust the received level. The measured spectral levels were reduced by 5 dB (16.7 x $\log_{10}$(3m/6m)) to scale for differences in pile diameter (von Pein *et al.* 2022). The piling of a 3.5-m FINO2 pile was recorded at a distance of 500 m, and the same hybrid propagation loss model was used to adjust the received levels to source levels; the hammer type was not provided in Matuschek and Betke (2009). For consistency, the FINO2 spectral levels were also reduced by 1 dB to scale for diameter (16.7 x $\log_{10}$(3m/3.5m) = 1 dB). The mean of the two pile spectra from these sources was taken as the representative spectrum of the 3-m pin pile for the Project (Figure 9). The broadband SEL source level is 208 dB re 1µPa^2-m^2-s.

This value is comparable to the estimated values of ~209 dB re 1µPa^2-m^2-s for a 96" (2.4 m) steel pile driven by a 1700 kJ Menck Hammer (Molnar *et al.* 2020; Table I-2-1a), which was estimated by back calculating the source level assuming transmission loss of 15 x $\log_{10}$ (range) based on a measured SEL of 188 dB at a range of 25 m from the pile during unmitigated impact pile driving. The steel pile (Molnar *et al.* 2020) was driven at an angle through a steel frame for the San Francisco Oakland Bay Bridge, and is, thus, considered to have been post-piled. The good agreement between the source level of the representative spectrum proposed to represent the 3-m skirt piles and the measured post-piled levels of Molnar *et al.* (2020) suggests that the modeling herein can be considered representative of post-piled pin piles.

4.4.3 Impact Pile Driving of 1.8-m Pin Piles (Revised Scenario 3)

The spectrum derived for the 3-m post piled pin pile (Figure 9) was scaled to represent the 1.8-m post-piled pin pile for the Met Tower foundation. The spectrum was scaled based on maximum hammer energy and pile diameter using the relationships presented in von Pein et al. (2022). This resulted in the source levels being scaled down by 8 dB (10*log10(500 kJ/1500 kJ) + 16.7*log10(1.8m/3m) = 8 dB) (Figure 10). The resulting broadband SEL source level is 199 dB re 1µPa^2-m^2-s.

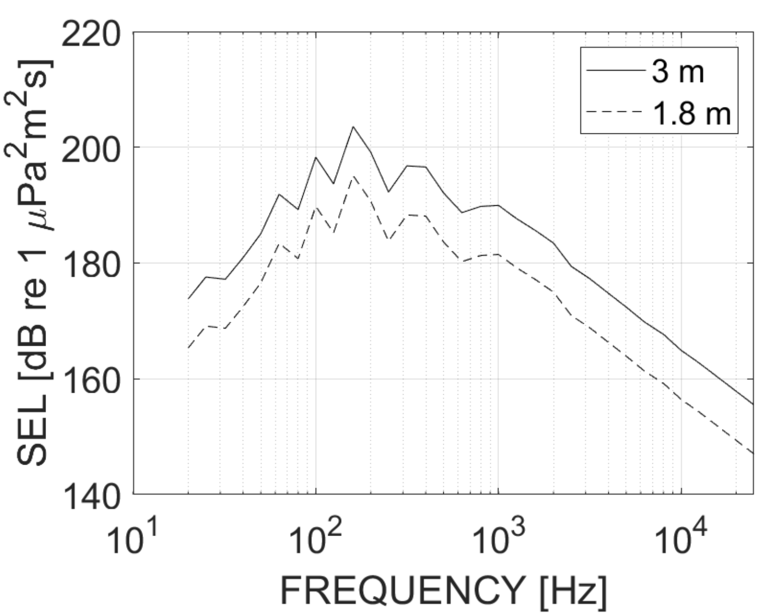

Figure 10. Source spectra for the 1.8-m pile derived from the spectra for the 3-m diameter pile.

4.4.4 Vibratory Driving of a 1.8-m Pin Piles (Scenario 3)

The spectral measurements of the vibratory pile driving of a 0.76-m pile from Dahl *et al.* (2015) were used to derive a representative spectrum to use in the modeling of a 1.8-m pin pile. Dahl et al. (2015) recorded sound levels on a vertical line array at a range of 16 m from the pile source. The received levels were adjusted to account for transmission loss (TL) using a 15 x $\log_{10}$ (range) model for the 16-m range between the source and VLA receiver. The values were further adjusted by a factor of 10 * log10(ratio of diameters) (i.e., 1.8-m/0.76-m) to approximate the difference in source level due to different pile diameters. The underlying assumption is that sound level will scale with pile diameter. Indeed, the measured sound level of vibratory driven piles was greater for 48" piles than 36" piles (Illingworth and Rodkin 2017). The TL value and source level correction factor were added to the received levels presented in Dahl et al. (2015) to produce an estimated source spectrum for vibratory driving of a 1.8-m pile for this project. Third octave band center frequencies from 63 Hz up to 2 kHz were used in the modeling. The broadband source level was 187 dB re 1 µPa-m.

4.4.5 Source Level Summary

To compute the ranges to regulatory thresholds, the source levels for the SEL and SPL (peak and RMS) for the unmitigated driving of a 11-m monopile, a 3-m pin pile, and a 1.8-m pile were derived (Table 13).

Table 13. Unmitigated source levels used for the US Wind pile driving modeling scenarios for a single strike at the modeled hammer energy (i.e., monopile hammer energy of 4400 kJ).

Source Scenario	***Source Levels***		
	SELss (dB re 1 µPa^2-m^2-s)	***Peak SPL (dB re 1 µPa-m)***	***SPLrms (dB re 1 µPa-m)***
11-m monopile (impact)	224	272	234
3-m pin pile (impact)	208	259	218
1.8-m pin pile (impact)	199	247	209
	SEL_{1sec}* (dB re 1 µPa^2-m^2-s)	***Peak SPL (dB re 1 µPa-m)***	***SPLrms (dB re 1 µPa-m)***
1.8-m pin pile (vibratory)	187	NA	187

NA=not applicable;

For the impact pile driving scenarios, the L_E(ss) (single strike SEL) SL was derived from the representative spectra. Assuming a signal length of 100 milliseconds (ms), the broadband L_p source level was calculated from the broadband unweighted L_E(ss) level using the following equation, where T = 0.1 s (100 ms). This resulted in 10 dB being added to the unweighted L_E(ss) level to represent the L_p source level:

$$L_{\mathrm{p}} = L_E(\mathrm{ss}) - 10\log 10\,T$$

The L_{pk} source level was generated from the unweighted L_E source level using the semi-empirical method described in Lippert *et al.* (2015). This method reflects range-dependent effects on the waveform structure to estimate the peak level from the SEL value using the equation:

$$L_{pk} = A\ \mathrm{SEL} + B + C$$

The term *A* SEL represents how peak amplitude changes with range. The *B* term represents the initial relationship between L_{pk} and L_E. The C term includes scaling factors between the pile being considered and previously measured piles. This calculation used values for Young's modulus of 210 GigaPascal (GPa), an axial velocity of 5,000 m/s, and ram masses of 200 and 70 tons for the monopile and pin piles, respectively.

For the vibratory pile driving scenario, the Lp source level was derived from the representative spectra. Assuming a signal length of 1 second, the broadband Lp source level was calculated from the broadband unweighted L_E level using the following equation, where T = 1 s:

$$L_{\mathrm{p}} = L_E(1\ \mathrm{sec}) - 10\log 10\,T$$

4.5 Implementation of Pile Schedule

The pile progression schedule (Table 10) was accounted for when calculating the acoustic ranges to SEL thresholds. The modeled sound fields represented the single strike SELs at the modeled strike energies. The single strike SEL fields were converted to cumulative SEL fields based on the different strike energy levels and the number of expected hammer blows at each energy. The difference between a single strike SEL and the cumulative SEL was calculated using 10 * log10(Number of strikes) for the specific hammer to be used on this project. For the 11-m monopile, ranges were calculated assuming one monopile is installed a day. For the 3-m skirt pile scenario, the acoustic ranges were calculated assuming four 3-m skirt piles were installed each day. For the 1.8-m pile scenario, the ranges were initially calculated assuming 60 minutes of vibratory pile driving a day. For the updated 1.8-m pin pile scenario using impact pile driving, the ranges to regulatory thresholds were calculated assuming three 1.8-piles were installed in a day.

4.6 Calculation of Acoustic Ranges to Regulatory Thresholds

The maximum received level-over-depth was calculated at each range step and along each radial. The maximum and 95th percentile range to each of the regulatory thresholds were then calculated. The maximum value represents the greatest distance along any one single radial and is in general higher than the 95th percentile because of different bathymetry and transmission paths along each radial. The 95th percentile range is an improved representation of the range to the threshold as it eliminates major outliers and better represents all the modeled radials. All ranges presented to regulatory threshold are the 95th percentile range. Because these values are taken from static sound fields, the SEL ranges reflect the ranges to stationary virtual receivers.

4.7 Summary of Acoustic Modeling Assumptions

The following modeling assumptions were made for the impulsive and non-impulsive scenarios in the acoustic propagation modeling:

1) A single modeling location was used as representative of conditions throughout the WEA. The small changes in absolute water depth suggest that this is a reasonable assumption. This assumption was tested with acoustic propagation model runs at the deepest and shallowest locations within the WEA to ensure the conditions at this single location were indeed representative (see Section 4.1).
2) The propagation modeling effort used sound velocity profiles from May. These are likely to represent the 'best' propagation environment for the proposed construction period (May – September). Thus, the ranges to isopleths and acoustic exposure predictions will likely be overestimates of varying degrees. Estimates for summer months are most likely to be highly overestimated due to summertime sound velocity profiles causing downward refracting propagation instead of a slight surface ducting effect in winter.
3) The monopile diameter of 11-m was modeled with a maximum strike energy of 4,400 kJ. Only one monopile would be driven in a given day.
4) Post-piled skirt pile diameter was assumed to be 3-m with a maximum strike energy of 1,500 kJ. Installation of four piles per day was considered.
5) The time needed to drive a 1.8-m pile was assumed to be one hour, based on the statement that vibratory driving is faster than impact driving (Saleem 2011). The one scaled experiment indicated that a pile could be driven a meter in about a minute with vibratory methods (Remspecher *et al.* 2019).
6) Vibratory piles were modeled as omnidirectional point sources.
7) Impact driven piles modeled as a vertical line array.
8) The seabed structure described by Fugro USA Marine (2020) was assumed to be valid for the entire WEA.
9) Monthly mean sound velocity profiles were used to represent average conditions. On any given day, the SVP may differ from the modeled SVP, altering the acoustic propagation.
10) Source characteristics for both monopiles and pin piles were derived from predictions and measurements made at other locations. The actual source spectrum produced during installation may differ from the modeled source spectrum.

5 ANIMAT MODELING

A separate AIM simulation was created and run for each combination of location and marine mammal and sea turtle species. Marine mammals and sea turtles were simulated by creating animats that were programmed with behavioral values describing dive depth, surfacing and dive durations, swimming speed, and course change relevant to each marine mammal species. A minimum and maximum value for each of these parameters was specified (Appendix B, Table B-1), with these data having been extracted from relevant scientific literature. The model simulation area was delineated by four boundaries composed of latitude (37.5°to 39°N) and longitude (73.75° to 75.5°W) lines. These boundaries extended one degree of latitude or longitude beyond each modeling site to ensure 1) the region in which substantial behavioral reactions that might be anticipated was captured, and 2) an adequate number of animats would be modeled in all directions.

Animats were randomly distributed over the model simulation area. The modeled marine mammal and sea turtle animats were set to populate the simulation area with densities often higher than those estimated in the marine environment. This "over population" of the modeling environment ensures that the result of the simulation is not unduly influenced by the chance placement of a few simulated marine mammals. To obtain final exposure estimates, the modeled results are normalized by the ratio of the modeled animat density to the real-world marine mammal density estimate (MGEL, 2022). This allows for greater statistical power without overestimating exposure.

Modeling included a number of conservative assumptions. During AIM modeling, the animats were programmed to "reflect" off the boundaries of the model area and remain within the simulation area; the animat reflects back into the model simulation area at a 45° angle. This reflection maintains the appropriate density of animats since no animats are allowed to diffuse out of the simulation area. It is also a conservative factor in the modeling results since it keeps animats within the simulation area and available for additional acoustic exposure during the 24-hr simulation period. Since acoustic exposure accumulates over the 24-hr modeling period, the reflected animat may have a higher acoustic exposure than if it were considered as two separate animals. Although the migratory state of species is considered in terms of their potentially differing swim or dive parameters during migration, the animats for migrating species are not programmed differently since the duration of the model event is 24 hours and the duration of any single exposure estimate is no longer than three hours.

An AIM simulation consists of a user-specified number of steps forward in time at which the received sound level and three-dimensional position of the animat were recorded to calculate exposure estimates. The predicted sound received level is sampled by AIM every 30 seconds. Animats sample the entire water column, even in shallow waters, when a 30-second timestep is used in the AIM simulations. Histogram counts at 1-m intervals of the water column illustrate that an example harbor porpoise during a 24-hr simulation using a 30-second time step appropriately sample all depths (Figure 11).

For each AIM time step, an animat is moved according to the rules describing its behavior. At the end of each time step, each animat "evaluates" its environment, potentially including its three-dimensional location and water depth. If an environmental variable has exceeded the user-specified boundary value (e.g., water too shallow), then the animat will alter its course to react to the environment. These responses to the environment are entitled "aversions." There are several potential aversion variables that can be used to build an animats' behavioral pattern.

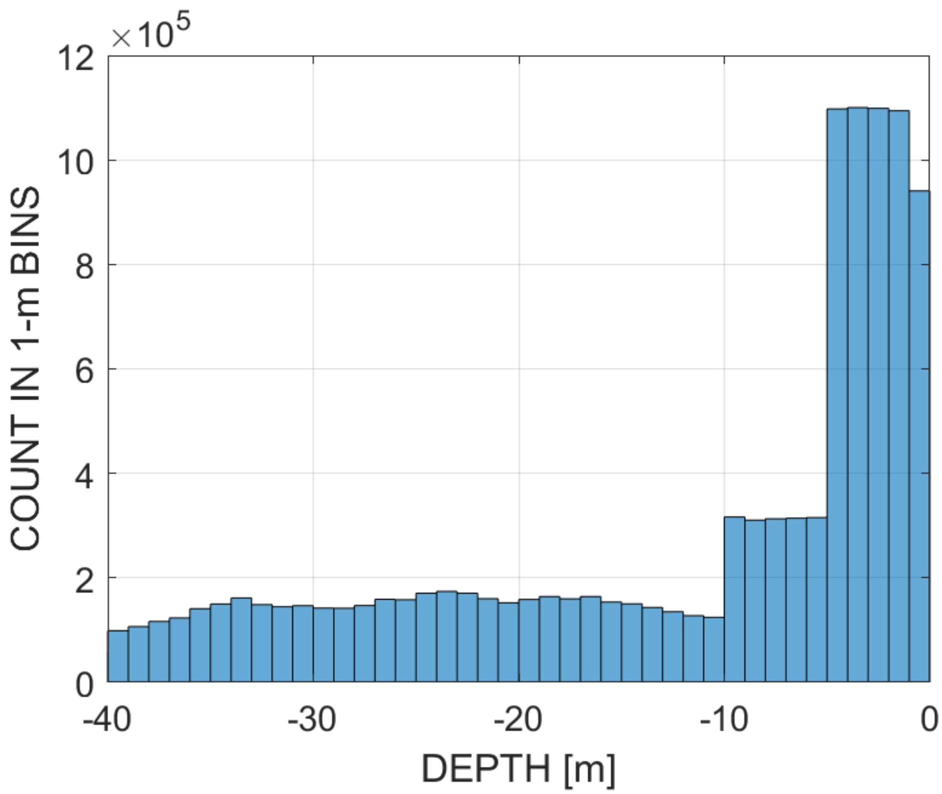

Figure 11. Histogram plot in 1-meter intervals showing the distribution of a harbor porpoise animat as it moves through the water column (from 0 to 40 meters water depth) during an AIM simulation using a 30-second time step.

5.1 Calculation of Exposure Estimates

To maximize sample size, AIM simulations are run with the source operating continuously for the entire modeling period. These results are then sampled to reflect the actual operating characteristics of the source. For example, to predict the exposures created by driving a monopile (nominally 2 hours), a 24-hour exposure history would be produced. Then multiple 2-hour time periods would be sequentially extracted from that simulation output (e.g., 0 to 2 hours, 2 to 4 hours). Thus, multiple sequential estimates were produced for each scenario, and the mean value of exposure levels were reported.

Furthermore, each simulation is populated with a far greater animat density than the real-world animal densities to increase sample size. The modeled animat density value was determined through a sensitivity analysis that examined the stability of the predicted estimate of exposure levels as a function of animat density. Therefore, the modeled density was determined to accurately capture the full distributional range of probabilities of exposure for the proposed activity.

The acoustic exposure history for each animat was analyzed to produce the metrics of maximum root- mean square sound pressure level, cumulative sound exposure level, and peak sound pressure level. These modeled exposure estimates were then scaled by the ratio of real-world density estimates to the modeled animat density. The local animal density was the average monthly density within the wind lease area buffered by 5.25 km on each side (Table 5). This buffer area was based on the greatest distance to a regulatory threshold for marine mammals, assuming 10 dB of sound mitigation. The greatest distance, 5.25 km, was the range to the behavioral threshold for the installation of 11-m monopiles.

The application of the real-world density and density scaling results in the predicted number of acoustic exposures for each species or species group for each pile driven. Summing the number of exposures above the relevant threshold provides an estimate of the number of regulatory exposures. The density-scaled acoustic exposures provided the per-foundation daily exposure estimates and were determined by month using the corresponding monthly animal density. These daily exposures were multiplied by the planned number of piles each month to determine the total number of exposures for the entire construction period.

5.2 Summary of Animat Modeling Assumptions

The following modeling assumptions were made for the impulsive and non-impulsive scenarios for animat modeling and exposure estimation:

1) Marine mammal and sea turtle species presence and densities were extracted from MGEL (2022), DoN (2007), and Barco *et al.* (2018), which represent the best available information.
2) Animats (virtual representations of animals) were assumed to remain in the vicinity of the pile driving location (1.75° longitude x 1.5° latitude box centered on the modeling location).
3) Water depth restrictions were set as appropriate for the animats of each species or species groups but no other behavioral aversions were applied.

6 RESULTS

6.1 Impulsive Scenarios

6.1.1 Monopile Foundation Installation (11-m Pile)

6.1.1.1 Ranges to Regulatory Thresholds

Ranges to the regulatory thresholds for the installation of 11-m monopiles have been calculated (Tables 14 to 16). The ranges to the regulatory behavior thresholds for the unmitigated pile driving of an 11-m monopile were 13,650 m, 27,750 m, and 3,100 m for marine mammals, fishes, and sea turtles, respectively (Table 16). The range to the thresholds for PTS injury to marine mammals was greatest for the LF cetaceans, with 8,850 m as the unmitigated range to the SEL threshold (Table 14). The range to injury thresholds for LF cetaceans does not vary from species to species because they are calculated from the sound fields directly, and animat-based range determinations were not employed. The ranges to the unmitigated SEL injury thresholds for fish ranged from 250 m to 15,300 m (Table 15) and for sea turtles was 1,400 m (Table 14). It is important to note the ranges to SEL thresholds assume that animals remain in the area for the total duration of the driving of a pile, and therefore, can be considered conservative estimates.

Table 14. Acoustic ranges (m) (95th percentile) to PTS regulatory threshold levels for marine mammals (NMFS 2018) and sea turtles (DoN 2017) during two hours of pile driving of an 11-m monopile in May assuming various sound reduction levels.

Hearing Group	Threshold	Acoustic Ranges (m) for Mitigation Levels (dB)		
		0	10	20
Low Frequency Cetaceans	SEL 183 dB ($L_{E,LF,24h}$)	8850	2900	650
	Peak 219 dB ($L_{pk,0\text{-}pk,flat}$)	100	<50	<50
Mid-Frequency Cetaceans	SEL 185 dB ($L_{E,MF,24h}$)	<50	<50	<50
	Peak 230 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
High Frequency Cetaceans	SEL 155 dB ($L_{E,HF,24h}$)	700	250	50
	Peak 202 dB ($L_{pk,0\text{-}pk,flat}$)	750	200	50
Phocid Pinnipeds Underwater	SEL 185 dB ($L_{E,PW,24h}$)	700	100	0
	Peak 218 dB ($L_{pk,0\text{-}pk,flat}$)	100	<50	<50
Sea Turtles	SEL 204 dB ($L_{E,TU,24h}$)	1400	250	0
	Peak 232 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50

Table 15. Acoustic ranges (m) (95th percentile) to injury and TTS thresholds for fish (Popper et al. 2014; FHWG 2008; GARFO 2019) for the installation of a single 11-m monopile modeled with a May SVP assuming 2 hours of installation.

Fish Group	Reference	Threshold Type	Threshold	Acoustic Ranges (m) for Mitigation Levels (dB)		
				0	10	20
Fish: No swim bladder	Popper et al. (2014)	Mortality and Potential Mortal Injury	219 dB ($L_{E,flat,24h}$)	150	0	0
			213 dB ($L_{pk,0\text{-}pk,flat}$)	200	50	<50
		Recoverable Injury	216 dB ($L_{E,flat,24h}$)	250	0	0
			213 dB ($L_{pk,0\text{-}pk,flat}$)	200	50	<50
		TTS	186 dB ($L_{E,flat,24h}$)	12000	4500	1350
Fish: Swim bladder not involved in hearing	Popper et al. (2014)	Mortality and Potential Mortal Injury	210 dB ($L_{E,flat,24h}$)	750	150	0
			207 dB ($L_{pk,0\text{-}pk,flat}$)	400	100	<50
		Recoverable Injury	203 dB ($L_{E,flat,24h}$)	2000	450	100
			207 dB ($L_{pk,0\text{-}pk,flat}$)	400	100	<50
		TTS	186 dB ($L_{E,flat,24h}$)	12000	4500	100

Table 15. Acoustic ranges (m) (95th percentile) to injury and TTS thresholds for fish (Popper et al. 2014; FHWG 2008; GARFO 2019) for the installation of a single 11-m monopile modeled with a May SVP assuming 2 hours of installation.

Fish Group	Reference	Threshold Type	Threshold	Acoustic Ranges (m) for Mitigation Levels (dB)		
				0	10	20
Fish: Swim bladder involved in hearing	Popper et al. (2014)	Mortality and Potential Mortal Injury	207 dB ($L_{E,flat,24h}$)	1150	200	0
			207 dB ($L_{pk,0-pk,flat}$)	400	100	<50
		Recoverable Injury	203 dB ($L_{E,flat,24h}$)	2000	450	0
			207 dB ($L_{pk,0-pk,flat}$)	400	100	<50
		TTS	186 dB ($L_{E,flat,24h}$)	12000	4500	1350
Fish ≥2 grams	FHWG (2008)/ GARFO (2019)	Injury	187 dB ($L_{E,flat,24h}$)	10950	4000	1150
			206 dB ($L_{pk,0-pk,flat}$)	450	150	<50
Fish <2 grams	FHWG (2008)/ GARFO (2019)	Injury	183 dB ($L_{E,flat,24h}$)	15300	6150	2000
			206 dB ($L_{pk,0-pk,flat}$)	450	150	<50

Table 16. Acoustic ranges (m) (95th percentile) to behavioral thresholds for marine mammals (NOAA 2005), sea turtles (DoN 2017), and fishes (GARFO 2019) for the installation of a single 11-m monopile modeled with a May SVP.

Animal Group	Threshold	Acoustic Ranges (m) for Mitigation Levels (dB)		
		0	10	20
Fish	150 dB (L_{rms})	27750	13650	5250
Marine Mammals	160 dB (L_{rms})	13650	5250	1650
Sea Turtles	175 dB (L_{rms})	3100	850	150

6.1.1.2 Sound Maps for the 11-m Monopile

Plan views of the sound fields predicted for an unmitigated single strike on an 11-m monopile assuming a May SVP are provided (Figure 12), illustrating the maximum value in the water column. All predicted isopleths show evidence of bearing dependence. While there is variation, most isopleths show better propagation (greater distance to isopleths) in the offshore direction compared to cross shore and inshore propagation paths.

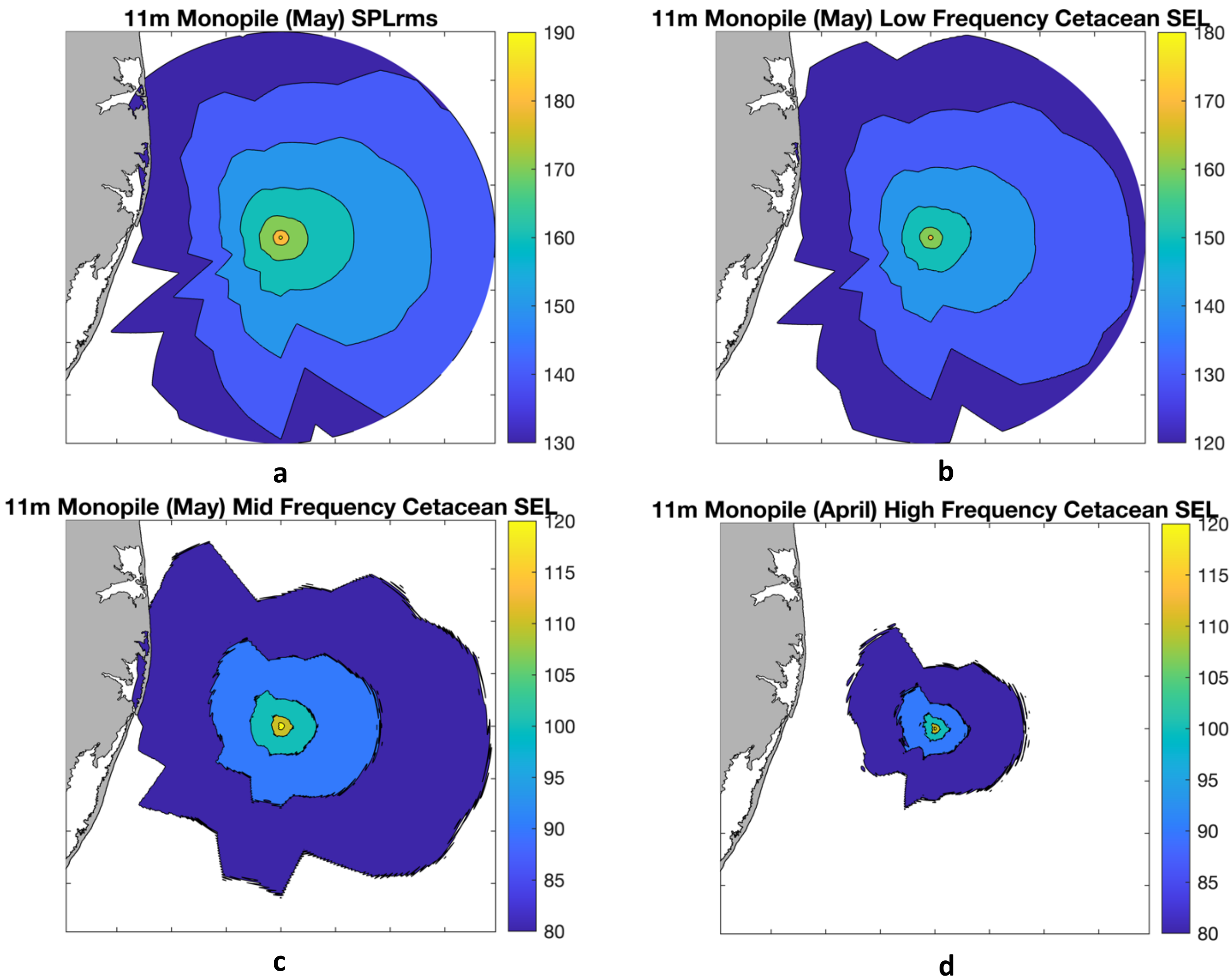

Figure 12. Acoustic propagation modeling results showing the expected sound field from a single strike at 4,400 kJ on an 11-m monopile, modeled using a May SVP. The maximum received level over depth is plotted to show the top-down view of the a) unweighted SPL and frequency-weighted single strike SEL (L_E (ss)) for the b) low frequency cetaceans, c) mid-frequency cetaceans, and d) high frequency cetaceans for the unmitigated pile driving of the 11-m monopile. The SEL sound fields have been weighted using the NMFS (2018) auditory weighting functions. The SPL sound levels are in dB re 1µPa while SEL values are in dB re 1µPa^{2}s. Map area is 100 km x 100 km.

6.1.1.3 Acoustic Exposure Tables for 11-m Monopile

The outputs of the animat modeling for marine mammals and sea turtles are presented in tables of the predicted numbers of animals exposed to levels exceeding regulatory thresholds for each of the three years of monopile driving activities based on 10 dB sound reduction level (Tables 17 and 18). Note that it is possible for low-frequency cetaceans to be exposed to cumulative SEL injury values at greater ranges than the range to the behavioral threshold. Such animals would be reported as SEL exposures and not as behavioral exposures, to prevent “double counting” animals. The animat exposure estimates are the product of the number of modeled exposures multiplied by the ratio of real-world density and model densities.

6.1.2 Skirt Pile Jacket Foundation Installation (3-m Pile)

6.1.2.1 Ranges to Regulatory Thresholds for 3-m Skirt Piles

The ranges to the injury thresholds for marine mammals, fishes, and sea turtles (Tables 19 to 21). The PTS SEL threshold for the 3-m skirt piles was greatest for the LF cetaceans, with a range of 5,500 m assuming four piles are installed in a day and no mitigation (Tables 20). The range to the injury thresholds (L_E *(cum)*) for fish and sea turtles ranged from 0 m to 9,050 m (Table 22). The ranges to the regulatory behavior thresholds for the pile driving of four 3-m skirt piles in a day without mitigation were 2,650 m, 9,250 m, and 200 m for marine mammals, fishes, and sea turtles, respectively (Tables 19, 20, and 21). It is important to note the ranges to SEL thresholds assume that animals remain in the area for the total duration of the driving of four piles, and therefore, can be considered conservative estimates.

6.1.2.2 Sound Maps for 3-m Pin Piles

Plan views of the sound fields predicted for an unmitigated single strike on a 3-m post-piled skirt pile assuming a May SVP are provided (Figure 13), illustrating the maximum value in the water column. All predicted isopleths show evidence of bearing dependence. All predicted isopleths show evidence of bearing dependence. The 160 dB SPL_{rms} isopleth (green-blue) has a radius of about 2.6 km.

6.1.2.3 Exposure Tables for 3-m Pin Piles

The outputs of the animat modeling are presented as tables of predicted numbers of marine mammal and sea turtle exposures exceeding regulatory thresholds for the installation of 3-m skirt piles (Tables 22 and 23) in the buffered lease area annually for the three years of the Project’s construction period with the application of 10 dB sound level reduction. The animat exposure estimates are the product of the number of modeled exposures multiplied by the ratio of real-world density and model density.

Table 17. Maximum annual injury (PTS; cumulative and peak sound exposure levels [SEL]) and behavior (sound pressure level [SPL]) acoustic exposure estimates of potentially affected marine mammals in the buffered Lease Area 0490 associated with the mitigated (10 dB sound level reduction) of pile driving of the 11-m monopiles during the three years of construction for the US Wind Maryland Offshore Wind Project. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Mammal Hearing Group	*Marine Mammal Species*	*Cumulative Injury SEL Acoustic Exposures*			*Peak Injury SEL Acoustic Exposures*			*Behavioral SPL Acoustic Exposures*		
		Year 1	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
LF Cetaceans (LFC)	Fin whale	0.39	1.16	0.680	0.00	0.00	0.00	3.94	11.57	6.83
	Common Minke whale	0.49	5.55	1.11	0.0	0.0	0.0	2.96	33.31	6.66
	Humpback whale	0.42	1.55	0.67	0.00	0.00	0.00	1.63	6.02	2.62
	North Atlantic right whale	0.01	0.05	0.02	0.00	0.00	0.00	0.06	0.24	0.08
	Sei whale	0.01	0.12	0.02	0.00	0.00	0.00	0.11	0.83	0.17
MF Cetaceans (MFC)	Atlantic spotted dolphin	0.00	0.00	0.00	0.00	0.00	0.00	14.07	38.86	50.75
	Blainville's beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Common bottlenose dolphin	0.00	0.00	0.00	0.00	0.00	0.00	846.85	2320.67	1711.04
	Cuvier's beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gervais' beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Killer whale	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.22	0.15
	Long-finned pilot whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pantropical spotted dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.45	0.31
	Risso's dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.79	4.33	1.94
	Rough toothed dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.11	0.08
	Short-beaked common dolphin	0.00	0.00	0.00	0.00	0.00	0.00	28.63	233.12	96.48
	Short-finned pilot whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sperm Whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Striped dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.45	0.31
	True's beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 17. Maximum annual injury (PTS; cumulative and peak sound exposure levels [SEL]) and behavior (sound pressure level [SPL]) acoustic exposure estimates of potentially affected marine mammals in the buffered Lease Area 0490 associated with the mitigated (10 dB sound level reduction) of pile driving of the 11-m monopiles during the three years of construction for the US Wind Maryland Offshore Wind Project. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Mammal Hearing Group	*Marine Mammal Species*	*Cumulative Injury SEL Acoustic Exposures*			*Peak Injury SEL Acoustic Exposures*			*Behavioral SPL Acoustic Exposures*		
		Year 1	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
HF Cetaceans (HFC)	Harbor porpoise	0.00	0.00	0.00	0.00	1.19	0.01	0.03	15.83	0.08
	Dwarf sperm whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pygmy sperm whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phocid Pinnipeds Underwater (PW)	Harbor seal	0.00	0.00	0.00	0.00	0.00	0.00	12.37	162.15	20.77
	Gray seal	0.00	0.00	0.00	0.00	0.00	0.00	5.50	72.17	9.25

Table 18. Maximum annual injury (cumulative and peak sound exposure levels [SEL]) and behavioral acoustic exposure estimates (sound pressure level [SPL]) of sea turtles associated with the mitigated (10 dB sound level reduction) pile driving of 11-m monopiles in the buffered lease area during the three years of construction for the US Wind Maryland Offshore Wind Project. Individuals are only reported once; animats receiving injury exposures are not reported as behavioral exposures.

Sea Turtle Species	***Cumulative Injury SEL Exposures***			***Peak Injury SEL Exposures***			***Behavioral SPL Exposures***		
	Year 1	***Year 2***	***Year 3***	***Year 1***	***Year 2***	***Year 3***	***Year 1***	***Year 2***	***Year 3***
Green turtle (Hardshelled Guild)	0	0	0	0	0	0	14.36	41.19	30.65
Kemp's Ridley turtle	0	0	0	0	0	0	0.75	1.97	1.37
Leatherback turtle	0	0	0	0	0	0	7.71	22.11	16.45
Loggerhead turtle (DoN 2007)	0	0	0	0	0	0	21.93	63.97	47.71
Loggerhead turtle (Barco et al. 2018*)	0	0	0	0	0	0	196.94	803.62	495.17

*For the loggerhead turtle, the spring and summer seasonal density breakdowns derived from the DoN (2007) and Barco et al. 2018 do not represent the same months. The DoN (2007) spring density included May while the summer density included June to August; the Barco et al. (2018) spring density included May to June and summer included July to August.

Table 19. Acoustic ranges (m) (95th percentile) to PTS regulatory threshold levels for marine mammals (NMFS 2018) and sea turtles (DoN 2017) during 8 hours of pile driving to install four 3-m skirt piles for the OSS jacket foundation in May assuming various sound reduction levels.

Hearing Group	Threshold	Acoustic Ranges (m) for Mitigation Levels (dB)		
		0	10	20
Low Frequency Cetaceans (LFC)	SEL 183 dB ($L_{E,LF,24h}$)	5500	1400	200
	Peak 219 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
Mid-Frequency Cetaceans (MFC)	SEL 185 dB ($L_{E,MF,24h}$)	0	0	0
	Peak 230 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
High Frequency Cetaceans (HFC)	SEL 155 dB ($L_{E,HF,24h}$)	300	100	0
	Peak 202 dB ($L_{pk,0\text{-}pk,flat}$)	150	<50	<50
Phocid Pinnipeds Underwater (PW)	SEL 185 dB ($L_{E,PW,24h}$)	350	50	0
	Peak 218 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
Sea Turtles (TU)	SEL 204 dB ($L_{E,TU,24h}$)	450	50	0
	Peak 232 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50

Table 20. Acoustic ranges (m) (95th percentile) to injury and TTS thresholds for fish (Popper et al. 2014; FHWG 2008, GARFO 2019) resulting from 8 hours of pile driving to install four 3-m skirt piles for the OSS jacket foundation in May assuming various sound reduction levels.

Fish Group	*Reference*	*Threshold Type*	*Threshold*	*Acoustic Ranges (m) for Mitigation Levels (dB)*		
				0	*10*	*20*
Fish: No swim bladder	Popper et al. (2014)	Mortality and Potential Mortal Injury	219 dB ($L_{E,flat,24h}$)	0	0	0
			213 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		Recoverable Injury	216 dB ($L_{E,flat,24h}$)	50	0	0
			213 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		TTS	186 dB ($L_{E,flat,24h}$)	6500	1750	300

Table 20. Acoustic ranges (m) (95th percentile) to injury and TTS thresholds for fish (Popper et al. 2014; FHWG 2008, GARFO 2019) resulting from 8 hours of pile driving to install four 3-m skirt piles for the OSS jacket foundation in May assuming various sound reduction levels.

Fish Group	*Reference*	*Threshold Type*	*Threshold*	*Acoustic Ranges (m) for Mitigation Levels (dB)*		
				0	*10*	*20*
Fish: Swim bladder not involved in hearing	Popper et al. (2014)	Mortality and Potential Mortal Injury	210 dB ($L_{E,flat,24h}$)	150	0	0
			207 dB ($L_{pk,0-pk,flat}$)	50	<50	<50
		Recoverable Injury	203 dB ($L_{E,flat,24h}$)	500	50	0
			207 dB ($L_{pk,0-pk,flat}$)	50	<50	<50
		TTS	186 dB ($L_{E,flat,24h}$)	6500	1750	300
Fish: Swim bladder involved in hearing	Popper et al. (2014)	Mortality and Potential Mortal Injury	207 dB ($L_{E,flat,24h}$)	250	50	0
			207 dB ($L_{pk,0-pk,flat}$)	50	<50	<50
		Recoverable Injury	203 dB ($L_{E,flat,24h}$)	500	50	0
			207 dB ($L_{pk,0-pk,flat}$)	50	<50	<50
		TTS	186 dB ($L_{E,flat,24h}$)	6500	1750	300
Fish ≥2 grams	FHWG (2008)/ GARFO (2019)	Injury	187 dB ($L_{E,flat,24h}$)	5650	1500	250
			206 dB ($L_{pk,0-pk,flat}$)	50	<50	<50
Fish <2 grams	FHWG (2008)/ GARFO (2019)	Injury	183 dB ($L_{E,flat,24h}$)	9050	2600	500
			206 dB ($L_{pk,0-pk,flat}$)	50	<50	<50

Table 21. Acoustic ranges (m) (95th percentile) to behavioral thresholds for marine mammals (NOAA 2005), sea turtles (DoN 2017), and fishes (GARFO 2019) resulting from 8 hours of pile driving to install four 3-m skirt piles for the OSS jacket foundation in May assuming various sound reduction levels.

Animal Group	***Threshold***	***Acoustic Ranges (m) for Mitigation Levels (dB)***		
		0	***10***	***20***
Fish	150 dB (L_{rms})	9250	2650	500
Marine Mammals	160 dB (L_{rms})	2650	500	50
Sea Turtles	175 dB (L_{rms})	200	0	0

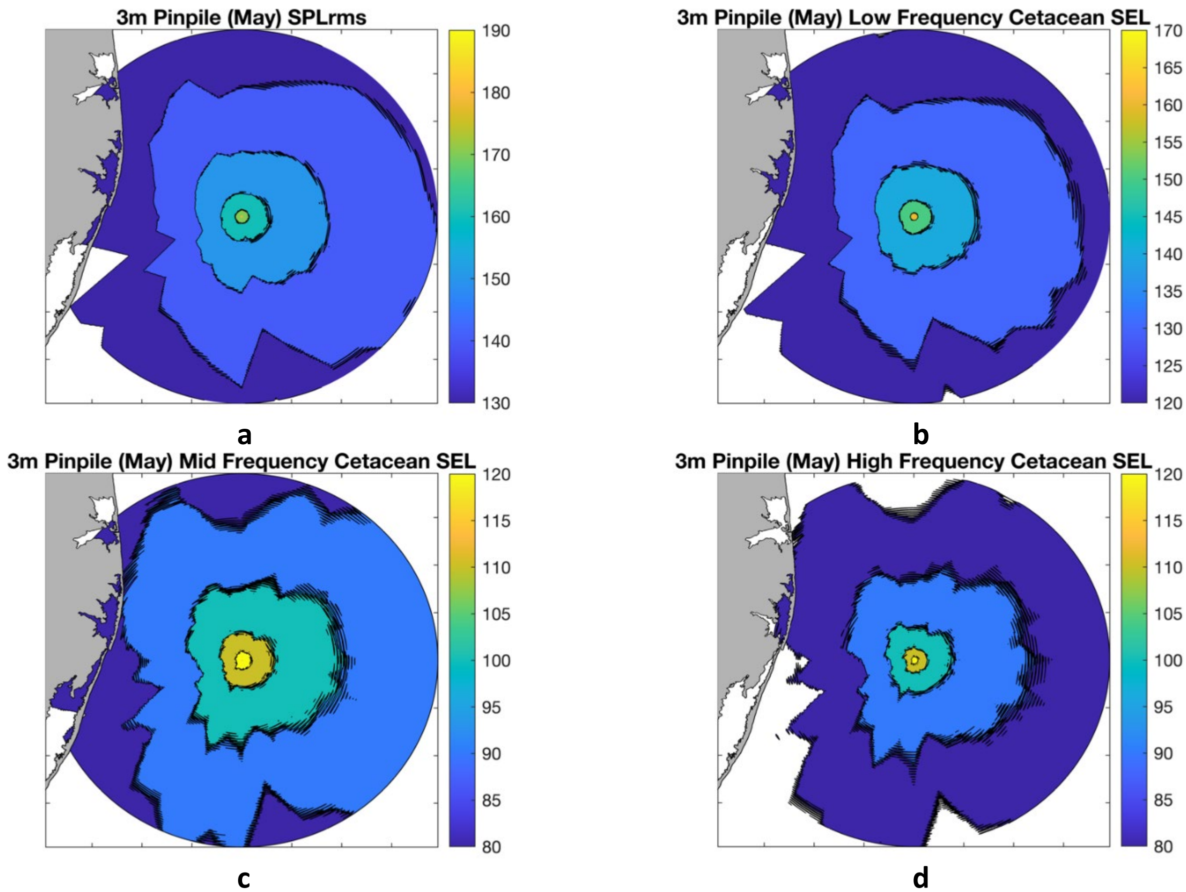

Figure 13. Acoustic propagation modeling results showing the expected sound field from a single strike at 1,500 kJ on a 3-m post-piled skirt pile, modeled using a May SVP. The maximum received level over depth is plotted to show the top-down view of the a) unweighted SPL and frequency-weighted single strike SEL (L_E (ss)) for the b) low frequency cetaceans, c) mid-frequency cetaceans, and d) high frequency cetaceans for the unmitigated pile driving of the 11-m monopile. The SEL sound fields have been weighted using the NMFS (2018) auditory weighting functions. The SPL sound levels are in dB re 1µPa while SEL values are in dB re 1µPa^2 s. Map area is 100 km x 100 km.

Table 22. Maximum injury (PTS; cumulative and peak sound exposure levels [SEL]) and behavior (sound pressure level [SPL]) acoustic exposure estimates of potentially affected marine mammals and sea turtles in the buffered lease area associated with the mitigated (10 dB sound level reduction) impact pile driving of 3-m skirt piles during the three years of construction for the US Wind Maryland Offshore Wind Project. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Mammal Hearing Group	*Marine Mammal Species*	*Cumulative Injury SEL Acoustic Exposures*			*Peak Injury SEL Acoustic Exposures*			*Behavioral SPL Acoustic Exposures*		
		Year 1	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
Low Frequency Cetaceans (LFC)	Fin whale	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.03
	Common Minke whale	0.00	0.00	0.00	0.0	0.0	0.0	0.04	0.08	0.04
	Humpback whale	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
	North Atlantic right whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sei whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mid-frequency Cetaceans (MFC)	Atlantic spotted dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.35	0.17
	Blainville's beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Common bottlenose dolphin	0.00	0.00	0.00	0.00	0.00	0.00	9.53	19.06	9.53
	Cuvier's beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gervais' beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Killer whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Long-finned pilot whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pantropical spotted dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Risso's dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01
	Rough toothed dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Short-beaked common dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.57	1.14	0.57
	Short-finned pilot whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sperm whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Striped dolphin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	True's beaked whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 22. Maximum injury (PTS; cumulative and peak sound exposure levels [SEL]) and behavior (sound pressure level [SPL]) acoustic exposure estimates of potentially affected marine mammals and sea turtles in the buffered lease area associated with the mitigated (10 dB sound level reduction) impact pile driving of 3-m skirt piles during the three years of construction for the US Wind Maryland Offshore Wind Project. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Mammal Hearing Group	Marine Mammal Species	Cumulative Injury SEL Acoustic Exposures			Peak Injury SEL Acoustic Exposures			Behavioral SPL Acoustic Exposures		
		Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
High Frequency Cetaceans (HFC)	Harbor porpoise	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dwarf sperm whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pygmy sperm whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phocid Pinnipeds Underwater (PW)	Harbor seal	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.11	0.06
	Gray seal	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.03

Table 23. Maximum injury (cumulative and peak sound exposure levels [SEL]) and behavioral (sound pressure level [SPL]) acoustic exposure estimates for sea turtles in the buffered lease area associated with mitigated (10 dB sound level reduction) impact pile driving of 3-m skirt piles during the three years of construction for the US Wind Maryland Offshore Wind Project. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Sea Turtle Species	*Cumulative Injury SEL Exposures*			*Peak Injury SEL Exposures*			*Behavioral SPL Exposures*		
	Year 1	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
Green turtle (Hardshelled Guild)	0	0	0	0	0	0	0	0	0
Kemp's Ridley turtle	0	0	0	0	0	0	0	0	0
Leatherback turtle	0	0	0	0	0	0	0	0	0
Loggerhead turtle (DoN 2007)	0	0	0	0	0	0	0	0	0
Loggerhead turtle (Barco et al. 2018)*	0	0	0	0	0	0	0	0	0

*For the loggerhead turtle, the spring and summer seasonal density breakdowns derived from the DoN (2007) and Barco et al. 2018 do not represent the same months. The DoN (2007) spring density included May while the summer density included June to August; the Barco et al. (2018) spring density included May to June and summer included July to August.

6.1.3 Pin Pile Foundation Installation (1.8-m Pile)

6.1.3.1 Ranges to Regulatory Thresholds for 1.8-m Pin Piles

The ranges to the regulatory thresholds for marine mammals, fishes, and sea turtles for the installation of 1.8-m pin piles by impact pile driving were derived (Tables 24 to 26). The range to the injury thresholds for marine mammals for the 1.8-m pin piles was greatest for the LF cetaceans, with a range for the PTS SEL threshold of 500 m assuming three piles are installed in a day and no mitigation (Table 24). The range to the injury thresholds (*L_E (cum)*) for fish and sea turtles ranged up to 950 m (Table s 24 and 25). The ranges to the regulatory behavior thresholds for the pile driving of three 1.8-m pin piles in a day without mitigation were 750 m, 3,300 m, and 50 m for marine mammals, fishes, and sea turtles, respectively (Tables 26).

Table 24. Acoustic ranges to PTS thresholds for marine mammals (NMFS 2018) and sea turtles (DoN 2017) for the impact pile driving installation of three 1.8-m post-piled pin piles for a jacket foundation modeled with a May SVP. The installation was modeled assuming 3,000 total hammer strikes at 500 kJ for a total of 360 minutes assuming various sound reduction levels.

Hearing Group	*Threshold*	*Acoustic Ranges (m) for Mitigation Levels (dB)*		
		0	*10*	*20*
Low Frequency Cetacean (LFC)	SEL 183 dB ($L_{E,LF,24h}$)	500	50	0
	Peak 219 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
Mid-Frequency Cetacean (MFC)	SEL 185 dB ($L_{E,MF,24h}$)	0	0	0
	Peak 230 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	0
High Frequency Cetacean (HFC)	SEL 155 dB ($L_{E,HF,24h}$)	0	0	0
	Peak 202 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
Phocid Pinniped Underwater (PW)	SEL 185 dB ($L_{E,PW,24h}$)	0	0	0
	Peak 218 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
Turtle (TU)	SEL 204 dB ($L_{E,TU,24h}$)	0	0	0
	Peak 232 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	0

Table 25. Acoustic ranges to injury and TTS thresholds for fish (Popper et al. 2014; FHWG 2008; GARFO 2019) for the impact pile driving installation of three 1.8-m post-piled pin piles for a jacket foundation modeled with a May SVP. The installation was modeled assuming 3,000 total hammer strikes at 500 kJ for a total of 360 minutes assuming various sound reduction levels.

Fish Group	***Reference***	***Threshold Type***	***Threshold***	***Acoustic Ranges (m) for Mitigation Levels (dB)***		
				0	***10***	***20***
Fish: No swim bladder	Popper et al. (2014)	Mortality and Potential Mortal Injury	219 dB ($L_{E,flat,24h}$)	0	0	0
			213 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		Recoverable Injury	216 dB ($L_{E,flat,24h}$)	0	0	0
			213 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		TTS	186 dB ($L_{E,flat,24h}$)	600	50	0
Fish: Swim bladder not involved in hearing	Popper et al. (2014))	Mortality and Potential Mortal Injury	210 dB ($L_{E,flat,24h}$)	0	0	0
			207 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		Recoverable Injury	203 dB ($L_{E,flat,24h}$)	0	0	0
		Recoverable Injury	207 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		TTS	186 dB ($L_{E,flat,24h}$)	600	50	0
Fish: Swim bladder involved in hearing	Popper et al. (2014)	Mortality and Potential Mortal Injury	207 dB ($L_{E,flat,24h}$)	0	0	0
			207 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		Recoverable Injury	203 dB ($L_{E,flat,24h}$)	0	0	0
			207 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
		TTS	186 dB ($L_{E,flat,24h}$)	600	50	0
Fish ≥2 grams	FHWG (2008)	Injury	187 dB ($L_{E,flat,24h}$)	500	50	0
			206 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50
Fish <2 grams	FHWG (2008)	Injury	183 dB ($L_{E,flat,24h}$)	950	150	0
			206 dB ($L_{pk,0\text{-}pk,flat}$)	<50	<50	<50

***Table 26. Acoustic ranges to behavioral thresholds for marine mammals (NOAA 2005), sea turtles (DoN 2017), and fishes (GARFO 2019) for the impact pile driving installation of three 1.8-m post-piled pin piles for a jacket foundation modeled with a May SVP* assuming various sound reduction levels.**

Animal Group	*Threshold*	*Acoustic Ranges (m) for Mitigation Levels (dB)*		
		0	*10*	*20*
Fish	150 dB (L_{rms})	3300	750	100
Marine Mammals	160 dB (L_{rms})	750	100	0
Sea Turtles	175 dB (L_{rms})	50	0	0

6.1.3.2 Sound Maps for 1.8-m Pin Piles

To illustrate the maximum sound level in the water column, plan views of the sound fields predicted for an unmitigated single strike on a 1.8-m pin pile assuming a May SVP have been prepared (Figure 14). All predicted isopleths show distinct evidence of bearing dependence. The maximum range of 750 km is estimated to the 160 dB re 1µPa isopleth (RMS SPL) sound field for the 1.8-m impact driven pin pile.

6.1.3.3 Exposure Tables for 1.8-m Pin Piles

The outputs of the animat modeling are presented as tables of predicted numbers of marine mammal and sea turtle exposures exceeding regulatory thresholds for the impact driving installation of 1.8-m pinpiles (Tables 27 and 28) in the buffered lease area annually for the three years of the Project's construction period with the application of 10 dB sound level reduction applied. The animat exposure estimates are the product of the number of modeled exposures multiplied by the ratio of real-world density and model density.

6.2 Non-Impulsive Scenarios

Vibratory pile driving of a 1.8-m pin pile was originally planned and modeled for the US Wind Offshore Maryland Wind Project. However, US Wind decided to forego vibratory pile driving of the 1.8-m pin piles planned for the installation of the Met Tower in favor of installing the pin piles by impact pile driving. Since the vibratory analysis was completed, the information on the vibratory pile driving modeling has been included for completeness.

6.2.1 Vibratory Pile Driving of a 1.8-m Pile

Note: This section has not been updated for this version of the report since vibratory pile driving was eliminated as a potential installation method of these pin piles. All analysis in this section is outdated and should not be considered in the final assessment of potential effect from the Project. The Met tower was assumed to be installed via vibratory pile driving of 1.8-m diameter piles. The predicted affected areas and exposure estimates are presented herein.

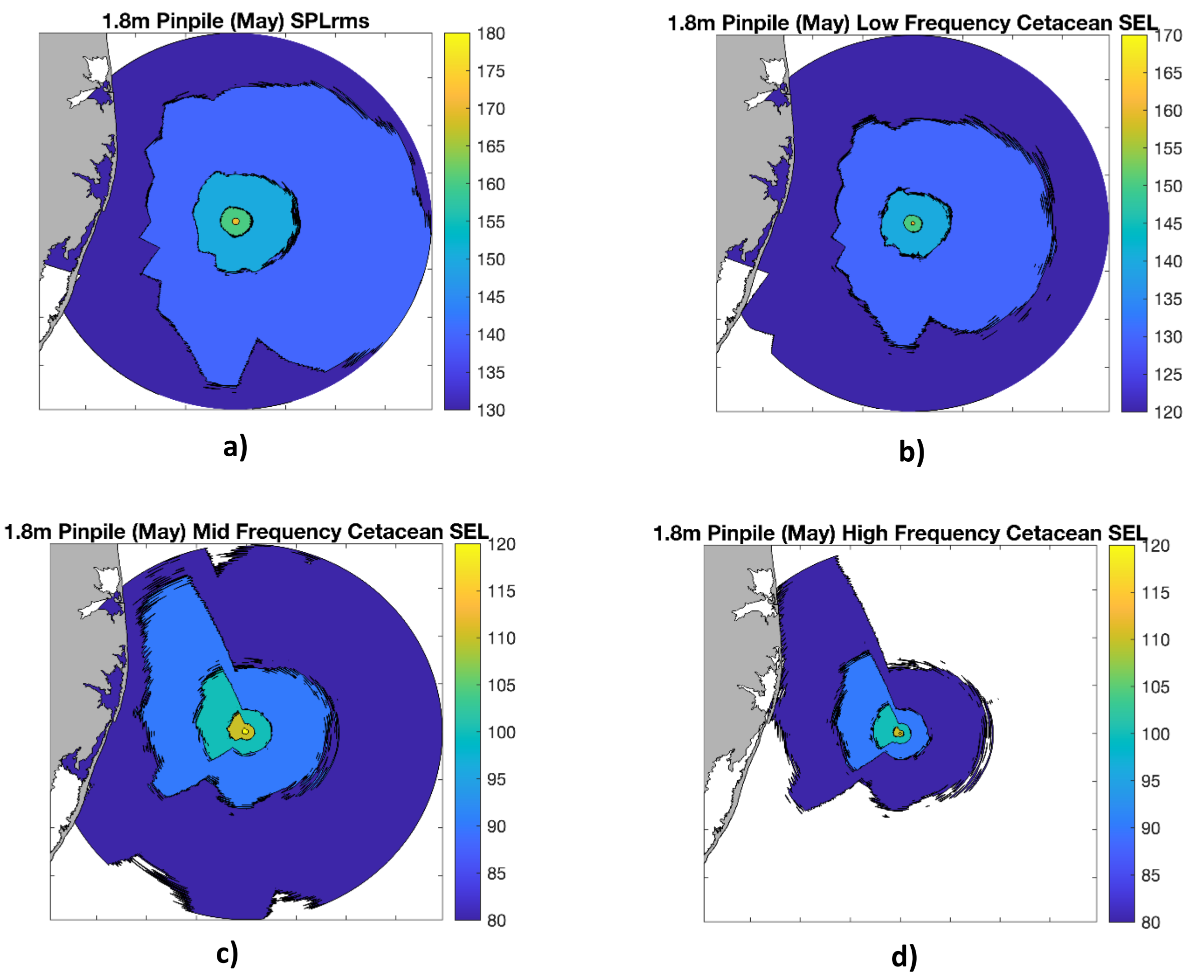

Figure 14. Acoustic propagation modeling results showing the expected sound field from a single strike at 500 kJ on a 1.8-m pin pile, modeled using a May SVP. The maximum received level over depth is plotted to show the top-down view of the a) unweighted SPL and frequency-weighted single strike SEL (L_E (ss)) for the b) low frequency cetaceans, c) mid-frequency cetaceans, and d) high frequency cetaceans for the unmitigated pile driving of the 11-m monopile. The SEL sound fields have been weighted using the NMFS (2018) auditory weighting functions. The SPL sound levels are in dB re 1µPa while SEL values are in dB re 1µPa^2 s. Map area is 100 km x 100 km.

Table 27. Maximum injury (PTS; cumulative and peak sound exposure levels [SEL]) and behavior (sound pressure level [SPL]) acoustic exposure estimates of potentially affected marine mammals in the buffered lease area associated with the mitigated (10 dB sound level reduction) impact pile driving of 1.8-m pin piles during the three years of construction for the US Wind Maryland Offshore Wind Project (Met Tower 1.8-m pin piles only installed in Year 2). Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Mammal Hearing Group	*Marine Mammal Species*	*Cumulative Injury SEL Acoustic Exposures*			*Peak Injury SEL Acoustic Exposures*			*Behavioral SPL Acoustic Exposures*		
		Year 1	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
Low Frequency Cetaceans	Fin whale		0.00			0.00			0.01	
	Common Minke whale		0.00			0.00			0.01	
	Humpback whale		0.00			0.00			0.01	
	North Atlantic right whale		0.00			0.00			0.00	
	Sei whale		0.00			0.00			0.00	
Mid Frequency Cetaceans	Atlantic spotted dolphin		0.00			0.00			0.00	
	Blainville’s beaked whale		0.00			0.00			0.00	
	Common bottlenose dolphin		0.00			0.00			1.91	
	Cuvier’s beaked whale		0.00			0.00			0.00	
	Gervais’ beaked whale		0.00			0.00			0.00	
	Killer whale		0.00			0.00			0.00	
	Long-finned pilot whale		0.00			0.00			0.00	
	Pantropical spotted dolphin		0.00			0.00			0.00	
	Risso's dolphin		0.00			0.00			0.00	
	Rough toothed dolphin		0.00			0.00			0.00	
	Short-beaked common dolphin		0.00			0.00			0.18	
	Short-finned pilot whale		0.00			0.00			0.00	
	Sperm Whale		0.00			0.00			0.00	
	Striped dolphin		0.00			0.00			0.00	
	True’s beaked whale		0.00			0.00			0.00	

Table 27. Maximum injury (PTS; cumulative and peak sound exposure levels [SEL]) and behavior (sound pressure level [SPL]) acoustic exposure estimates of potentially affected marine mammals in the buffered lease area associated with the mitigated (10 dB sound level reduction) impact pile driving of 1.8-m pin piles during the three years of construction for the US Wind Maryland Offshore Wind Project (Met Tower 1.8-m pin piles only installed in Year 2). Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Mammal Hearing Group	Marine Mammal Species	Cumulative Injury SEL Acoustic Exposures			Peak Injury SEL Acoustic Exposures			Behavioral SPL Acoustic Exposures		
		Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
High Frequency Cetaceans	Harbor porpoise		0.00			0.00			0.00	
	Dwarf sperm whale		0.00			0.00			0.00	
	Pygmy sperm whale		0.00			0.00			0.00	
Phocid Pinnipeds Underwater	Harbor seal		0.00			0.00			0.06	
	Gray seal		0.00			0.00			0.03	

* Densities of are not differentiated by species for either species of seals, so the takes estimated are the same for both species.

Table 28. Maximum injury (cumulative and peak sound exposure levels [SEL]) and behavioral (sound pressure level [SPL]) acoustic exposure estimates for sea turtles in the buffered lease area associated with mitigated (10 dB sound level reduction) pile driving of 1.8-m pin piles during the three years of construction for the US Wind Maryland Offshore Wind Project (MET Tower 1.8-m pin piles only installed in Year 2). Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Sea Turtle Species	*Cumulative Injury SEL Acoustic Exposures*			*Peak Injury SEL Acoustic Exposures*			*Behavioral SPL Acoustic Exposures*		
	Year 1	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
Green turtle (Hardshelled Guild)		0			0			0	
Kemp’s Ridley turtle		0			0			0	
Leatherback turtle		0			0			0	
Loggerhead turtle (DoN 2007)		0			0			0	
Loggerhead turtle (Barco et al. 2018)*		0			0			0	

*For the loggerhead turtle, the spring and summer seasonal density breakdowns derived from the DoN (2007) and Barco et al. 2018 do not represent the same months. The DoN (2007) spring density included May while the summer density included June to August; the Barco et al. (2018) spring density included May to June and summer included July to August.

6.2.1.1 Ranges to Regulatory Thresholds

The ranges to regulatory behavior thresholds for vibratory pile driving are 23,700 m for marine mammals, 1,400 m for fishes, and less than 50 m for sea turtles (Tables 29 through 31). The large disparity in the ranges to regulatory thresholds is due to the 120 dB re 1µPa SPL_{rms} threshold that NOAA Fisheries specifies for marine mammals and the fish behavioral threshold of 150 dB. The ranges to injury isopleths for marine mammals were all under 50 m (Table 29). The range to the injury thresholds (L_{E} *(cum)*) for fish and sea turtles were all less than 50 m (Table 31). It is important to note the ranges to SEL thresholds assume that animals remain in the area for the total duration of the driving of a pile, and therefore can be considered conservative estimates.

Table 29. Acoustic ranges (m) to regulatory threshold levels for marine mammals (NMFS 2018) during vibratory pile driving. Cumulative SELs (L_E(cum)) were determined assuming a one-hour period.

Marine Mammal Hearing Group	*Acoustic Ranges (m) for Non-impulsive Signals—Injury SEL (dB re 1µPa^2-s, 24 hr)*	*Acoustic Ranges (m) for NMFS Behavioral Threshold (120 dB re 1µPa, flat)*
Low-frequency (LF) cetaceans	< 50	23,700
Mid-frequency (MF) cetaceans	< 50	
High-frequency (HF) cetaceans	< 50	
Phocid pinnipeds underwater	< 50	

Table 30. Acoustic ranges (m) to regulatory behavioral threshold levels for fishes , and sea turtles (GARFO 2019) during vibratory pile driving. Cumulative SELs (L_E(cum)) were determined assuming a one-hour period.

Group	*Acoustic Ranges (m) for Behavioral Threshold (L_{rms} dB re 1µPa, flat)*
Fishes (< 2g)	1,400
Fishes (> 2g)	
Sea Turtles	< 50

Table 31. Acoustic ranges (m) to regulatory injury threshold levels for fishes and sea turtles (FHWG 2008, DoN 2017, GARFO 2019, Popper et al. 2014) during vibratory pile driving.

Group	*Acoustic Ranges (m) for Injury*	*Acoustic Ranges (m) for TTS*
Fishes without swim bladders	--	--
Fishes with swim bladder not involved in hearing	--	--
Fishes with swim bladder involved in hearing	< 50	300
Fishes (> 2g)	--	--
Fishes (< 2g)	--	--
Sea Turtles	< 50	< 50

6.2.1.2 Sound Maps for Vibratory Pile Driving

Plan views of the sound fields predicted for vibratory pile driving were derived for May (Figure 15), along the maximum value in the water column. Sound fields are shown in 10 dB steps by different colors. The color scales are far lower than the impact pile driving figures, reflecting the lower source level of vibratory pile drivers. Sub-plots a-d show the unweighted SPL_{rms} field and the three frequency-weighted SEL sound fields. All predicted isopleths show evidence of bearing dependence. While there is variation, most isopleths show better propagation (greater distance to isopleths) in the offshore direction compared to cross shore and inshore propagation paths.

6.2.1.3 Exposure Tables

The outputs of the animat modeling for marine mammals and sea turtles for vibratory driving of a 1.8-m pile are presented as tables of the predicted numbers of acoustic exposures to the regulatory thresholds for each taxon (Tables 32 through 34) for the May through November construction period. These values are for a single 1.8 m pile. The animat exposure estimates are the product of the number of modeled exposures multiplied by the ratio of real-world density and model density. The acoustic injury exposures (Table 32) were all small due to the small area encompassed within the acoustic thresholds, which is indicated by the acoustic ranges to thresholds being < 50 m (Table 29).

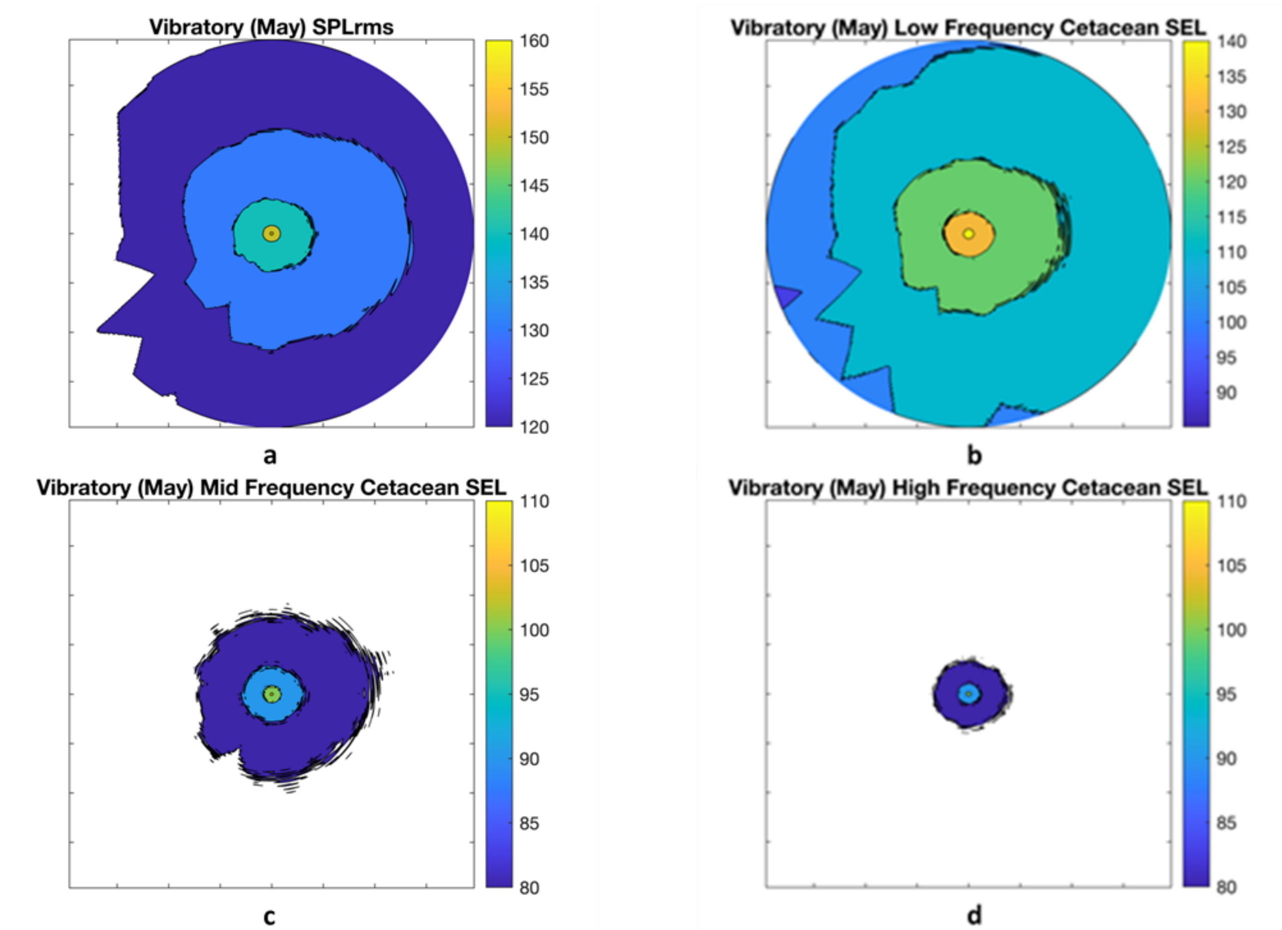

Figure 15. Sound maps for May showing the maximum over depth a) unweighted SPL, and frequency-weighted SEL (L_E (1 sec)) for the b) low frequency cetaceans, c) mid-frequency cetaceans, and d) high frequency cetaceans for vibratory pile driving. Note the change of scale between a and b, and c and d. The sound fields have been weighted using the NMFS (2018) auditory weighting functions. The SPL sound levels are in dB re 1µPa while SEL values are in dB re 1µPa^{2}s. Map area is 50 km x 50 km.

Table 32. Marine mammal injury acoustic exposure estimates (cumulative and peak sound exposure levels [SEL]) associated with unmitigated vibratory driving of a single 1.8-m pile for the US Wind Maryland Offshore Wind project's May through November construction period. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Species	*Acoustic Injury Exposures—PTS SEL Cumulative (cum) and Peak*													
	SEL_{cum}	*Peak*	*SEL_{cum}*	*Peak*	*SEL_{cum}*	*Peak*	*SEL_{cum}*	*Peak*	*SEL_{cum}*	*Peak*	*SEL_{cum}*	*Peak*	*SEL_{cum}*	*Peak*
	May		*June*		*July*		*August*		*September*		*October*		*November*	
Atlantic spotted dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Blainville's beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Common bottlenose dolphin (Western North Atlantic Northern Migratory Coastal stock)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Common bottlenose dolphin (Western North Atlantic Offshore stock)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Common dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Common minke whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 32. Marine mammal injury acoustic exposure estimates (cumulative and peak sound exposure levels [SEL]) associated with unmitigated vibratory driving of a single 1.8-m pile for the US Wind Maryland Offshore Wind project's May through November construction period. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Species	Acoustic Injury Exposures—PTS SEL Cumulative (cum) and Peak													
	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak
	May		June		July		August		September		October		November	
Cuvier's beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fin whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gervais' beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gray seal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Harbor porpoise	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Harbor seal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Humpback whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Killer whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Kogia spp.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Long-finned pilot whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
North Atlantic right whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pantropical spotted dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Risso's dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rough-toothed dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 32. Marine mammal injury acoustic exposure estimates (cumulative and peak sound exposure levels [SEL]) associated with unmitigated vibratory driving of a single 1.8-m pile for the US Wind Maryland Offshore Wind project's May through November construction period. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Species	Acoustic Injury Exposures—PTS SEL Cumulative ($_{cum}$) and Peak													
	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak	SEL_{cum}	Peak
	May		June		July		August		September		October		November	
Short-finned pilot whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sperm whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Striped dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
True's beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 33. Behavioral acoustic exposure estimates (in sound pressure level [SPL]) for marine mammals associated with unmitigated vibratory driving of a single 1.8-m pile for the US Wind Maryland Offshore Wind project's May through November construction period. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Species	Acoustic Behavioral Exposures (SPL dB re1 µPa)						
	May	June	July	August	September	October	November
Atlantic spotted dolphin	21.0648	34.0296	45.8683	88.6138	51.9005	54.9738	33.4467
Blainville's beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Common bottlenose dolphin (Western North Atlantic Northern Migratory Coastal stock)	193.8845	178.2312	204.6037	201.0544	205.7010	194.0619	194.0603
Common bottlenose dolphin (Western North Atlantic Offshore stock)	167.9475	359.9673	220.8499	219.9687	185.5843	190.7697	207.6147
Common dolphin	620.6116	440.8613	194.9750	125.3227	54.7351	146.7066	396.1885
Common minke whale	12.4770	4.4278	1.1178	0.7822	0.9047	1.7285	0.5048

Table 33. Behavioral acoustic exposure estimates (in sound pressure level [SPL]) for marine mammals associated with unmitigated vibratory driving of a single 1.8-m pile for the US Wind Maryland Offshore Wind project's May through November construction period. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Marine Species	***Acoustic Behavioral Exposures (SPL dB re1 µPa)***						
	May	***June***	***July***	***August***	***September***	***October***	***November***
Cuvier's beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fin whale	5.1843	6.4100	3.2280	1.9375	3.1405	3.9622	2.0555
Gervais' beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gray seal	93.1234	21.0595	7.2117	3.9450	7.2898	37.8792	51.3452
Harbor porpoise	12.5984	0.1203	0.0934	0.0828	0.0522	0.0611	0.1161
Harbor seal	93.1234	21.0595	7.2117	3.9450	7.2898	37.8792	51.3452
Humpback whale	3.5394	3.3751	0.5081	0.2950	0.7211	1.8434	1.4465
Killer whale	0.0687	0.0687	0.0687	0.0687	0.0687	0.0687	0.0687
Kogia spp.	0.4531	0.4531	0.4531	0.4531	0.4531	0.4531	0.4531
Long-finned pilot whale	36.1285	36.1285	36.1285	36.1285	36.1285	36.1285	36.1285
North Atlantic right whale	0.2568	0.0878	0.0345	0.0313	0.0534	0.1126	0.2430
Pantropical spotted dolphin	0.2080	0.2080	0.2080	0.2080	0.2080	0.2080	0.2080
Risso's dolphin	22.4895	53.4727	37.2022	30.5274	40.0493	34.2513	17.1061
Rough-toothed dolphin	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250
Short-finned pilot whale	36.1285	36.1285	36.1285	36.1285	36.1285	36.1285	36.1285
Sperm whale	0.1448	0.2663	0.2772	0.2531	0.2778	0.1495	0.1175
Striped dolphin	101.4889	101.4889	101.4889	101.4889	101.4889	101.4889	101.4889
True's beaked whale	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 34. Sea turtle injury (cumulative and peak sound exposure levels [SEL]) and behavioral (sound pressure level [SPL]) acoustic exposures associated with unmitigated vibratory driving of a single 1.8-m pile for the US Wind Maryland Offshore Wind project's May through November construction period. Individuals are only reported once; animals receiving injury exposures are not reported as behavioral exposures.

Sea Turtle Species	Cumulative Injury SEL Exposures			Peak Injury SEL Exposures			Behavioral SPL Exposures		
	Spring (May)	Summer (Jun-Aug)	Fall (Sep-Nov)	Spring (May)	Summer (Jun-Aug)	Fall (Sep-Nov)	Spring (May)	Summer (Jun-Aug)	Fall (Sep-Nov)
Green turtle (Hardshelled Guild)	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Kemp's Ridley turtle	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Leatherback turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Loggerhead turtle (DoN 2007)	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Loggerhead turtle (Barco et al. 2018)	1.51	1.51	1.51	0.00	0.00	0.00	0.00	0.00	0.00

7 TOTAL MARINE MAMMAL AND SEA TURTLE TAKE ESTIMATION FOR PILE DRIVING AND HRG SURVEY ACTIVITIES

The maximum number of annual, mitigated (10 dB sound level reduction) acoustic exposure estimates resulting impact pile driving (monopile and pin piled) and HRG surveys in the buffered Lease Area 0490 have been combined to derive the total annual number of marine mammals (Table 35) estimated for all three years during which construction and surveys are planned); HRG surveys are not included in the annual exposure estimates of sea turtles (Table 36). From these estimates, annual and total mitigated (10 dB sound reduction level) marine mammal Level A and Level B takes (harassment) have been estimated (Tables 38 and 39) for a subset of the modeled species with the consideration of group size (Table 37).

To investigate the applicability of group size for each marine mammal and sea turtle species requested, the protected species observer (PSO) survey data for the lease area from 2021 through 2022 were assessed, and the available data on the observed species and group sizes compiled (RPS 2023). For species not observed during the PSO surveys, other available literature sources were reviewed to obtain group size information. Group sizes of the remainder of group size information was obtained from DoN (2017b), which encompassed the lease area. Few species had group sizes larger than 10 individuals (Table 37). Group size has been utilized to derive both the requested annual and overall (full Project duration) Level A and Level B marine mammal takes (Tables 38 and 39). In recognition that only whole marine animals can be authorized for takes, the number of marine mammal (Level A or Level B takes of marine mammals) and sea turtle takes has been rounded upwards to the nearest integer. For consistency, group sizes of 1 were estimated for all sea turtle species (Table 40). Takes were derived according to the general guideline that if the acoustic exposure was less than the mean group size, then the requested take was the mean group size rounded to the nearest integer. Takes for some species were further adjusted based on the number and frequency of groups of animals anticipated to be encountered based on the PSO data (Table 38). The total number of marine mammal (Level A and Level B) takes (Table 39) and sea turtle takes (Table 40) are summations of the annual (per year) take estimates (Tables 38 and 36, respectively).

Table 35. Maximum Annual MMPA Level A and Level B Acoustic Estimates of Potentially Affected Marine Mammals in the Buffered Lease Area 0490 Resulting from Acoustic Exposure During Mitigated (10 dB Sound Reduction Level) Impact Pile Driving (Monopile, Skirt Pile, and Pin Pile) and HRG Survey Activities During Each Year of the Planned Construction and Survey Activities for the US Wind Offshore Wind Project.

Marine Mammal Hearing Group	Marine Mammal Species	Level A Harassment						Level B Harassment					
		Year 1		Year 2		Year 3		Year 1		Year 2		Year 3	
		Pile Driving	HRG Surveys	Pile Driving	HRG Surveys	Pile Driving	HRG Surveys	Pile Driving	HRG Surveys	Pile Driving	HRG Surveys	Pile Driving	HRG Surveys
Low Frequency Cetaceans	Fin whale	0.39		1.16	0	0.68	0	3.97		11.65	0.3	6.86	0.3
	Common Minke whale	0.49		5.55	0	1.11	0	3.00		33.39	1.2	6.70	1.2
	Humpback whale	0.42		1.55	0	0.67	0	2.54		9.33	0.3	4.06	0.3
	North Atlantic right whale	0.01		0.05	0	0.02	0	0.06		0.24	0.1	0.08	0.1
	Sei whale	0.01		0.12	0	0.02	0	0.11		0.83	0.1	0.17	0.1
Mid-Frequency Cetaceans	Atlantic spotted dolphin	0.00		0.00	0	0.00	0	14.24		39.21	2.3	50.92	2.3
	Blainville's beaked whale	0.00		0.00		0.00		0.00		0.00	0	0.00	0
	Common bottlenose dolphin	0.00		0.00	0	0.00	0	856.38		2341.64	32.1	1720.57	32.1
	Cuvier's beaked whale	0.00		0.00		0.00		0.00		0.00	0	0.00	0
	Gervais' beaked whale	0.00		0.00		0.00		0.00		0.00	0	0.00	0
	Killer whale	0.00		0.00		0.00		0.08		0.22	0	0.15	0
	Long-finned pilot whale	0.00		0.00	0	0.00	0	0.00		0.00	0.1	0.00	0.1
	Pantropical spotted dolphin	0.00		0.00	0	0.00	0	0.17		0.45	0	0.31	0
	Risso's dolphin	0.00		0.00	0	0.00	0	0.27		1.50	0.3	0.67	0.3
	Rough toothed dolphin	0.00		0.00		0.00		0.04		0.11	0	0.08	0
	Short-beaked common dolphin	0.00		0.00	0	0.00	0	29.20		234.44	12.4	97.06	12.4
	Short-finned pilot whale	0.00		0.00	0	0.00	0	0.00		0.00	0.1	0.00	0.1
	Sperm whale	0.00		0.00		0.00		0.00		0.00	0	0.00	0
	Striped dolphin	0.00		0.00		0.00		0.17		0.45	0	0.31	9
	True's beaked whale	0.00		0.00		0.00		0.00		0.00	0	0.00	0
High Frequency Cetaceans	Harbor porpoise	0.00		1.19	0	0.01	0	0.03		15.83	5.7	0.09	5.7
	Dwarf sperm whale	0.00		0.00		0.00		0.00		0.00	0	0.00	0
	Pygmy sperm whale	0.00		0.00		0.00		0.00		0.00	0	0.00	0
Pinnipeds in Water	Harbor seal	0.00		0.00	0	0.00	0	12.42		162.32	18.3	20.83	18.3
	Gray seal	0.00		0.00	0	0.00	0	5.53		72.25	8.2	9.27	8.2

Table 36. Maximum Total Acoustic Exposures for Injury (PTS; Cumulative and Peak Sound Exposure Levels [SEL]) and Behavior (Sound Pressure Level [SPL]) of Potentially Affected Sea Turtles in the Buffered Lease Area Resulting from Acoustic Exposure During Mitigated (10 dB Sound Reduction Level) Impact Pile Driving (Monopile and Pin Pile (3-m and1.8-m) During the Three Years of Construction Planned for the US Wind Maryland Offshore Wind Project.

Sea Turtle Species	*Cumulative Injury SEL Exposures*			*Peak Injury SEL Exposures*			*Behavioral SPL Exposures*		
	Year 1	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
Green turtle (Hard-Shelled Guild)	0.00	0.00	0.00	0.00	0.00	0.00	86.20	0.00	0.00
Kemp’s ridley turtle	0.00	0.00	0.00	0.00	0.00	0.00	4.09	0.00	0.00
Leatherback turtle	0.00	0.00	0.00	0.00	0.00	0.00	46.26	0.00	0.00
Loggerhead turtle (DoN 2007)	0.00	0.00	0.00	0.00	0.00	0.00	133.61	0.00	0.00
Loggerhead turtle (Barco et al. 2018)	0.00	0.00	0.00	0.00	0.00	0.00	1495.73	0.00	0.00

Table 37. Group size estimates for marine mammal species for which takes are requested.

Marine Mammal Hearing Group	Marine Mammal Species	Mean Group Size	Group Size References**
Low Frequency Cetaceans (LFC)	Fin whale	1.64	RPS, 2023
	Common Minke whale	1.00	RPS, 2023
	Humpback whale	1.95	RPS, 2023
	North Atlantic right whale	2.00	RPS, 2023
	Sei whale	1.00	RPS, 2023
Mid Frequency Cetaceans (MFC)	Atlantic spotted dolphin	5.89	RPS, 2023
	Common Bottlenose dolphin	11.53	RPS, 2023
	Pantropical spotted dolphin	4.33	RPS, 2023
	Risso's dolphin	8.47	DoN, 2017b
	Short-beaked common dolphin	7.00	RPS, 2023
	Pilot whales (both spp. combined)	26.00	DoN, 2017b
High Frequency Cetaceans (HFC)	Harbor porpoise	3.00	RPS, 2023
Pinnipeds Under Water (PW)	Gray seal	1.00	RPS, 2023
	Harbor seal*	1.00	RPS, 2023

*Neither DoN (2017b) nor RPS (2023) included group sizes for the harbor seal, so the RPS gray seal group size of 1.00 was used as a proxy for the harbor seal.
**No PSO data from the Smultea Associates PSO interim report were used for these group sizes as that report covered a time period in which no construction/HRG activities are planned.

Table 38. Annual MMPA Level A and Level B Takes of Potentially Affected Marine Mammals in the Buffered Lease Area Resulting from Acoustic Exposure During Mitigated (10 dB Sound Reduction Level) Impact Pile Driving (Monopile, Skirt Pile, and Pin Pile) and Micro-Siting HRG Survey Activities During Each of the Three Years of the Planned Construction and Survey Activities for the US Wind Offshore Wind Project (Takes Rounded Up to Nearest Integer).

Marine Mammal Hearing Group	Marine Mammal Species	Abundance*	Year 1				Year 2				Year 3			
			Level A Takes	Percent of Stock Affected	Level B Takes	Percent of Stock Affected	Level A Takes	Percent of Stock Affected	Level B Takes	Percent of Stock Affected	Level A Takes	Percent of Stock Affected	Level B Takes	Percent of Stock Affected
Low Frequency Cetaceans	Fin whale[a]	6,802	2	0.029	4	0.059	2	0.029	12	0.18	2	0.029	8	0.118
	Common Minke whale[b]	21,968	1	0.005	3	0.014	6	0.027	35	0.16	2	0.009	8	0.036
	Humpback whale[c]	1,396	2	0.143	3	0.215	2	0.143	10	0.72	2	0.072	5	0.358
	North Atlantic right whale[d]	338	0		2	0.592	0		2	0.59	0		2	0.592
	Sei whale[e]	6,292	1	0.016	1	0.016	1	0.016	1	0.02	1	0.016	1	0.016
Mid-Frequency Cetaceans	Atlantic spotted dolphin[f]	39,921	0		30	0.075	0		60	0.15	0		60	0.150
	Common Bottlenose dolphin**	62,851/ 6,639 (offshore/ coastal)	0		857	1.36 (off-shore)	0		2,374	2.64 (offshore)/ 10.74 (coastal)	0		1,753	0.42 (offshore)/ 22.46 (coastal)
	Pantropical spotted dolphin[d]	6,593	0		5	0.076	0		5	0.08	0		5	0.076
	Risso's dolphin[d]	35,215	0		9	0.026	0		9	0.03	0		9	0.026
	Short-beaked common dolphin	172,974	0		30	0.017	0		247	0.14	0		110	0.064
	Pilot whale (both species combined)[g]	39,215/ 28,924 (long-finned/short -finned)	0		26	0.066 (long-finned)/ 0.09 (short-finned)	0		26	0.066 (long-finned)/ 0.09 (short-finned)	0		26	0.066 (long-finned)/ 0.09 (short-finned)
High Frequency Cetaceans	Harbor porpoise[h]	95,543	0		3	0.003	3	0.003	22	0.02	3	0.001	9	0.009

Pinnipeds in Water	Gray seal	27,300	0		6	0.022	0		81	0.30	0		18	0.066
	Harbor seal	61,336	0		13	0.021	0		181	0.30	0		40	0.065

[*]Abundances: Hayes et al. 2023

**Two stocks of common bottlenose dolphin (the Western North Atlantic northern migratory coastal stock and the Western North Atlantic offshore stock) may occur in the Project area; both stocks are presented together here.

[a] Level A take was adjusted by mean group size in Years 1, 2 and 3.

[b] Level A take was adjusted by mean group size in Year 1.

[c] Level A take was adjusted by mean group size in Years 1, 2 and 3.

[d] Level B take was adjusted by mean group size in Years 1, 2 and 3.

[e] Level A and Level B take were adjusted by mean group size in Years 1, 2, and 3.

[f] Level B take adjusted based on expected groups in Year 1.~~-~~Level B take adjusted based on expected groups in Years 2 and 3~~.~~

[g] Level B take was adjusted by mean group size in Years 1, 2 and 3.

[h]~~-~~No Level A take is requested for Year 1. Level A take was adjusted by mean group size in Years 2 and 3. Level B take was adjusted by mean group size in Year 1. Level B take adjusted based on expected groups in~~,~~ Year 3

Table 39. Total MMPA Level A (PTS Cumulative and Peak) and Level B (Behavior) Harassment Takes Associated with Acoustic Exposure During Mitigated (10 dB Sound Reduction Level) Impact Pile Driving (Monopile, Skirt Pile, and Pin Pile) and HRG Survey Activities for the Full Duration (Three Years) of the Construction and Survey Periods for the US Wind Offshore Wind Project (Take Estimates Rounded Up to Nearest Integer).

Marine Mammal Hearing Group	Marine Mammal Species	Abundance[2]	MMPA Level A Harassment Requested	Percent of Stock Affected	MMPA Level B (Behavior) Harassment Requested	Percent of Stock Affected
Low Frequency Cetaceans	Fin whale	6,802	6	0.088	24	0.353
	Common minke whale	21,968	9	0.041	46	0.209
	Humpback whale	1,396	6	0.430	18	1.289
	North Atlantic right whale	338	0	0.000	6	1.775
	Sei whale	6,292	3	0.048	3	0.048
Mid-Frequency Cetaceans	Atlantic spotted dolphin	39,921	0	0.000	150	0.376
	Common Bottlenose dolphin[1]	69,490	0	0.000	4,984	7.17
	Pantropical spotted dolphin	6,593	0	0.000	15	0.228
	Risso's dolphin	35,215	0	0.000	27	0.077
	Short-beaked common dolphin	172,974	0	0.000	387	0.224
	Pilot whales (both species combined)	68,139	0	0.000	78	0.114
High Frequency Cetaceans	Harbor porpoise	95,543	6	0.006	34	0.036
Pinnipeds in Water	Gray seal	27,300	0	0.000	105	0.385
	Harbor seal	61,336	0	0.000	234	0.382

[1] Two stocks of common bottlenose dolphin (the Western North Atlantic northern migratory coastal stock and the Western North Atlantic offshore stock) may occur in the Project area; both stocks are presented together here.
[2] Abundances: Hayes et al. 2023

Table 40. Total Sea Turtle Takes Associated with Acoustic Exposure During Mitigated (10 dB Sound Reduction Level) Impact Pile Driving (Monopile, Skirt Pile, and Pin Pile) Activities for the Full Duration (Three Years) of the Construction and Survey Periods for the US Wind Offshore Wind Project (Take Estimates Rounded Up to Nearest Integer).

Sea Turtle Species	*Group Size*	*Abundance**	*PTS SEL Takes*	*Percent of Stock Taken*	*Behavioral Takes*	*Percent of Stock Affected*
Green turtle	1	167,424	0		87	0.052
Kemp's ridley turtle	1	248,307	0		5	0.002
Leatherback turtle	1	64,000	0		47	0.006
Loggerhead turtle (DoN 2007)	1	79,000	0		134	0.170
Loggerhead turtle (Barco et al. 2018)	1	79,000	0		1496	1.894

*Mean abundance estimates used from NOAA 2016, NMFS and USFWS 2015, The Turtle Expert Working Group 2007, and Casale and Tucker 2017

No injury (PTS) takes of sea turtles were estimated over the three years of construction and survey activities, but behavioral takes of sea turtles are estimated for all potentially occurring species (Table 40). Total behavioral takes for all years of pile driving activities were relatively low for all sea turtle species except the loggerhead turtle, which had an estimated maximum behavioral take of 134 (1496) turtles over the entire construction period (Table 40).

8 DISCUSSION

8.1 Sound Attenuation Levels for Mitigation

The effect of sound level mitigation methods (e.g., bubble curtains) was examined for the impact pile driving scenarios. Sound attenuation from 10 to 20 dB was observed to significantly decrease the ranges to injury regulatory thresholds for marine mammals, sea turtles, and fishes. For example, a reduction in the sound level by 10 dB decreased the range to the LF cetacean PTS threshold for monopile installation from 8,850 m to 2,900 m, while a 20 dB sound level reduction, significantly further decreased the range to the PTS threshold for LF cetaceans to only 650 m during the installation of the 11-m monopile. The ranges to the LF cetacean PTS threshold were reduced from 5,500 m to 1,400 m to 200 m when the sound level was attenuated from 0 to 10 to 20 dB, respectively, during the installation of four 3-m pin piles for the jacket foundation. The ranges to the SEL, peak, and SPL marine mammal thresholds were larger for the installation of a single 11-m monopile in a day than for four 3-m pin piles in a day.

8.2 Sources of Uncertainty

Major sources of uncertainties inherent in the modeling presented herein include animal densities, animal movements, and the pile driving spectrum.

8.2.1 Animal Density

Animal density estimates are a source of uncertainty in modeling and analysis as they can result in a large effect on the calculated number of acoustically exposed animals. The fidelity of animal density estimates improves as additional population level data are collected and both collection and analysis methodologies are refined.

Marine mammal density estimates used in this analysis were taken from the MGEL (2022), the methodology of which is based on Roberts et al. (2016). These density data are the most recent and best available data for the Project area. Densities of sea turtles are much scarcer, particularly at-sea densities, as abundance and density estimations for sea turtles are most frequently based on the number of nesting females counted when they come ashore or the number nests laid on nesting beaches as sea turtles are so difficult to enumerate at sea. Even these land-based density estimates are not accurate as they can grossly underestimate the number of sea turtles since they are only counts of the number of nesting female turtles, and female turtles can lay more than one nest in a season and don't necessarily nest every year. For the Project analysis, two sources provided the best available at-sea density estimates for potentially occurring sea turtles: DoN (2007) and Barco *et al*. (2018). The Barco et al. (2018) densities were used in addition to the DoN (2007) densities for the loggerhead turtle as they provided more recent density estimates and correction factors even if the seasonality of the densities were different and the density estimates were significantly higher than the older Navy density estimates (DoN 2007). However, both the densities and resulting exposure estimates based on both DoN (2007) and Barco *et al*. (2018) have been provided for the loggerhead turtle.

Last, although green turtles may occur seasonally in the Project area, no at-sea density estimates are available for this more rarely occurring species. Since available occurrence data for the green turtle were included in the "Hardshelled Guild" in the DoN (2007) density dataset, the seasonal density estimates from this guild were used as surrogate densities for the green turtle. The U.S. Navy set a precedent for use of this turtle guild's density estimates to represent the green turtle (DoN 2017a). Albeit not ideal, these hardshelled guild data represent the best available data for green turtle densities in the Project area.

8.2.2 Animal Movement

The movement parameters used to create the animat paths during the AIM simulations are based on the most recent and most complete reported values of real sea turtle and marine mammal swim and diving behavior (Appendix B, Table B-1). However, the recorded range of behavior may not be complete as little information is known about the movements of some marine mammal and sea turtle species. This uncertainty is considered to have a small potential to affect the number of exposed animals.

8.2.3 Source Spectra

There were no pile driving source spectra available for the impact and vibratory hammers that will be used to install the monopile or pin pile foundation. Therefore, representative spectra were extracted from the existing literature that sometimes required scaling computations to best fit the surrogate data to the hammer and pile diameters planned for use in the Project.

8.2.4 Acoustic Propagation Modeling

The Project will span multiple years and seasons. A single set of propagation models based on the May propagation was run to reduce complexity of the modeling procedure. The May sound velocity profile was selected to represent the environmental conditions of all possible construction months as it provided the greatest propagation (Figure 6).

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Appendix A: Acoustic Concepts and Terminology

This section outlines some of the relevant concepts in acoustics, particularly underwater acoustics, to help the non-specialist reader better understand the modeling assessment and results presented in this report. Sound is the result of particles vibrating to create mechanical waves that travel through a medium, such as air or water. These waves create pressure changes that vary in space and time, resulting in time-varying pressure disturbances that oscillate above and below the ambient pressure.

Sound levels are typically reported in units of decibels (dB). The decibel is defined as a ratio of measured acoustic intensity (I) and a reference intensity level (I_{ref}).

$$\text{decibels (dB)} = 10 \times \log_{10}(I/I_{\mathrm{ref}})$$

However, sound is often measured as pressure (p) rather than directly as intensity. The intensity of a plane sound wave in the far field is proportional to the square of its pressure, as shown in the following equation:

$$I = p^2/\rho c$$

where ρ is the density of the medium (e.g., water) and c is the speed of sound in that medium. The sound pressure level (SPL) in decibels can be computed directly from the measured pressure with the following equations, where p is the pressure and p_o is the reference pressure.

$$\text{SPL} = 10 \times \log_{10}(p^2/p^2_{\mathrm{o}})$$

$$\text{SPL} = 20 \times \log_{10}(p/p_{\mathrm{o}})$$

Care must be taken when reporting and reading sound levels in decibels to ensure that measurements are properly described. To compare sound levels given in decibels to one another, a standard reference intensity or reference pressure must be used. In underwater acoustics, the traditional standard reference pressure (p_{o}) is 1 microPascal (mPa), leading to the use of the unit “dB re 1 mPa”, which represents a decibel referenced to a pressure of 1 microPascal.

In addition to units, the acoustic measurement type and measurement bandwidth must be considered. Measurement type refers to how the pressure was measured. Changing the” type” of measurement from peak-to-peak (pk-pk) to root-mean-square (RMS) can change the reported sound level of a given continuous sound by up to 9 dB. RMS, peak (also reported as 0-peak), and pk-pk are the most common sound measurement types. RMS measures are essentially an average intensity over a given amount of time, which is often not stated as part of the method for calculating the RMS sound level. These RMS measures are most appropriate for longer (i.e., non-impulsive) signals. Impulsive signals, such as those from impact pile driving, are best measured with a peak or peak-to-peak measurement. The primary portion of these signals is of such limited duration that it is difficult to define a start and end point of the signal. A typical approach is to use the time between the 5$^{\text{th}}$ and 95$^{\text{th}}$ percentile of cumulative amplitude. Zero to peak or pk-pk measurements simply measure the maximum amplitude of the signal, without consideration of time and avoid this problematic issue. Sound Exposure Level (SEL) also avoids the problem by specifying a fixed time value.

Another measurement type that is applied to impulsive signals and their effect upon animals is sound exposure level (SEL). This metric, appropriate for all signal types, is the integration of sound energy produced from a source, normalized to the level necessary to produce that amount of energy in a single second. These values are reported with units of dB re 1 mPa^2-s. SEL can be the energy accumulated over a given time period, indicated as L_E(cum), or it can be the energy integrated over a single pile driving strike, indicated as L_E(ss).

The measurement bandwidth, or frequency range, of a sound signal, and the frequencies over which the sound level is calculated must also be properly considered. In general, most sounds can be classified as tonal (or narrow band in that the signal spans only one or a small range of frequencies) or broadband (spanning many frequencies). When SPL is calculated, the frequencies over which the measurements were made should be indicated. Spectral levels are measurements made at a single frequency and have units of dB re 1µPa^2/Hz. Broadband SPL measurements encompass the energy contained in all the frequencies in a signal and are reported in units of dB re 1mPa^2. There can be a significant difference between spectral and broadband measurements of the same signal (Figure A-1).

It is also critical to define bandwidths when presenting spectra. Spectra are frequently presented in third-octave bands in bioacoustics to approximate the bandwidths of mammalian auditory system. Figure A-2 for instance, shows two spectra of the same vessel recording, where the blue line is the power spectral density spectrum and the frequency resolution is 1 Hz; that is, the amount of energy that occurs in each single frequency over the full range of analyzed frequencies. In Figure A-2, not surprisingly, the red line is always higher than the blue line, since it is aggregating energy over multiple frequencies. Furthermore, the difference between the two types of spectra increases with frequency because the bandwidth of the third-octave bands increases in proportion to the frequency.

The formal definitions of the sound metrics used in this report are:

- **RMS Sound Pressure Level (SPL_{rms} or L_P)** – Defined as an integral over a specified time interval (*T*) of squared sound pressure time series (*p(t)*) divided by the duration of the time interval and the squared reference pressure (P_o), for a specified frequency range. For impulsive signals, such as from impact pile driving, the measurement period is defined as the time period that contains 90 percent of the sound energy (T_{90}) (Madsen 2005). Continuous sources, such as vibratory piling driving, thruster operations, and shipping are commonly described in terms of an RMS sound pressure level (L_p).

$$L_P \text{ (dB re 1 } \mu\text{Pa)} = 20\, log_{10} \sqrt{\frac{1}{T_{90}} \int_{T_{90}} p^2(t)dt}$$

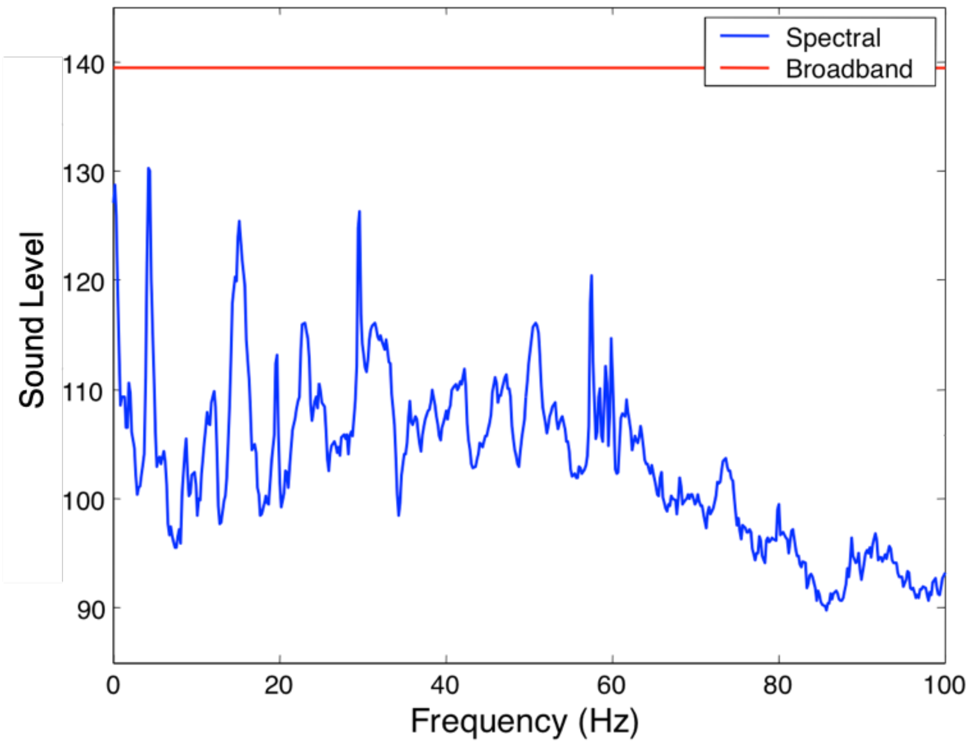


Figure A-1. Comparison of spectral and broadband source levels. A sample sound spectrum is shown in blue. The maximum spectral level of this signal is 130 dB re 1µPa²/Hz. The broadband level is the integration of all the energy from all frequencies. In this example, the broadband level is 139 dB re 1µPa. Thus, depending on the measurement bandwidth, the same sound can have different numerical values accurately describing its amplitude.

- **Sound Exposure Level (SEL or L_E)** – Sound exposure level is similar to the L_P but further specifies the sound pressure over a specified time interval or event, and for a specified frequency range expressed in dB re 1 µPa²s. The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T_{100}):

$$L_E \text{ (dB re 1 µPa}^2\cdot\text{s)} = 10\, log_{10}\left(\frac{1}{T_0}\int_{T_0}^{T_{100}} p^2(t)dt \;/\; p_0^2\right)$$

where T_0 is a reference time interval of 1 s. The L_E represents the total acoustic energy received at a given location. Unless otherwise stated, sound exposure levels for pulse noise sources (*i.e.*, impact hammer pile driving) presented in this report refer to a single pulse.

L_E can be calculated as a cumulative metric over periods with multiple acoustic events. In the case of impulsive sources like impact piling, L_E describes the summation of energy for

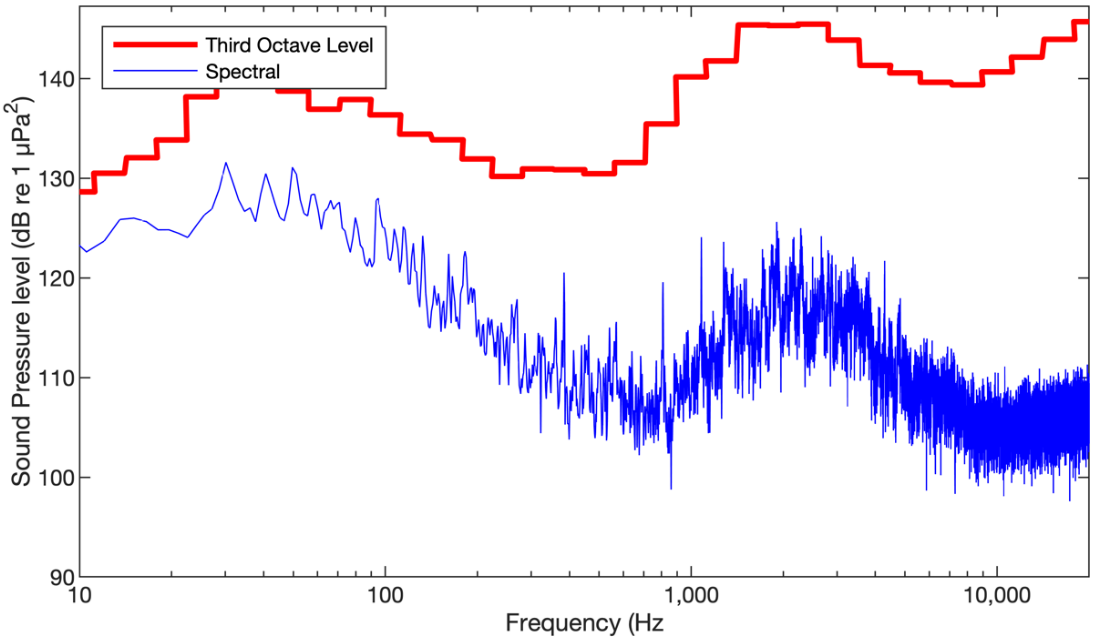


Figure A-2. Comparison of spectral (blue) and third-octave band level (red) spectra.

the entire impulse normalized to one second and can be expanded to represent the summation of energy from multiple pulses. The latter is written L_E (cum) denoting that it represents the cumulative sound exposure over the duration of the activity. The sound exposure level is often used in the assessment of marine mammal and fish behavior over a 24-hour period and will be written as $L_{E,\,24h}$.

The cumulative SEL (dB re 1 µPa2·s) can be computed by summing (in linear units) the LE of the *N* individual events:

$$L_E\,(\text{cum}) = 10\,log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E\,i}}{10}}\right)$$

- **Peak Level (L_{pk})** – Maximum noise level over a given event is expressed as $L_{pk.}$ and is calculated using the maximum variation of the absolute value of the pressure from zero within the wave. The peak level is commonly used as a descriptor for impulsive sound sources. The L_{pk} can be calculated using the formula below where *t* is the time. Pulses are characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures.

$$L_{pk}\,(\text{dB re 1 µPa}) = 20\,log_{10}[\max p(t)]$$

- **Peak-to-Peak Level (L_{pp})** – Noise level over a given event is expressed as $L_{pp.}$ and is calculated using the minimum to maximum variation within the wave. The L_{pp} can be calculated using the formula below where *t* is the time:

$$L_{pp}\,(\text{dB re 1 µPa}) = 20\,\log_{10}\,(\max p(t) - \min\,(p(t)).$$

APPENDIX B: ANIMAT MODELING PARAMETERS

Parameters that Define Animat Movement in AIM

Animals move through four dimensions: three-dimensional space and time. Several parameters are used in AIM to produce simulated movements that accurately represent expected real animal movement patterns. This section provides short descriptions of the various parameters, with nominal values as examples of how the parameters are implemented in AIM. The actual values used in the modeling of the US Wind Project pile driving operations and the literature from which that information was obtained are detailed in this appendix (Table B-1). Table B-1 represents a portion of MAI's ongoing effort to review existing literature and obtain relevant dive and swim information for marine mammal and sea turtle species. When scientific papers or reports contain numeric descriptions of movement behaviors (e.g., dive times), these numeric values are added to MAIs Animat Movement Library. This compendium of movement values for each marine mammal and sea turtle species are then interpreted by an MAI subject matter expert to derive a set of summary values that represent each species/modeling group/behavioral state.

Marine Mammal Diving Patterns

Diving parameters, such as time limits, depth limits, heading variance, and speed, are specified for each animat in the AIM model (Figure B-1). As an example, a dive pattern is presented that consists of a shallow, respiratory sequence (Figure B-1) followed by a deeper, longer dive (bottom row of Figure B-1). The horizontal component of the dive is handled with the "heading variance" term, which allows the animal to change course up to a certain number of degrees at each movement step. For this example, the animal can change course 20° during a shallow dive and 10° during a deep dive (Figure B-1). Using the defined diving parameters, AIM generates realistic dive patterns (Figure B-2).

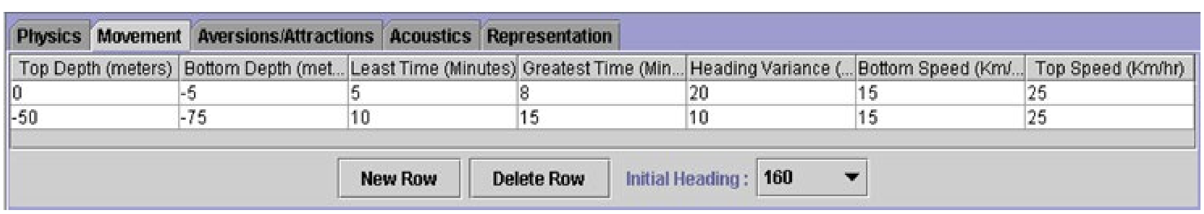


Figure B-1. Example of AIM marine mammal movement parameters, with the top row showing the parameters of a shallow, respiratory dive (diving from surface to 5 m for 5 to 8 min) and the bottom row showing a deeper, longer dive (diving between 50 and 75 m for 10 to 15 min).

Aversions

In addition to movement patterns, animats can be programmed to avoid certain environmental characteristics (Figure B-3). For example, aversions can be used to constrain an animal to a particular depth regime. (e.g., an animat can be constrained to waters between 2,000 and 5,000 m deep). An animat will continue to turn until the aversion is satisfied. In this example,

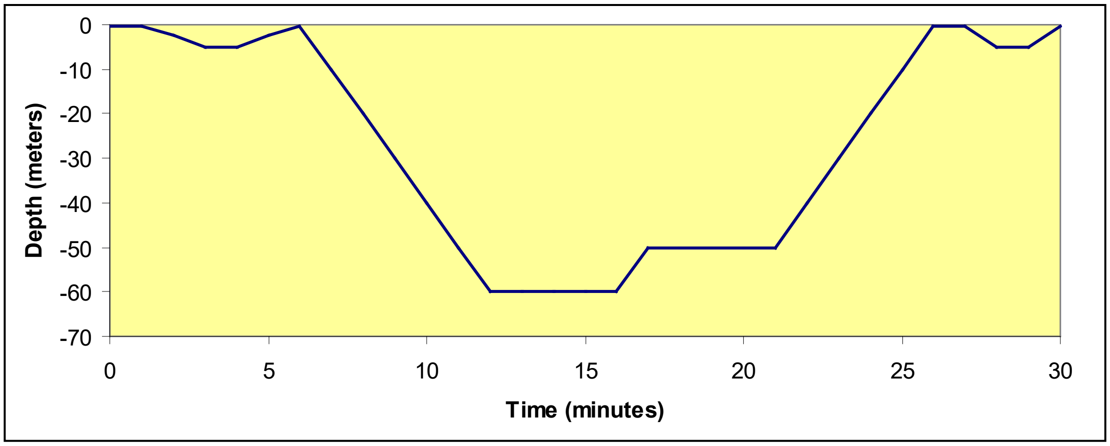
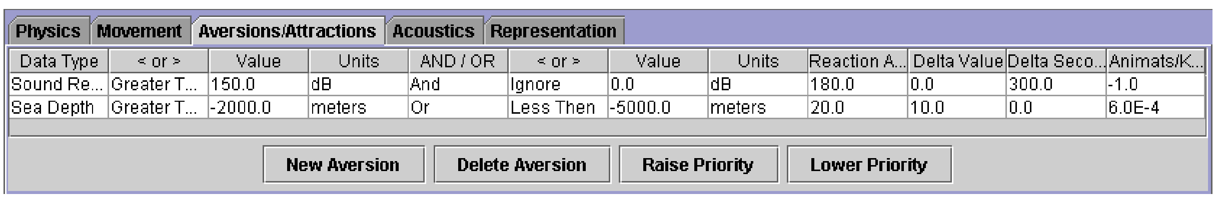


Figure B-2. Marine mammal dive pattern based on animat data in Figure B-1. The animat makes a shallow dive from the surface to 5 m for approximately 6 min, surfaces, and then makes a deep dive to 60 m for about 5 min, changes depth to 50 m for another 5 min, and then surfaces.



Data Type	< or >	Value	Units	AND / OR	< or >	Value	Units	Reaction A...	Delta Value	Delta Seco...	Animats/K...
Sound Re...	Greater T...	150.0	dB	And	Ignore	0.0	dB	180.0	0.0	300.0	-1.0
Sea Depth	Greater T...	-2000.0	meters	Or	Less Then	-5000.0	meters	20.0	10.0	0.0	6.0E-4

Figure B-3. Example of depth aversion parameters for modeling of marine mammal movements.

animat makes 20° turns in water depths shallower than 2,000 m or deeper than 5,000 m to remain within that depth range.

Heading Variance

There is little data that summarizes movement in terms of heading variance, or the amount the course of the animal changes per unit time. Therefore, the default value used in the modeling is 30 degrees. Exceptions are made for migratory animals, which tend to have more linear travel; therefore, these animals typically are assigned a value of 10 degrees. Foraging animals tend to have less linear travel, as they may be trying to remain within a food patch. Therefore, foraging animals are assigned a higher heading variance value, typically 45 to 60 degrees.

These types of data have been reported in the literature as “linearity”, “tortuosity” and “meander” (Soule and Wilcock, 2013). “Meander” is defined as the ratio of the total distance along the smoothed path to the net distance traveled; a value of 1 would indicate a straight path.

Residency

The amount of time that an animal spends in an area can have a tremendous influence on how the animal samples an acoustic field. For example, individuals displaying high residency in the area of a localized noise source will experience higher exposures than animals that transit once through that area. However, since the animat exposure models are run for a 24-hour period, in accordance with the NMFS 24-hour reset rule, the effect of residency in animat modeling is minimized.

Parameters of Marine Mammal Movement Behaviors Used in Impact Analysis

Dive and swim speed information for each marine mammal or marine mammal group is a critical component of accurately and realistically modeling marine mammal movements when assessing potential exposure to underwater acoustic sound. All parameters except speed use an uniform distribution between the minimum and maximum values. Speed parameters include the minimum and maximum as well as the statistical distribution used to select speed values. Options include a normal distribution and a gamma distribution. When gamma distributions are specified, they are typically the result of fitting to an existing dataset. The mean of the normal distribution is the mean of the minimum and maximum speed. The minimum and maximum values are four standard deviations below or above the distribution mean. Dive and swim parameters for marine mammals potentially occurring in the US Wind Project modeled area are summarized in Table B-1.

Table B-1. Animat movement (dive and swim) parameters of the marine mammal and sea turtle species of interest in the modeling area for the US Wind Project; multiple entries in a single cell represent multiple modeled diving states of the species. The underlying statistic distribution is uniform for all parameters except speed, which uses either a normal or user-specified gamma distribution. Literature references for each type of information are listed numerically in the row below the relevant species, with the full literature citations listed after the table in the numerical order presented.

Modeled Species/Species Group	Min/Max Surface Time (Min)	Surface/ Dive Angle (°)	Dive Depth in Meters Min/Max (Percentage)	Min/Max Dive Time (Min)	Heading Variance (Angle/Time)	Min/ Max Speed (kph)	Speed Distribution	Depth Limit (m)/ Reaction Angle
Fin Whale	2/4	64/54	20/40 (25) 20/40 (25) 50/150 (22) 50/150 (22) 150/527 (6)	2/4 2/4 5/8 5/8 10/18	30/300 90/300 30/300 90/300 90/300	1/8	Normal	20/ reflect
Literature References	[1-4].	[5]	[3-9]	[1, 3-6, 8, 10]	[11, 12]	[8, 11, 13-15]		[13, 16-19]
Humpback Whale	1/3	75	10/60 (20) 40/100 (75) 100/150 (5)	7/10 7/10 7/15	90/300 90/90 90/90	1/8	Normal	10/ reflect
Literature References	[20-22]		[20, 21, 23-25]	[20-22]	[26, 27]	[26, 28-30]		[31-33]
Common Minke Whale (Foraging)	1/3	75	75/150 (14) 25/45 (29) 5/25 (57)	2/7 1/5 0.5/1.5	90/90 90/300 10/300	1/11	Gamma (3,1.5)	20 / reflect
Literature References	[34]		[35-38]	[34, 36, 37, 39-42]		[34, 43, 44]	[34]	[34, 45, 46]
North Atlantic Right Whale (Foraging)	4/5	75	113/130 (50)	11/13	90/90	1/4	Normal	20

Table B-1. Animat movement (dive and swim) parameters of the marine mammal and sea turtle species of interest in the modeling area for the US Wind Project; multiple entries in a single cell represent multiple modeled diving states of the species. The underlying statistic distribution is uniform for all parameters except speed, which uses either a normal or user-specified gamma distribution. Literature references for each type of information are listed numerically in the row below the relevant species, with the full literature citations listed after the table in the numerical order presented.

Modeled Species/Species Group	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle (°)*	*Dive Depth in Meters Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (m)/ Reaction Angle*
			113/130 (50)	11/13	30/90			
Literature References	[47, 48]		[48-53]	[48, 49, 54]	[55]	[49, 55, 56]		[57, 58]
Atlantic Spotted Dolphin, Pantropical Spotted Dolphin, Striped Dolphin (Stenella spp.).	1/1	75	Day: 5/25 (50) Night: 10/400 (10) Night: 10/100(40)	1/4	30	2/15	Normal	10/ reflect
Literature References			[59-62]	[60, 62-64]		[63, 65-67]		[68, 69]
Beaked Whales (Blainville's, Cuvier's, Gervais, and True's)	1/6	75	2000/3000(5) 1000/2000 (25) 200/500 (70)	100/140 48/74 12/30	30/300 (50) 90/300 (50)	2/7	Normal	50/ reflect
Literature References	[70-73]		[73-80]	[70-76, 80, 81]	[70, 82, 83]	[75, 79, 84-86]		[68, 70, 71, 84, 87-89]
Common Bottlenose Dolphin	1/1	75	15/98	1/3	90/300 (50) 90/90 (50)	2/16	Normal	10/ reflect
Literature References	[90-92]		[90, 93, 94]	[91, 94]		[91, 95-98]		[68, 99, 100]

Table B-1. Animat movement (dive and swim) parameters of the marine mammal and sea turtle species of interest in the modeling area for the US Wind Project; multiple entries in a single cell represent multiple modeled diving states of the species. The underlying statistic distribution is uniform for all parameters except speed, which uses either a normal or user-specified gamma distribution. Literature references for each type of information are listed numerically in the row below the relevant species, with the full literature citations listed after the table in the numerical order presented.

Modeled Species/Species Group	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle (°)*	*Dive Depth in Meters Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (m)/ Reaction Angle*
Common Dolphin	1/1	75	50/200	1/5	30	2/9	Normal	20/ reflect
Literature References			[101, 102]	[103]		[104, 105]		[106, 107]
Harbor Porpoise	1/1	17/31	1/10 (35) 10/40 (45) 40/100 (15) 100/230 (5)	1/4	43/30	2/8	Normal	10/ reflect
Literature References	[108, 109]		[108, 110]	[108-111]	[109]	[108-113]		[114-116]
Killer Whale	1/1	75	10/180	1/10	30/300 (50) 90/150 (50)	3/12	Normal	25/ reflect
Literature References	[117]		[118-122]	[120]		[43, 120, 123-125]		
Kogia spp.	1/2	75	200/1000	2/43	30	1/11	Normal	117/ reflect
Literature References	[126, 127]		[68, 128]	[127, 129, 130]		[130]		[68, 126, 131]

Table B-1. Animat movement (dive and swim) parameters of the marine mammal and sea turtle species of interest in the modeling area for the US Wind Project; multiple entries in a single cell represent multiple modeled diving states of the species. The underlying statistic distribution is uniform for all parameters except speed, which uses either a normal or user-specified gamma distribution. Literature references for each type of information are listed numerically in the row below the relevant species, with the full literature citations listed after the table in the numerical order presented.

Modeled Species/Species Group	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle (°)*	*Dive Depth in Meters Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (m)/ Reaction Angle*
Pilot Whales	1/1	75	5/100 (80) 10/1000 (20)	1/10 5/21	30	2/12	Normal	50/ reflect
Literature References	[132]		[80, 133-137]	[132-138]		[133, 137-141]		[68, 107, 142]
Risso's Dolphin	1/3	75	150/1000	2/12	30/300 (50) 90/300 (50)	2/12	Normal	100/ reflect
Literature References	[143, 144]		[144, 145]	[143, 145]		[139, 143]		[68, 107, 146]
Rough-toothed Dolphin	1/3	75	50/600	1/7	30/300 (50) 90/300 (50)	5/16	Normal	194/ reflect
Literature References				[147, 148]		[148, 149]		[68, 148, 150]
Sperm Whale	8/11	90/75	600/1000 (100)	35/65	30/300 (50) 90/300 (50)	1/8	Normal	40/reflect
Literature References	[151, 152]	[153]	[80, 154-161]	[80, 154, 160]	[156, 162-164]	[151, 156, 162, 165-168]		[68, 169-171]
Harbor Seal	1/1		1/1(35) 5/20(15)	1/2 1/2	10/300 30/300	1/4	Normal	10/reflect

Table B-1. Animat movement (dive and swim) parameters of the marine mammal and sea turtle species of interest in the modeling area for the US Wind Project; multiple entries in a single cell represent multiple modeled diving states of the species. The underlying statistic distribution is uniform for all parameters except speed, which uses either a normal or user-specified gamma distribution. Literature references for each type of information are listed numerically in the row below the relevant species, with the full literature citations listed after the table in the numerical order presented.

Modeled Species/Species Group	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle (°)*	*Dive Depth in Meters Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (m)/ Reaction Angle*
			50/200(25) 50/200(25)	4/7 4/7	90/90 30/300			
Literature References	[172, 173]		[172-176]	[172-175, 177]		[172, 173]		[173, 174]
Sea Turtle (representative of commonly occurring turtles)**	1/2		15/266 (50) 15/266 (50)	2/92	10/300 180/300	0/4.5	Normal	10/reflect
Literature References			[178-183]	[183-188]	[183, 189]	[184, 189]		

**Leatherback turtle dive/swim information was used to represent all commonly occurring sea turtle species since more information on their dive and swim behaviors is available.

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APPENDIX C: MARINE MAMMAL ACOUSTIC EXPOSURE TABLES FOR VARIOUS MITIGATION SCENARIOS

These exposure tables are based on the modeling area for US Wind's lease area rather than the buffered lease area and were originally completed to inform decisions about varying sound reduction levels as potential mitigation measures for US Wind. They are included for completeness.

Table C-1. 11-m monopile exposure estimates with no mitigation applied.

Marine Mammal Species	*Behavioral Exposures*		*Cumulative SEL Injury Exposures*		*Peak SPL Injury Exposures*	
	April-Nov	*May-Oct*	*April-Nov*	*May-Oct*	*April-Nov*	*May-Oct*
Risso's dolphin	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Common dolphin	110.87	85.09	0.00000	0.00000	0.00000	0.00000
Fin whale	0.00	0.00	1.27949	1.38116	0.01000	0.01079
Harbor porpoise	3.97	0.79	0.00000	0.00000	0.04616	0.00915
Harbor seal	2.93	1.23	0.00630	0.00265	0.00126	0.00053
Killer whale	0.01	0.01	0.00000	0.00000	0.00000	0.00000
Rough-toothed dolphin	0.13	0.13	0.00000	0.00000	0.00000	0.00000
Common minke whale	0.00	0.00	0.52306	0.50374	0.00265	0.00255
Humpback whale	0.00	0.00	0.50633	0.43871	0.00256	0.00222
Kogia spp.	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Pilot whales	0.00	0.00	0.00000	0.00000	0.00000	0.00000
North Atlantic right whale	0.00	0.00	0.09747	0.01239	0.00012	0.00000
Blainville's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Cuvier's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Gervais' beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
True's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Sperm whale	0.10	0.12	0.00000	0.00000	0.00000	0.00000
Atlantic spotted dolphin	10.05	10.64	0.00000	0.00000	0.00000	0.00000
Pantropical spotted dolphin	0.01	0.01	0.00000	0.00000	0.00000	0.00000
Striped dolphin	26.97	26.97	0.00000	0.00000	0.00000	0.00000
Common bottlenose dolphin	194.13	229.40	0.00000	0.00000	0.00000	0.00000

Table C-2. 11-m monopile exposure estimates with 3 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0.00	0.00	0.00000	0.00000	0	0
Common dolphin	71.59	54.94	0.00000	0.00000	0	0
Fin whale	0.00	0.00	0.78135	0.84344	0	0
Harbor porpoise	2.48	0.49	0.00000	0.00000	0.02865	0
Harbor seal	1.77	0.74	0.00378	0.00159	0	0
Killer whale	0.00	0.00	0.00000	0.00000	0	0
Rough-toothed dolphin	0.08	0.08	0.00000	0.00000	0	0
Common minke whale	0.00	0.00	0.29199	0.28120	0	0
Humpback whale	0.00	0.00	0.28265	0.24490	0	0
Kogia spp.	0.00	0.00	0.00000	0.00000	0	0
Pilot whales	0.00	0.00	0.00000	0.00000	0	0
North Atlantic right whale	0.00	0.00	0.05354	0.00757	0	0
Blainville's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Cuvier's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Gervais' beaked whale	0.00	0.00	0.00000	0.00000	0	0
True's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Sperm whale	0.06	0.07	0.00000	0.00000	0	0
Atlantic spotted dolphin	6.24	6.60	0.00000	0.00000	0	0
Pantropical spotted dolphin	0.01	0.01	0.00000	0.00000	0	0
Striped dolphin	16.73	16.73	0.00000	0.00000	0	0
Common bottlenose dolphin	125.03	147.74	0.00000	0.00000	0	0

Table C-3. 11-m monopile exposure estimates with 6 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Common dolphin	45.14	34.64	0.00000	0.00000	0.00000	0.00000
Fin whale	0.00	0.00	0.42483	0.45859	0.00000	0.00000
Harbor porpoise	1.53	0.30	0.00000	0.00000	0.02388	0.00473
Harbor seal	0.98	0.41	0.00000	0.00000	0.00000	0.00000
Killer whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Rough-toothed dolphin	0.04	0.04	0.00000	0.00000	0.00000	0.00000
Common minke whale	0.00	0.00	0.16288	0.15686	0.00000	0.00000
Humpback whale	0.00	0.00	0.15767	0.13661	0.00000	0.00000
Kogia spp.	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Pilot whales	0.00	0.00	0.00000	0.00000	0.00000	0.00000
North Atlantic right whale	0.00	0.00	0.02821	0.00414	0.00000	0.00000
Blainville's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Cuvier's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Gervais' beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
True's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Sperm whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Atlantic spotted dolphin	3.89	4.11	0.00000	0.00000	0.00000	0.00000
Pantropical spotted dolphin	0.01	0.01	0.00000	0.00000	0.00000	0.00000
Striped dolphin	10.43	10.43	0.00000	0.00000	0.00000	0.00000
Common bottlenose dolphin	80.79	95.46	0.00000	0.00000	0.00000	0.00000

Table C-4. 11-m monopile exposure estimates with 9 dB reduction as mitigation.

Marine Mammal Species	***Behavioral Exposures***		***Cumulative SEL Injury Exposures***		***Peak SPL Injury Exposures***	
	April-Nov	***May-Oct***	***April-Nov***	***May-Oct***	***April-Nov***	***May-Oct***
Risso's dolphin	0.00	0.00	0	0	0	0
Common dolphin	28.51	21.88	0	0	0	0
Fin whale	0.00	0.00	0.17660	0.19063	0	0
Harbor porpoise	0.98	0.19	0	0	0.01592	0.00316
Harbor seal	0.57	0.24	0	0	0	0
Killer whale	0.00	0.00	0	0	0	0
Rough-toothed dolphin	0.02	0.02	0	0	0	0
Common minke whale	0.00	0.00	0.09071	0.08736	0	0
Humpback whale	0.00	0.00	0.08781	0.07608	0	0
Kogia spp.	0.00	0.00	0	0	0	0
Pilot whales	0.00	0.00	0	0	0	0
North Atlantic right whale	0.00	0.00	0.01368	0.00225	0	0
Blainville's beaked whale	0.00	0.00	0	0	0	0
Cuvier's beaked whale	0.00	0.00	0	0	0	0
Gervais' beaked whale	0.00	0.00	0	0	0	0
True's beaked whale	0.00	0.00	0	0	0	0
Sperm whale	0.00	0.00	0	0	0	0
Atlantic spotted dolphin	2.52	2.67	0	0	0	0
Pantropical spotted dolphin	0.00	0.00	0	0	0	0
Striped dolphin	6.77	6.77	0	0	0	0
Common bottlenose dolphin	55.45	65.52	0	0	0	0

Table C-5. 11-m monopile exposure estimates with 12 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0.00	0.00	0.00000	0.00000	0	0
Common dolphin	17.05	13.09	0.00000	0.00000	0	0
Fin whale	0.00	0.00	1.27949	1.38116	0	0
Harbor porpoise	0.61	0.12	0.00000	0.00000	0	0
Harbor seal	0.15	0.06	0.00630	0.00265	0	0
Killer whale	0.00	0.00	0.00000	0.00000	0	0
Rough-toothed dolphin	0.01	0.01	0.00000	0.00000	0	0
Common minke whale	0.00	0.00	0.52306	0.50374	0	0
Humpback whale	0.00	0.00	0.50633	0.43871	0	0
Kogia spp.	0.00	0.00	0.00000	0.00000	0	0
Pilot whales	0.00	0.00	0.00000	0.00000	0	0
North Atlantic right whale	0.00	0.00	0.09747	0.00114	0	0
Blainville's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Cuvier's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Gervais' beaked whale	0.00	0.00	0.00000	0.00000	0	0
True's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Sperm whale	0.00	0.00	0.00000	0.00000	0	0
Atlantic spotted dolphin	1.56	1.65	0.00000	0.00000	0	0
Pantropical spotted dolphin	0.00	0.00	0.00000	0.00000	0	0
Striped dolphin	4.18	4.18	0.00000	0.00000	0	0
Common bottlenose dolphin	33.51	39.59	0.00000	0.00000	0	0

Table C-6. 11-m monopile exposure estimates with 15 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0.00	0.00	0	0	0	0
Common dolphin	10.40	7.98	0	0	0	0
Fin whale	0.00	0.00	0.01833	0.01978	0	0
Harbor porpoise	0.37	0.07	0	0	0	0
Harbor seal	0.19	0.08	0.00000	0	0	0
Killer whale	0.00	0.00	0	0	0	0
Rough-toothed dolphin	0.00	0.00	0	0	0	0
Common minke whale	0.00	0.00	0.01589	0.01530	0	0
Humpback whale	0.00	0.00	0.01538	0.01333	0	0
Kogia spp.	0.00	0.00	0	0	0	0
Pilot whales	0.00	0.00	0	0	0	0
North Atlantic right whale	0.00	0.00	0.00312	0.00041	0	0
Blainville's beaked whale	0.00	0.00	0	0	0	0
Cuvier's beaked whale	0.00	0.00	0	0	0	0
Gervais' beaked whale	0.00	0.00	0	0	0	0
True's beaked whale	0.00	0.00	0	0	0	0
Sperm whale	0.00	0.00	0	0	0	0
Atlantic spotted dolphin	0.94	0.99	0	0	0	0
Pantropical spotted dolphin	0.00	0.00	0	0	0	0
Striped dolphin	2.52	2.52	0	0	0	0
Common bottlenose dolphin	21.23	25.08	0	0	0	0

Table C-7. 11-m monopile exposure estimates with 18 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0.00	0.00	0	0	0	0
Common dolphin	6.74	5.17	0	0	0	0
Fin whale	0.00	0.00	0.00167	0.00180	0	0
Harbor porpoise	0.21	0.04	0	0	0	0
Harbor seal	0.11	0.04	0	0	0	0
Killer whale	0.00	0.00	0	0	0	0
Rough-toothed dolphin	0.00	0.00	0	0	0	0
Common minke whale	0.00	0.00	0.00331	0.00319	0	0
Humpback whale	0.00	0.00	0.00320	0.00278	0	0
Kogia spp.	0.00	0.00	0	0	0	0
Pilot whales	0.00	0.00	0	0	0	0
North Atlantic right whale	0.00	0.00	0.00084	0.00019	0	0
Blainville's beaked whale	0.00	0.00	0	0	0	0
Cuvier's beaked whale	0.00	0.00	0	0	0	0
Gervais' beaked whale	0.00	0.00	0	0	0	0
True's beaked whale	0.00	0.00	0	0	0	0
Sperm whale	0.00	0.00	0	0	0	0
Atlantic spotted dolphin	0.61	0.65	0	0	0	0
Pantropical spotted dolphin	0.00	0.00	0	0	0	0
Striped dolphin	1.64	1.64	0	0	0	0
Common bottlenose dolphin	13.41	15.85	0	0	0	0

Table C-8. 11-m monopile exposure estimates with 20 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0.00	0.00	0.00000	0.00000	0	0
Common dolphin	4.84	3.72	0.00000	0.00000	0	0
Fin whale	0.00	0.00	0.00000	0.57009	0	0
Harbor porpoise	0.14	0.03	0.00000	0.00000	0	0
Harbor seal	0.07	0.03	0.00000	0.00000	0	0
Killer whale	0.00	0.00	0.00000	0.00000	0	0
Rough-toothed dolphin	0.00	0.00	0.00000	0.00000	0	0
Common minke whale	0.00	0.00	0.00000	0.19129	0	0
Humpback whale	0.00	0.00	0.00000	0.16660	0	0
Kogia spp.	0.00	0.00	0.00000	0.00000	0	0
Pilot whales	0.00	0.00	0.00000	0.00000	0	0
North Atlantic right whale	0.00	0.00	0.00024	0.00009	0	0
Blainville's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Cuvier's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Gervais' beaked whale	0.00	0.00	0.00000	0.00000	0	0
True's beaked whale	0.00	0.00	0.00000	0.00000	0	0
Sperm whale	0.00	0.00	0.00000	0.00000	0	0
Atlantic spotted dolphin	0.43	0.46	0.00000	0.00000	0	0
Pantropical spotted dolphin	0.00	0.00	0.00000	0.00000	0	0
Striped dolphin	1.16	1.16	0.00000	0.00000	0	0
Common bottlenose dolphin	9.54	11.27	0.00000	0.00000	0	0

Table C-9. 3-m pinpile exposure estimates with no mitigation applied.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Common dolphin	0.00	0.00	6.94798	5.33209	0.00000	0.00000
Fin whale	0.00	0.00	0.55228	0.59616	0.00500	0.00540
Harbor porpoise	0.85	0.17	0.00955	0.00189	0.05014	0.00994
Harbor seal	0.67	0.28	0.00000	0.00000	0.00189	0.00079
Killer whale	0.00	0.00	0.00063	0.00063	0.00000	0.00000
Rough-toothed dolphin	0.00	0.00	0.00042	0.00042	0.00000	0.00000
Common minke whale	0.00	0.00	0.21949	0.21138	0.00596	0.00574
Humpback whale	0.00	0.00	0.21247	0.18409	0.00577	0.00500
Kogia spp.	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Pilot whales	0.00	0.00	0.00000	0.00000	0.00000	0.00000
North Atlantic right whale	0.00	0.00	0.03529	0.00540	0.00018	0.00013
Blainville's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Cuvier's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Gervais' beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
True's beaked whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Sperm whale	0.00	0.00	0.00000	0.00000	0.00000	0.00000
Atlantic spotted dolphin	0.00	0.00	0.72240	0.76487	0.00000	0.00000
Pantropical spotted dolphin	0.00	0.00	0.00099	0.00099	0.00000	0.00000
Striped dolphin	0.00	0.00	1.93810	1.93810	0.00000	0.00000
Common bottlenose dolphin	0.00	0.00	8.94316	10.56801	0.00000	0.00000

Table C-1. 3-m pinpile exposure estimates with 3 dB reduction as mitigation.

Marine Mammal Species	***Behavioral Exposures***		***Cumulative SEL Injury Exposures***		***Peak SPL Injury Exposures***	
	April-Nov	***May-Oct***	***April-Nov***	***May-Oct***	***April-Nov***	***May-Oct***
Risso's dolphin	0	0	0	0	0	0
Common dolphin	0	0	3.03185	2.32673	0	0
Fin whale	0	0	0.23491	0.25357	0	0
Harbor porpoise	0.52	0.10	0	0	0.02626	0.00521
Harbor seal	0.36	0.15	0	0	0	0
Killer whale	0	0	0.00028	0.00028	0	0
Rough-toothed dolphin	0	0	0	0	0	0
Common minke whale	0	0	0.10825	0.10425	0	0
Humpback whale	0	0	0.10479	0.09080	0	0
Kogia spp.	0	0	0	0	0	0
Pilot whales	0	0	0	0	0	0
North Atlantic right whale	0	0	0.01585	0.0026	0	0
Blainville's beaked whale	0	0	0	0	0	0
Cuvier's beaked whale	0	0	0	0	0	0
Gervais' beaked whale	0	0	0	0	0	0
True's beaked whale	0	0	0	0	0	0
Sperm whale	0	0	0	0	0	0
Atlantic spotted dolphin	0	0	0.27021	0.28610	0	0
Pantropical spotted dolphin	0	0	0.00037	0.00037	0	0
Striped dolphin	0	0	0.72494	0.72494	0	0
Common bottlenose dolphin	0	0	3.66670	4.33289	0	0

Table C-2. 3-m pinpile exposure estimates with 6 dB reduction as mitigation.

Marine Mammal Species	***Behavioral Exposures***		***Cumulative SEL Injury Exposures***		***Peak SPL Injury Exposures***	
	April-Nov	***May-Oct***	***April-Nov***	***May-Oct***	***April-Nov***	***May-Oct***
Risso's dolphin	0	0	0.00000	0.00000	0	0
Common dolphin	0	0	1.32643	1.01794	0	0
Fin whale	0	0	0.08996	0.09711	0	0
Harbor porpoise	0.33	0.07	0.00000	0.00000	0.01433	0.00284
Harbor seal	0.22	0.09	0.00000	0.00000	0	0
Killer whale	0	0	0.00009	0.00009	0	0
Rough-toothed dolphin	0	0	0.00000	0.00000	0	0
Common minke whale	0	0	0.04866	0.04687	0	0
Humpback whale	0	0	0.04711	0.04082	0	0
Kogia spp.	0	0	0.00000	0.00000	0	0
Pilot whales	0	0	0.00000	0.00000	0	0
North Atlantic right whale	0	0	0.00684	0.00122	0	0
Blainville's beaked whale	0	0	0.00000	0.00000	0	0
Cuvier's beaked whale	0	0	0.00000	0.00000	0	0
Gervais' beaked whale	0	0	0.00000	0.00000	0	0
True's beaked whale	0	0	0.00000	0.00000	0	0
Sperm whale	0	0	0.00000	0.00000	0	0
Atlantic spotted dolphin	0	0	0.11029	0.11677	0	0
Pantropical spotted dolphin	0	0	0.00015	0.00015	0	0
Striped dolphin	0	0	0.29589	0.29589	0	0
Common bottlenose dolphin	0	0	0.89432	1.05680	0	0

Table C-3. 3-m pinpile exposure estimates with 9 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0	0	0	0	0	0
Common dolphin	0	0	0.31582	0.24237	0	0
Fin whale	0	0	0.01250	0.01349	0	0
Harbor porpoise	0.20	0.04	0	0	0.01433	0.00284
Harbor seal	0.12	0.05	0	0	0	0
Killer whale	0	0	0.00002	0.00002	0	0
Rough-toothed dolphin	0	0	0	0	0	0
Common minke whale	0	0	0.01688	0.01626	0	0
Humpback whale	0	0	0.01634	0.01416	0	0
Kogia spp.	0	0	0	0	0	0
Pilot whales	0	0	0	0	0	0
North Atlantic right whale	0	0	0.00270	0.00039	0	0
Blainville's beaked whale	0	0	0	0	0	0
Cuvier's beaked whale	0	0	0	0	0	0
Gervais' beaked whale	0	0	0	0	0	0
True's beaked whale	0	0	0	0	0	0
Sperm whale	0	0	0	0	0	0
Atlantic spotted dolphin	0	0	0.02206	0.02335	0	0
Pantropical spotted dolphin	0	0	0.00003	0.00003	0	0
Striped dolphin	0	0	0.05918	0.05918	0	0
Common bottlenose dolphin	0	0	0.26829	0.31704	0	0

Table C-4. 3-m pinpile exposure estimates with 12 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0	0	0.00000	0.00000	0	0
Common dolphin	0	0	0.00000	0.00000	0	0
Fin whale	0	0	0.00250	0.00270	0	0
Harbor porpoise	0.11	0.02	0.00000	0.00000	0.00478	0.00095
Harbor seal	0.06	0.02	0.00000	0.00000	0	0
Killer whale	0	0	0.00000	0.00000	0	0
Rough-toothed dolphin	0	0	0.00000	0.00000	0	0
Common minke whale	0	0	0.00298	0.00287	0	0
Humpback whale	0	0	0.00288	0.00250	0	0
Kogia spp.	0	0	0.00000	0.00000	0	0
Pilot whales	0	0	0.00000	0.00000	0	0
North Atlantic right whale	0	0	0.00144	0.00026	0	0
Blainville's beaked whale	0	0	0.00000	0.00000	0	0
Cuvier's beaked whale	0	0	0.00000	0.00000	0	0
Gervais' beaked whale	0	0	0.00000	0.00000	0	0
True's beaked whale	0	0	0.00000	0.00000	0	0
Sperm whale	0	0	0.00000	0.00000	0	0
Atlantic spotted dolphin	0	0	0.00000	0.00000	0	0
Pantropical spotted dolphin	0	0	0.00000	0.00000	0	0
Striped dolphin	0	0	0.00000	0.00000	0	0
Common bottlenose dolphin	0	0	0.00000	0.00000	0	0

Table C-5. 3-m pinpile exposure estimates with 15 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0	0	0	0	0	0
Common dolphin	0	0	0	0	0	0
Fin whale	0	0	0	0	0	0
Harbor porpoise	0.06	0.01	0	0	0	0
Harbor seal	0.03	0.01	0	0	0	0
Killer whale	0	0	0	0	0	0
Rough-toothed dolphin	0	0	0	0	0	0
Common minke whale	0	0	0	0	0	0
Humpback whale	0	0	0	0	0	0
Kogia spp.	0	0	0	0	0	0
Pilot whales	0	0	0	0	0	0
North Atlantic right whale	0	0	0.00072	0.00013	0	0
Blainville's beaked whale	0	0	0	0	0	0
Cuvier's beaked whale	0	0	0	0	0	0
Gervais' beaked whale	0	0	0	0	0	0
True's beaked whale	0	0	0	0	0	0
Sperm whale	0	0	0	0	0	0
Atlantic spotted dolphin	0	0	0	0	0	0
Pantropical spotted dolphin	0	0	0	0	0	0
Striped dolphin	0	0	0	0	0	0
Common bottlenose dolphin	0	0	0	0	0	0

Table C-6. 3-m pinpile exposure estimates with 18 dB reduction as mitigation.

Marine Mammal Species	***Behavioral Exposures***		***Cumulative SEL Injury Exposures***		***Peak SPL Injury Exposures***	
	April-Nov	***May-Oct***	***April-Nov***	***May-Oct***	***April-Nov***	***May-Oct***
Risso's dolphin	0	0	0	0	0	0
Common dolphin	0	0	0	0	0	0
Fin whale	0	0	0	0	0	0
Harbor porpoise	0.05	0.01	0	0	0	0
Harbor seal	0.01	0.01	0	0	0	0
Killer whale	0	0	0	0	0	0
Rough-toothed dolphin	0	0	0	0	0	0
Common minke whale	0	0	0	0	0	0
Humpback whale	0	0	0	0	0	0
Kogia spp.	0	0	0	0	0	0
Pilot whales	0	0	0	0	0	0
North Atlantic right whale	0	0	0.00036	0.00010	0	0
Blainville's beaked whale	0	0	0	0	0	0
Cuvier's beaked whale	0	0	0	0	0	0
Gervais' beaked whale	0	0	0	0	0	0
True's beaked whale	0	0	0	0	0	0
Sperm whale	0	0	0	0	0	0
Atlantic spotted dolphin	0	0	0	0	0	0
Pantropical spotted dolphin	0	0	0	0	0	0
Striped dolphin	0	0	0	0	0	0
Common bottlenose dolphin	0	0	0	0	0	0

Table C-7. 3-m pinpile exposure estimates with 20 dB reduction as mitigation.

Marine Mammal Species	Behavioral Exposures		Cumulative SEL Injury Exposures		Peak SPL Injury Exposures	
	April-Nov	May-Oct	April-Nov	May-Oct	April-Nov	May-Oct
Risso's dolphin	0	0	0	0	0	0
Common dolphin	0	0	0	0	0	0
Fin whale	0	0	0	0	0	0
Harbor porpoise	0.04	0.01	0	0	0	0
Harbor seal	0.01	0.00	0	0	0	0
Killer whale	0	0	0	0	0	0
Rough-toothed dolphin	0	0	0	0	0	0
Common minke whale	0	0	0	0	0	0
Humpback whale	0	0	0	0	0	0
Kogia spp.	0	0	0	0	0	0
Pilot whales	0	0	0	0	0	0
North Atlantic right whale	0	0	0	0	0	0
Blainville's beaked whale	0	0	0	0	0	0
Cuvier's beaked whale	0	0	0	0	0	0
Gervais' beaked whale	0	0	0	0	0	0
True's beaked whale	0	0	0	0	0	0
Sperm whale	0	0	0	0	0	0
Atlantic spotted dolphin	0	0	0	0	0	0
Pantropical spotted dolphin	0	0	0	0	0	0
Striped dolphin	0	0	0	0	0	0
Common bottlenose dolphin	0.18	0.21	0	0	0	0