Appendix J. Overview of Acoustic Modeling Reports

J.1. Introduction

This appendix is focused on providing an overview of the methods, assumptions, and results of the technical acoustic modeling reports prepared for the Projects (COP Appendices M-1 and M-2; Empire 2023). Readers who may be less familiar with acoustic terminology are recommended to refer to Section M-1.1.1, *Acoustic Concepts and Terminology*, in Appendix M-1 of the COP (Empire 2023), Appendix A, *Glossary*, to Appendix M-2 of the COP (Empire 2023), and Appendix D, *Underwater Acoustics*, to Appendix M-2 of the COP (Empire 2023).

The 2,076-MW Projects, which encompass EW 1 and EW 2, would consist of up to 147 WTGs, up to two OSS, and interarray and export cables. The Projects would be on the OCS offshore New York in BOEM's Lease Area OCS-A 0512. The primary underwater noise-producing activity for the Projects would be impact pile driving during construction. Other modeled noise-producing activities include drilling during WTG foundation installation and vibratory pile driving during cofferdam installation. This appendix focuses on the quantitative underwater noise modeling conducted for Project activities (i.e., impact pile driving and vibratory pile driving). Qualitative assessments of lower noise-level activities, including cable laying (i.e., operation of dynamic positioning thrusters by the cable-laying vessel), WTG operation, and marina activities (including bulkhead repairs and the removal of berthing piles) are also provided in Appendices M-1 and M-2 of the COP (Empire 2023).

For the quantitative modeling assessment for impact pile driving for foundation installation, predicted sound fields were generated for 31.5-foot (9.6-meter) diameter[1] monopiles, 36.1-foot (11-meter) diameter R3 monopiles, 36.1-foot (11-meter) diameter T1 monopiles, and 36.1-foot (11-meter) diameter U3 monopiles for WTG foundations and 8.2-foot (2.5-meter) diameter pin piles for jacketed OSS foundations. Modeling scenarios included two representative locations each for the R3, T1, and U3 monopile foundations; three representative locations for the 31.5-foot (9.6-meter) monopile foundations; and two locations for the jacket foundations with pin piles to represent the types of piles and range of water depths in the Project area (COP Appendix M-2, Figure 2; Empire 2023). For each of their respective monopile foundation locations, modeling was conducted at a maximum hammer energy of 2,000 kJ for R3 monopiles, 2,500 kJ for the T1 monopiles, and 1,300 kJ for the U3 monopiles. At each 31.5-foot (9.6-meter) monopile location, modeling was conducted for a typical scenario, with a maximum hammer energy of 2,300 kJ, and a difficult-to-drive scenario, with a maximum hammer energy of 5,225 kJ. Modeling scenarios included one or two monopiles driven per day, two to three pin piles driven per day, and all possible combinations of monopiles and pin piles driven per day. Sound field predictions were made for both summertime and wintertime conditions to account for variation in sound propagation caused by water temperature, as well as different levels of noise attenuation, including 0 (i.e., no mitigation), 6, 10, and 15 dB. In addition to impact pile driving for foundation installation, predicted sound fields for impact pile driving for goal post installation (as an alternative to the use of cofferdams for cable landfalls) at one representative location were also calculated.

For the quantitative modeling assessment for vibratory pile driving associated with cofferdam installation, predicted sound fields were generated for five locations: the anticipated EW 1 export cable landfall site, three representative locations for the EW 2 export cable landfall site, and one representative location for the western approach to EW 2 Landfall C. The representative locations for EW 2 export cable landfall sites include a location representative of EW 2 Landfalls A, B, and E; a location representative of a

[1] The diameter provided for tapered monopiles is the diameter at the expected waterline.

shallow-water option for EW 2 Landfall C; and a location representative of a deep-water option for EW 2 Landfall C. Additional predicted sound fields were generated for vibratory pile driving associated with marina activities: one representative location for sheetpile installation at the EW 2 Onshore Substation C, and one representative location for berthing pile removal at the EW 2 Onshore Substation C marina. Sound field predictions were made for the conditions that resulted in the greatest sound propagation (i.e., maximum underwater noise impacts).

The predicted sound fields for impact pile driving and vibratory pile driving were used to predict ranges to isopleths associated with acoustic criteria for injury and behavioral impacts. These ranges were then used to estimate the number of marine animals that could be exposed to sound levels exceeding acoustic criteria for each modeled noise source.

J.2. Acoustic Models and Assumptions

The quantitative assessments of noise-producing activities rely upon a variety of acoustic models to predict the potential effect of Project activities on marine animals. The models used in the quantitative analyses include:

1. GRL Wave Equation Analysis Program (GRLWEAP) Model: to model the force applied to the pile by the impact hammer
2. Finite Difference Model: to compute pile vibration and near-field sound radiation after the impact hammer strikes the pile to calculate source levels
3. Full Waveform Range-dependent Acoustic Model (FWRAM): to calculate the time-dependent sound field, SPL, and SEL metrics for impact pile driving
4. dBSea Parabolic Equation (dBSeaPE) Method: to calculate one-third octave band noise levels for drilling and vibratory pile driving in the 12.5- to 800-Hz frequency range
5. dBSea Ray Tracing (dBSeaRay) Method: to calculate one-third octave band noise levels for drilling and vibratory pile driving in the 1,000- to 20,000-Hz frequency range
6. JASMINE Model: the JASCO Applied Sciences animat[2] movement and exposure model used to estimate the number of animals exposed to sound levels exceeding regulatory criteria (Section J.5)

FWRAM, dBSeaPE, and dBSeaRay predict the propagation of the source signal through the physical environment. As such, these models require accurate descriptions of ocean bathymetry, seafloor sediment properties, and sound speed profile (SSP) in the water column. The assumptions of these models and their inputs are critical to the accuracy of the model output.

J.2.1 Physical Environment

The bathymetry information used to model impact pile driving was compiled from the Shuttle Radar Topography Mission data (Becker et al. 2009). Bathymetry data used to model drilling and vibratory pile driving were obtained from the National Geographic Data Center's U.S. Coastal Relief Model. A simplified geoacoustic profile of the sediment properties for modeling was developed based on site-specific geotechnical data collected by Empire. SSPs used to model impact pile driving were extracted from the U.S. Navy's Generalized Digital Environmental Model (Naval Oceanographic Office 2003). SSPs used to model vibratory pile driving were obtained using the NOAA Sound Speed Manager software, which incorporates the World Ocean Atlas 2009 extension algorithms (World Ocean Atlas 2009). Water temperatures and density change seasonally and vertically within the water column; therefore, representative summer and winter SSPs were used for modeling. For the impact pile driving assessment, seasonal SSPs were calculated by averaging monthly SSPs for the summer months (i.e., May

[2] Animat = simulated animal

through September) and the winter months (i.e., December through March). For the goal post installation and vibratory pile driving assessments, a seasonal monthly SSP was selected to represent the maximum underwater noise impacts. A sensitivity analysis identified the December SSP as having the greatest sound propagation. Therefore, the December SSP was used for assessment of these activities.

J.2.2 Sound Source Details

J.2.2.1. Impact Pile Driving for Foundation Installation

Pile dimensions, hammer energy, and number of strikes are required inputs for the modeling of impact pile driving for foundation installation (Table J-1).

Typical installation of the 78.5-meter-long WTG foundation 9.6-meter diameter monopiles with an IHC S-5500 hammer was expected to begin with 450-kJ hammer strikes that would be scaled up to 2,300 kJ at the end of the pile installation. A total of 5,497 strikes were expected per pile, and the strike rate was estimated at 30 strikes per minute. Spectral source levels for the 9.6-meter monopiles under a typical installation were estimated at up to approximately 200 dB re 1 μPa^2s. A difficult installation of the 78.5-meter-long WTG foundation 9.6-meter diameter monopiles with an IHC S-5500 hammer was expected to begin with 450-kJ hammer strikes that would be scaled up to 5,225 kJ at the end of the pile installation. A total of 7,165 strikes were expected per pile, and the strike rate was estimated at 30 strikes per minute. Installation of the 75.3-meter-long WTG foundation 11-meter diameter R3 monopiles with an IHC S-5500 hammer was expected to begin with 500-kJ hammer strikes that would be scaled up to 2,000 kJ at the end of the pile installation. A total of 4,025 strikes were expected per pile, and the strike rate was estimated at 30 strikes per minute. Spectral source levels for the 11-meter R3 monopiles under were estimated at up to approximately 195 dB re 1 μPa^2s. Installation of the 84.1-meter-long WTG foundation 11-meter diameter T1 monopiles with an IHC S-5500 hammer was expected to begin with 500-kJ hammer strikes that would be scaled up to 2,500 kJ at the end of the pile installation. A total of 4,919 strikes were expected per pile, and the strike rate was estimated at 30 strikes per minute. Spectral source levels for the 11-meter T1 monopiles under a typical installation were estimated at up to approximately 195 dB re 1 μPa^2s. Installation of the 97.5-meter-long WTG foundation 11-meter diameter U3 monopiles with an IHC S-5500 hammer was expected to begin with 450-kJ hammer strikes that would be scaled up to 1,300 kJ at the end of the pile installation. A total of 7,335 strikes were expected per pile, and the strike rate was estimated at 30 strikes per minute. Spectral source levels for the 11-meter U3 monopiles were estimated at up to approximately 190 dB re 1 μPa^2s. Installation of the 57- to 66-meter-long pin piles for the OSS jacket foundations with an IHC S-4000 hammer was expected to scale from 500 to 3,200 kJ during pile installation. For the EW 1 OSS, 4,340 strikes were predicted for each pin pile, with a strike rate of 30 strikes per minute. For the EW 2 OSS, 3,711 strikes were predicted for each pin pile, with a strike rate of 30 strikes per minute. Spectral source levels for the pin piles were estimated at up to approximately 185 dB re 1 μPa^2s. No simultaneous pile driving was included in the modeling assumptions.

J.2.2.2. Impact Pile Driving for Goal Post Installation

The source level of the impact pile driver for goal post installation was assumed to be 200 dB re 1 µPa peak SPL and 174 dB re 1 μPa^2s SEL. A total of 2,000 strikes are expected per pile, and anticipated drive time is 2 hours per pile.

Table J-1 Key Assumptions Used in the Underwater Acoustic Modeling of Impact Pile Driving

Foundation type	Scenario	Modeled maximum impact hammer energy (kJ)	Number of Strikes	Strike Rate (min^{-1})	Pile diameter (m)	Pile wall thickness (mm)	Maximum Seabed penetration (m)	Piles per day
Monopile	Typical	2,300	5,497	30	9.6	73–101	38	1–2
Monopile	Difficult-to-Drive	5,225	7,165	30	9.6	73–101	38	1-2
R3 Monopile	Typical	2,000	4,025	30	11	8.5	55	1-2
T1 Monopile	Typical	2,500	4,919	30	11	8.5	55	1-2
U3 Monopile	Typical	1,300	7,335	30	11	8.5	55	1-2
Jacket	Typical	3,200	3,711/4,340[1]	30	2.5	50	56	2–3

[1] Number of strikes for OSS2/OSS1
min = minute; m = meter; mm = millimeter

J.2.2.3. Vibratory Pile Driving

The source level of the vibratory pile driver was assumed to be 189 dB re 1 μPa^2s SEL with an 1,800-kilonewton vibratory force over a 24-hour assessment period for cofferdam installation; for vibratory pile driving associated with sheetpile installation, the source level was assumed to be 160 dB re 1 μPa^2s SEL; and for pile driving associated with berthing pile removal, the source level was assumed to be 165 dB re 1 μPa^2s SEL.

J.2.3 Noise Attenuation

No specific noise-attenuation system was identified for the assessment of impact pile-driving noise associated with foundation installation. However, a minimum sound-source attenuation of 10 dB was assumed to model impact pile driving. This level of attenuation was selected as an achievable reduction in sound levels when one noise-attenuation system is in use (Empire 2023 citing Austin and Li 2016; Empire 2023 citing Bellman 2014; Empire 2023 citing Buehler et al. 2015; Empire 2023 citing Koschinski and Lüdemann 2013). An attenuation of 10 dB produces a 90-percent reduction in sound levels. Additional levels of attenuation (0, 6, and 15 dB) were also modeled for comparison. These results are presented in Appendix H, *Acoustic Ranges*, and Appendix I, *Animal Movement and Exposure* Modeling, to Appendix M-2 of the COP (Empire 2023).

The use of noise attenuation is not anticipated for vibratory pile driving associated with cofferdam installation, sheetpile installation, or removal of berthing piles, or for impact driving of goal post piles. Therefore, noise attenuation was not included in the analysis of these activities.

J.3. Methodology

J.3.1 Noise Propagation Modeling

J.3.1.1. Impact Pile Driving for Foundation Installation

To model the sound from impact pile driving, including WTG foundation monopiles, OSS jacket foundation pin piles, and goal post piles, the force of the pile-driving hammers was computed using the GRLWEAP 2010 wave equation model (Pile Dynamics 2010). The forcing functions from GRLWEAP were used as inputs to the Finite Difference model to compute the resulting pile vibrations. The sound radiating from the pile was simulated using a vertical array of discrete point sources. Their amplitudes and phases were derived using an inverse technique, such that their collective particle velocity, calculated using a near-field wave-number integration model, matched the particle velocity in the water at the pile wall. The sound field propagating away from the vertical array was calculated using the FWRAM, which utilizes an array starter method to accurately model sound propagation from a spatially distributed sound source (Empire 2023 citing MacGillivray and Chapman 2012).

FWRAM was used to model synthetic pressure waveforms over a 10- to 1,024-Hz frequency range. Pressure wave forms were computed as a function of range and depth using Fourier synthesis of transfer functions. The modeled pressure waveforms were post-processed to calculate SPL and SEL metrics moving away from the sound source, both vertically (i.e., with depth) and horizontally (i.e., over range). A 20-dB-per-decade decay rate was used to extend the sound field frequency range up to 65,000 Hz.

J.3.1.2. Impact Pile Driving for Goal Post Installation

Modeling of goal post installation utilized the optional User Spreadsheet Tool developed by NMFS, which generates estimated distances to cumulative and peak sound exposure thresholds based on user-provided sound source characteristics. Unlike foundation installation, which is a significantly more impactful offshore activity with complex propagation mechanics that benefit from the more robust modeling described in Section J.3.1.1, goal post installation is a standard, small-scale, coastal activity. These types of activities are typically evaluated with simpler propagation models, such as those used in the NMFS optional User Spreadsheet Tool, because evaluation of activities of this scale does not benefit from more complicated modeling. The use of the optional User Spreadsheet Tool to evaluate impact pile driving for goal post installation was discussed and agreed to by NMFS and BOEM acousticians.

J.3.1.3. Vibratory Pile Driving

Vibratory pile-driving activities include cofferdam installation, sheetpile installation for bulkhead repairs, and berthing pile removal. dBSea software was used to model vibratory pile-driving for cofferdam installation by calculating noise levels throughout the Project area in one-third octave bands. To analyze vibratory pile-driving noise, a split solver was used to cover frequencies from 12.5 to 20,000 Hz. dBSeaPE was used for frequencies from 12.5 to 800 Hz, and dBSeaRay was used for frequencies from 1,000 to 20,000 Hz. Modeling of sheetpile installation and berthing pile removal utilized the optional User Spreadsheet Tool developed by NMFS.

J.3.2 Ranges to Regulatory Thresholds

A maximum-over-depth approach was used to calculate distances to acoustic thresholds associated with injury and behavioral effects on marine animals (i.e., isopleths) (Section J.5). For this approach, the maximum received sound level that occurs within the water column at a given range was used as the sound level at that distance. The 95th percentile of all isopleth distances from the source ($R_{95\%}$) was used to represent the range to regulatory thresholds for the determination of ensonified areas (Figure J-1). As shown on Figure J-1, 95 percent of the area exceeding a specific acoustic threshold occurs within this range from the source.

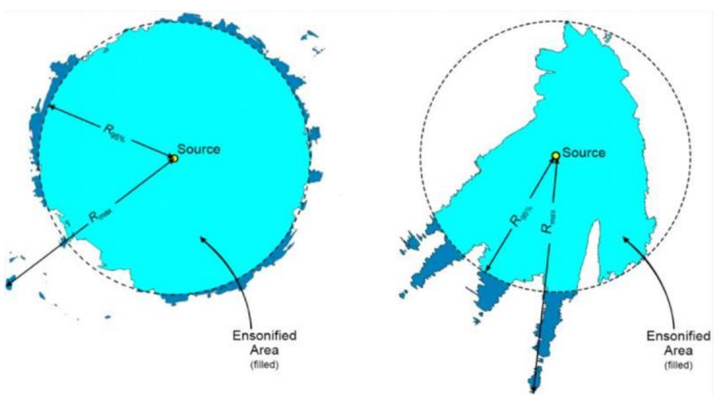

Figure J-1 Illustration of Ensonified Areas Based on $R_{95\%}$, which Was Calculated from Maximum Isopleth Ranges (R_{max})

J.3.3 Animal Movement Modeling

Predicted animal movements, in combination with predicted ensonified areas, are needed to estimate animal exposures to underwater noise during Project construction. Models using simulated animals, called "animats," are generally used to predict animal movements (Dean 1998; Frankel et al. 2002). Such modeling is typically conducted for individual species but may be conducted for representative species groups if sufficient data are not available. Animat models require input data describing a variety of species-specific behavioral parameters, such as the range of swimming speeds, dive depths, and course changes. Animat models simulate four-dimensional movements of the animat across latitude, longitude, depth, and time.

The JASMINE animat modeling program was used to simulate animal movement through predicted ensonified areas modeled for the Projects to estimate the probability of exposure to sound levels exceeding regulatory thresholds (Section J.5). As the input parameters for the model are based on observations of swimming behavior collected over relatively short periods (i.e., hours to days) and do not include large-scale movements over relatively long periods (e.g., migration patterns), a simulation period of 7 days was selected for this modeling effort. The simulation area was limited to a maximum distance of 38 miles (70 kilometers) of the Lease Area. All simulations were seeded with an animat density of 0.5 animat per km^2 over the entire simulation area to generate statistically reliable probability density functions.

Within each simulation, the animat served as a sound receiver, sampling sound levels within the predicted ensonified area as the animat moved. For each simulation, JASMINE provided output quantifying the exposure history (i.e., received sound levels over the course of the simulation period) for each animat as it moved through the environment during noise-producing Project activities. Each animat's exposure history was used to identify maximum received SPLs, and exposure levels were summed over a 24-hour period to determine received SELs. These SPLs and SELs were then compared to regulatory thresholds.

To estimate the number of marine animals likely to be exposed to sound levels exceeding the regulatory thresholds over the duration of the Projects, four different construction schedules occurring over a 2-year period were modeled, with 96 monopiles and 24 pin piles being installed in Year 1 and 51 monopiles and no pin piles being installed in Year 2 (COP Volume 2, Appendix M-2, Section 1.2.2; Empire 2023). In construction schedule 1, one monopile and two pin piles are driven per day; in construction schedule 2, one monopile and three pin piles are driven per day; in construction schedule 3, two monopiles and 2 pin piles are driven per day; and in construction schedule 4, two monopiles and three pin piles are driven per day.

Behavioral aversion to sound sources was modeled for a subset of scenarios for comparison purposes only. Parameters determining aversion at specified sound levels were implemented for two species: NARW (*Eubalaena glacialis*) and harbor porpoise (*Phocoena phocoena*). NARW was selected due to its critically endangered status, and harbor porpoise was selected based on its documented strong aversive response to loud sounds. Aversion for these two marine mammal species was implemented by allowing the animats to change course away from the sound source, with heading changes determined by received sound levels. Aversion thresholds were based on the Wood et al. (2012) step function (COP Appendix M-2, Tables I-1 and I-2; Empire 2023). Animats remained in the aversive state for a specified amount of time based on received sound levels before returning to a normal state.

J.4. Marine Species Present in the Project Area

Thirty-nine marine mammal stocks (38 species) and four species of sea turtles potentially occur near the Project area. All four sea turtle species and six marine mammal species are listed under the ESA; all marine mammals are protected under the MMPA. Species with common or uncommon occurrence (Table J-2) were selected for quantitative movement modeling and exposure estimates. Rare species were not modeled because acoustic impacts on these species would approach zero due to their low densities.

Table J-2 Marine Mammal and Sea Turtle Species Quantitatively Analyzed

Species	Stock	Abundance
Mysticetes		
Fin whale *Balaenoptera physalus*	Western North Atlantic	6,802
Humpback whale *Megaptera novaeangliae*	Gulf of Maine	1,396

Species	Stock	Abundance
Minke whale *B. acutorostrata*	Canadian Eastern Coastal	21,968
NARW *E. glacialis*	Western	368
Sei whale *B. borealis*	Nova Scotia	6,292
Odontocetes		
Atlantic spotted dolphin *Stenella frontalis*	Western North Atlantic	39,921
Atlantic white-sided dolphin *Lagenorhynchus acutus*	Western North Atlantic	93,233
Bottlenose dolphin *Tursiops truncatus*	Western North Atlantic Offshore	62,851
	Western North Atlantic Northern Migratory Coastal	6,639
Harbor porpoise *P. phocoena*	Gulf of Maine/Bay of Fundy	95,543
Long-finned pilot whale *Globicephala melas*	Western North Atlantic	39,215
Risso's dolphin *Grampus griseus*	Western North Atlantic	35,493
Short-beaked common dolphin *Delphinus delphis*	Western North Atlantic	172,974
Short-finned pilot whale *G. macrorhynchus*	Western North Atlantic	28,924
Sperm whale *Physeter macrocephalus*	North Atlantic	4,349
Pinnipeds		
Gray seal *Halichoerus grypus*	Western North Atlantic	27,300
Harbor seal *Phoca vitulina*	Western North Atlantic	61,336
Harp seal *Pagophilus groenlandicus*	Western North Atlantic	Unknown
Sea Turtles		
Green sea turtle *Chelonia mydas*	--	--
Kemp's ridley sea turtle *Lepidochelys kempii*	--	--
Leatherback sea turtle *Dermochelys coriacea*	--	--
Loggerhead sea turtle *Caretta caretta*	--	--

Source: COP Volume 2, Section 3.15, and COP Appendix M-2; Empire 2023

J.4.1 Marine Mammal Densities

J.4.1.1. Lease Area

To estimate marine mammal exposures for impact pile driving for foundation installation, estimates of mean monthly density (animals per 100 km^2) for all common and uncommon marine mammal species occurring in the Project area (Table J-2) were obtained from the Duke University Marine Geospatial Ecology Laboratory (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b), including the recently updated model results for the NARW. These densities are provided in Table J-3. The updated model includes new NARW abundance estimates for Cape Cod Bay in December. The modeling used the most recent 2010 to 2018 density predictions for the NARW.

Densities were calculated for a 3.4-mile (5.5-kilometer) buffered polygon around the Lease Area perimeter. This buffer size was selected as the largest 10 dB-attenuated exposure range, rounded up to the nearest 0.5 kilometer. All species, scenarios, and threshold criteria were included in this calculation.

Mean density for each month was determined by calculating the unweighted mean density of all grid cells partially or fully within the buffered polygon. Grid cells were 6.2 by 6.2 miles (10 by 10 kilometers), except for NARW, which were 3.1 by 3.1 miles (5 by 5 kilometers). Densities were computed monthly, annually, and for the May through December period to coincide with proposed pile-driving activities for the Projects. In cases where monthly densities were unavailable, annual mean densities were used instead.

Although long-finned and short-finned pilot whales were modeled separately, only one density model was available for pilot whales that encompasses both pilot whale species (Roberts et al. 2016a, 2016b, 2017). Densities for each species were calculated by estimating the total pilot whale densities in the buffered polygon and then scaling by relative abundance of both species.

J.4.1.2. Cable Landfall Area

To estimate marine mammal exposures for vibratory pile driving for cofferdam installation, average seasonal densities in the cable landfall area were obtained from the Duke University Marine Geospatial Ecology Laboratory (Roberts et al. 2016b, 2017, 2018, 2020, 2021a). These densities are provided in Table J-4.

Table J-3 Mean Monthly Marine Mammal Density Estimates for Impact Pile Driving for Foundation Installation

Species	Monthly Densities (animals per 100 km^2)												Annual Mean Density
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Fin whale	0.099	0.095	0.115	0.189	0.236	0.258	0.232	0.172	0.163	0.189	0.105	0.084	0.161
Humpback whale	0.061	0.031	0.020	0.044	0.042	0.048	0.020	0.013	0.062	0.129	0.054	0.065	0.049
Minke whale	0.036	0.044	0.045	0.148	0.148	0.080	0.012	0.013	0.062	0.035	0.018	0.026	0.051
NARW	0.479	0.548	0.645	0.726	0.122	0.007	0.002	0.002	0.002	0.005	0.031	0.230	0.233
Sei whale	0.001	0.001	0.001	0.021	0.018	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.004
Atlantic spotted dolphin	0.005	0.002	0.003	0.011	0.027	0.114	0.283	0.148	0.263	0.146	0.145	0.015	0.097
Atlantic white sided dolphin	0.755	0.501	0.588	1.537	2.533	2.111	0.741	0.260	0.495	1.158	1.012	1.254	1.079
Bottlenose dolphin	0.629	0.045	0.018	0.305	0.705	2.442	2.679	2.941	2.240	1.318	1.284	0.651	1.271
Harbor porpoise	7.573	11.683	11.252	6.946	2.059	0.037	0.051	0.079	0.072	0.157	2.874	6.549	4.111
Long-finned pilot whale	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
Risso’s dolphin	0.006	0.003	0.001	0.001	0.003	0.003	0.014	0.030	0.012	0.003	0.006	0.014	0.008
Short-beaked common dolphin	7.494	1.434	0.573	0.947	1.038	0.930	0.863	2.235	3.413	5.013	4.336	11.713	3.332
Short-finned pilot whale	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
Sperm whale	0.001	0.001	0.001	0.001	0.006	0.027	0.042	0.029	0.027	0.009	0.007	0.001	0.013
Seals	5.941	11.886	10.158	8.808	6.431	0.266	0.017	0.008	0.022	0.095	0.318	3.984	3.994

Sources: Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b

Table J-4 Mean Seasonal Marine Mammal Density Estimates for Vibratory Pile Driving for Cofferdam Installation

Species	Seasonal Densities (animals per 100 km^2)	
	EW 1 Cofferdams	EW 2 Cofferdams
NARW	0.29	0.029
Humpback whale	0.07	0.07
Fin whale	0.17	0.17
Sei whale	0.01	0.01
Sperm whale	0.02	0.02
Minke whale	0.08	0.08
Bottlenose dolphin (Western North Atlantic Northern Migratory Coastal Stock)	6.6	6.6
Atlantic spotted dolphin	0.14	0.14
Short-beaked common dolphin	4.94	4.94
Atlantic white-sided dolphin	1.02	1.02
Risso's dolphin	0.01	0.01
Pilot whale spp.	0.11	0.11
Harbor porpoise	9.07	9.07

Sources: Roberts et al. 2016b, 2017, 2018, 2020, 2021a

J.4.2 Sea Turtle Densities

Density estimates for sea turtles in the Project area are limited. Aerial survey data collected by the New York State Energy Research and Development Authority (Normandeau Associates and APEM 2018, 2019a, 2019b, 2019c, 2020) were used to develop seasonal density estimates for quantitative analysis of acoustic impacts on sea turtles. Maximum seasonal abundance for each species was extracted from the aerial survey data and corrected to represent the Project area. Corrected abundance was scaled by the Project area to obtain species density in units of animals per km^2 (Table J-5).

Table J-5 Mean Seasonal Sea Turtle Density Estimates for All Modeled Sea Turtle Species

Species	Seasonal Densities (animals per 100 km^2)			
	Spring	Summer	Fall	Winter
Green sea turtle	0.000	0.000	0.000	0.000
Kemp's ridley sea turtle	0.001	0.010	0.002	0.000
Leatherback sea turtle	0.000	0.003	0.008	0.000
Loggerhead sea turtle	0.003	0.268	0.002	0.000

J.5. Acoustic Impact Criteria

J.5.1 Marine Mammals

Marine mammal acoustic criteria used for the modeling effort were derived from the current U.S. regulatory acoustic criteria. Peak SPLs (L_{pk}) and frequency-weighted accumulated SELs ($L_{E,24h}$) were taken from the NOAA Technical Guidance (NMFS 2018) for marine mammal injury thresholds (Table

J-6). SPL (L_p) for marine mammal behavioral thresholds were based on the unweighted NMFS (2005) (Table J-6) and the frequency-weighted Wood et al. (2012) criteria (Table J-7).

Table J-6 NMFS Regulatory Acoustic Criteria for Marine Mammals

Functional Hearing Group	Sound Source Type				
	Impulsive			Non-Impulsive	
	Level A $L_{E,\,24h}$[1]	Level A L_{pk}[2]	Level B L_p[2]	Level A $L_{E,\,24h}$[1]	Level B L_p[2]
LFC	183	219	160	199	120
MFC	185	230		198	
HFC	155	202		173	
Phocid pinnipeds in water	185	218		201	

Sources: NMFS 2005, 2018
[1] Measured in dB re 1 μPa²s
[2] Measured in dB re 1 μPa

Table J-7 Frequency-Weighted Acoustic Criteria for Probabilistic Behavioral Response to Impulsive Noise Sources in Marine Mammals

Marine Mammal Group	Probabilistic Response			
	L_p[1] > 120	L_p[1] > 140	L_p[1] > 160	L_p[1] > 180
Beaked whales and harbor porpoises	50%	90%	--	--
Migrating mysticetes	10%	50%	90%	--
All other species	--	10%	50%	90%

[1] Measured in dB re 1 μPa

J.5.2 Sea Turtles

Peak SPLs and frequency-weighted accumulated SELs from Finneran et al. (2017) were used for the onset of PTS and TTS in sea turtles (Table J-8 and Table J-9). Behavioral response thresholds for sea turtles were obtained from McCauley et al. (2000).

J.5.3 Fish

Injury thresholds (L_{pk} and $L_{E,\,24hr}$) for different sized fish (i.e., less than 2 grams or 2 grams and larger) were based on the Fisheries Hydroacoustic Working Group (2008) and Stadler and Woodbury (2009). Injury thresholds (L_{pk} and $L_{E,\,24hr}$) for fish with different hearing capabilities (i.e., without swim bladder, with swim bladder not involved in hearing, and with swim bladder involved in hearing) were obtained from Popper et al. (2014). Behavioral thresholds for fish were developed by the NMFS Greater Atlantic Regional Fisheries Office (Andersson et al. 2007; Mueller-Blenkle et al. 2010; Purser and Radford 2011; Wysocki et al. 2007) (Table J-8 and Table J-9).

Table J-8 Acoustic Metrics and Thresholds for Impulsive Noise Sources for Fish and Sea Turtles

Faunal Group	Injury		Impairment		Behavior
	L_{pk}[1]	$L_{E,\,24hr}$[2]	L_{pk}[1]	$L_{E,\,24hr}$[2]	L_p[1]
Fish equal to or greater than 2 grams	206	187	--	--	150
Fish less than 2 grams		183	--	--	

Faunal Group	Injury		Impairment		Behavior
	L_{pk}[1]	$L_{E, 24hr}$[2]	L_{pk}[1]	$L_{E, 24hr}$[2]	L_p[1]
Fish without swim bladder	213	216	--	--	--
Fish with swim bladder not involved in hearing	207	203	--	--	--
Fish with swim bladder involved in hearing	207	203	--	--	--
Sea turtles	232	204	226	189	175

Sources: Andersson et al. 2007; Finneran et al. 2017; Fisheries Hydroacoustic Working Group 2008; McCauley et al. 2000; Mueller-Blenkle et al. 2010; Popper et al. 2014; Purser and Radford 2011; Stadler and Woodbury 2009; Wysocki et al. 2007
[1] Measured in dB re 1 μPa
[2] Measured dB re 1 $\mu Pa^2 s$

Table J-9 Acoustic Metrics and Thresholds for Non-Impulsive Noise Sources for Fish and Sea Turtles

Faunal Group	Injury		Impairment		Behavior
	L_p[1]	$L_{E, 24hr}$[2]	L_p[1]	$L_{E, 24hr}$[2]	L_p[1]
Fish equal to or greater than 2 grams	--	--	--	--	150
Fish less than 2 grams	--	--	--	--	
Fish without swim bladder	--	--	--	--	--
Fish with swim bladder not involved in hearing	--	--	--	--	--
Fish with swim bladder involved in hearing	170	--	158	--	--
Sea turtles	--	220	--	200	175

Sources: Andersson et al. 2007; Finneran et al. 2017; Fisheries Hydroacoustic Working Group 2008; McCauley et al. 2000; Mueller-Blenkle et al. 2010; Popper et al. 2014; Purser and Radford 2011; Stadler and Woodbury 2009; Wysocki et al. 2007
[1] Measured in dB re 1 μPa
[2] Measured dB re 1 $\mu Pa^2 s$

J.6. Results

J.6.1 Ranges to Acoustic Regulatory Thresholds

J.6.1.1. Impact Pile Driving for Foundation Installation

The complete results of acoustic modeling for impact pile driving of monopiles and pin piles presented in Appendix M-2 (Empire 2023) for the multiple combinations of the two modeled seasons, four modeled locations (two locations for monopiles and two locations for pin piles), varying levels of attenuation, pile-driving scenarios (i.e., typical and difficult-to-drive), and driving schedules are too numerous to replicate here. Instead, summaries of exposure ranges ($ER_{95\%}$) for marine mammals and sea turtles are presented herein (Table J-10 through Table J-23). Additionally, summaries of ranges to acoustic thresholds for sea turtles and fish are presented herein and are based on the maximum acoustic range (R_{max}) among the modeled scenarios for sea turtles and fish (Table J-24 through Table J-30). Variation in ranges presented in the tables arises from a number of factors, including differences in model assumptions for different foundation types (e.g., maximum hammer energy, number of strikes), differences in sound speed profiles due to differences in water column properties between seasons, differences in modeled location and the associated differences in environmental inputs (e.g., depth, sediment properties), and differences in schedule assumptions[3] (i.e., number of piles driven per day). Model inputs such as hammer energy,

[3] Differences in schedule assumptions would only be expected to affect ranges to SEL ($L_{E,24h}$) thresholds.

number of strikes (i.e., driving duration) at each energy level, and embedment depth are more significant inputs to the acoustic model than foundation diameter. The amount of sound generated during pile driving varies with the number of required strikes, and the energy required to drive piles to a desired depth depends on the sediment resistance encountered. Sediment types with greater resistance require higher hammer energy or an increased number of strikes relative to installations in softer sediment. For example, the greater ranges to Level B thresholds for marine mammals associated with 9.6-meter monopiles compared to those associated with 11-meter monopiles result mainly from the generally higher hammer energy used for the smaller monopiles (see Table J-1) due to the firmer substrates in which the smaller monopiles would be installed.

Table J-10 Exposure Ranges ($ER_{95\%}$) to MMPA Level A (Injury) and Level B (Behavioral Disturbance) Thresholds for Marine Mammals Due to Sound from Impact Pile Driving of One 9.6-meter Monopile WTG Foundation per Day with 0 and 10 dB of Noise Attenuation

Functional Hearing Group	Range (kilometers)											
	Typical Scenario						Difficult-to-Drive Scenario					
	0 dB			10 dB			0 dB			10 dB		
	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p
LFC	0.00	3.07	7.35	0.01	0.88	3.40	0.05	4.28	8.97	<0.01	1.80	5.24
MFC	0.00	0.00	7.09	0.00	0.00	3.40	0.00	0.00	8.82	0.00	0.00	5.14
HFC	0.22	0.00	7.04	0.00	0.00	3.15	0.57	0.02	8.71	0.08	0.00	5.04
PW	<0.01	0.11	7.37	0.00	0.00	3.54	<0.01	0.54	9.09	0.00	0.00	5.35

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
PW = phocid pinniped in water

Table J-11 Exposure Ranges ($ER_{95\%}$) to MMPA Level A (Injury) and Level B (Behavioral Disturbance) Thresholds for Marine Mammals Due to Sound from Impact Pile Driving of Two 9.6-meter Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Functional Hearing Group	Range (kilometers)											
	Typical Scenario						Difficult-to-Drive Scenario					
	0 dB			10 dB			0 dB			10 dB		
	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p
LFC	0.02	3.14	7.10	0.00	1.01	3.46	0.05	4.46	8.79	0.00	1.95	4.87
MFC	<0.01	0.00	6.86	0.00	0.00	3.32	<0.01	0.00	8.56	0.00	0.00	4.92
HFC	0.27	<0.01	6.80	<0.01	0.00	3.22	0.55	0.04	8.56	0.04	0.00	4.75
PW	0.03	0.13	7.22	0.00	0.00	3.50	0.07	0.52	8.96	0.00	<0.01	5.19

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
PW = phocid pinniped in water

Table J-12 Exposure Ranges ($ER_{95\%}$) to MMPA Level A (Injury) and Level B (Behavioral Disturbance) Thresholds for Marine Mammals Due to Sound from Typical Impact Pile Driving of One and Two 11-meter U3 Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Functional Hearing Group	Range (kilometers)											
	1 Monopile per Day						2 Monopiles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p
LFC	<0.01	2.70	5.61	<0.01	0.90	2.71	0.02	2.30	5.55	0.00	0.82	2.59
MFC	0.00	0.00	5.55	0.00	0.00	2.63	0.00	0.00	5.40	0.00	0.00	2.53
HFC	0.20	0.00	5.39	0.00	0.00	2.53	0.24	0.00	5.32	<0.01	0.00	2.51
PW	0.00	0.08	5.79	0.00	0.00	2.70	<0.01	0.04	5.71	<0.01	<0.01	2,67

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling,* to COP Appendix M-2 (Empire 2023)
PW = phocid pinniped in water

Table J-13 Exposure Ranges ($ER_{95\%}$) to MMPA Level A (Injury) and Level B (Behavioral Disturbance) Thresholds for Marine Mammals Due to Sound from Typical Impact Pile Driving of One and Two 11-meter T1 Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Functional Hearing Group	Range (kilometers)											
	1 Monopile per Day						2 Monopiles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p
LFC	<0.01	2.87	7.20	0.00	0.87	3.56	0.01	2.66	6.99	0.00	0.83	3.53
MFC	0.00	0.00	6.87	0.00	0.00	3.48	<0.01	0.00	6.76	0.00	0.00	3.35
HFC	0.22	0.00	6.87	0.00	0.00	3.41	0.24	0.00	6.64	<0.01	0.00	3.35
PW	<0.01	0.12	7.30	0.00	0.00	4.98	<0.01	0.14	7.20	0.00	0.00	3.66

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling,* to COP Appendix M-2 (Empire 2023)
PW = phocid pinniped in water

Table J-14 Exposure Ranges ($ER_{95\%}$) to MMPA Level A (Injury) and Level B (Behavioral Disturbance) Thresholds for Marine Mammals Due to Sound from Typical Impact Pile Driving of One and Two 11-meter R3 Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Functional Hearing Group	Range (kilometers)											
	1 Monopile per Day						2 Monopiles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p
LFC	<0.01	2.73	6.41	0.00	0.87	3.17	0.01	2.50	6.42	<0.01	0.48	3.14
MFC	<0.01	0.00	6.42	0.00	0.00	3.10	<0.01	0.00	6.25	0.00	0.00	4,21
HFC	0.23	0.00	6.27	0.00	0.00	3.07	0.26	0.00	6.23	<0.01	0.00	3.09
PW	<0.01	0.12	6.46	0.00	0.00	3.25	0.01	0.04	6.42	0.00	0.00	3.25

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
PW = phocid pinniped in water

Table J-15 Exposure Ranges ($ER_{95\%}$) to MMPA Level A (Injury) and Level B (Behavioral Disturbance) Thresholds for Marine Mammals Due to Sound from Impact Pile Driving of OSS1 Jacket Foundations with 0 and 10 dB of Noise Attenuation

Functional Hearing Group	Range (kilometers)											
	Two Pin Piles per Day						Three Pin Piles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E,\ 24h}$	Level B L_p
LFC	0.00	0.46	2.49	0.00	0.00	0.90	0.00	0.55	2.45	0.00	0.00	0.85
MFC	0.00	0.00	2.56	0.00	0.00	0.88	0.00	0.00	2.41	0.00	0.00	0.87
HFC	0.00	0.00	2.50	0.00	0.00	0.86	0.00	0.00	2.47	0.00	0.00	0.79
PW	0.00	0.00	2.62	0.00	0.00	0.99	0.00	0.00	2.60	0.00	0.00	0.99

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
PW = phocid pinniped in water

Table J-16 Exposure Ranges ($ER_{95\%}$) to MMPA Level A (Injury) and Level B (Behavioral Disturbance) Thresholds for Marine Mammals Due to Sound from Impact Pile Driving of OSS2 Jacket Foundations with 0 and 10 dB of Noise Attenuation

Functional Hearing Group	Range (kilometers)											
	Two Pin Piles per Day						Three Pin Piles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p	Level A L_{pk}	Level A $L_{E, 24h}$	Level B L_p
LFC	0.00	0.86	2.58	0.00	0.00	0.84	0.00	0.85	2.53	0.00	0.00	0.84
MFC	0.00	0.00	2.40	0.00	0.00	0.83	0.00	0.00	2.39	0.00	0.00	0.78
HFC	0.00	0.00	2.34	0.00	0.00	0.71	0.00	0.00	2.43	0.00	0.00	0.71
PW	0.00	0.00	2.68	0.00	0.00	0.79	0.00	0.00	2.67	0.00	0.00	0.78

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
PW = phocid pinniped in water

Table J-17 Exposure Ranges ($ER_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Sea Turtles Due to Sound from Impact Pile Driving of One 9.6-meter Monopile WTG Foundation per Day with 0 and 10 dB of Noise Attenuation

Species	Range (kilometers)											
	Typical Scenario						Difficult-to-Drive Scenario					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p
Kemp's ridley turtle	0.00	0.41	1.96	0.00	0.00	0.51	0.00	0.97	3.37	0.00	0.10	1.29
Leatherback turtle	0.00	0.79	2.37	0.00	0.00	0.73	0.00	1.54	3.87	0.00	0.15	1.60
Loggerhead turtle	0.00	0.00	1.99	0.00	0.00	0.38	0.00	0.48	3.19	0.00	0.00	1.24
Green turtle	0.00	0.39	2.13	0.00	0.00	0.36	0.00	1.44	3.61	0.00	0.17	1.67

Source: Summarized from Appendix I, *Animal Movement and Exposure Modeling,* to COP Appendix M-2 (Empire 2023)
Beh. = behavior; Inj. = injury

Table J-18 Exposure Ranges ($ER_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Sea Turtles Due to Sound from Impact Pile Driving of Two 9.6-meter Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Species	Range (kilometers)											
	Typical Scenario						Difficult-to-Drive Scenario					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p
Kemp's ridley turtle	0.00	0.37	1.90	0.00	0.00	0.67	<0.01	0.96	3.36	0	0.12	0.67
Leatherback turtle	0.00	0.80	2.35	0.00	0.06	0.75	0	1.57	3.85	0	0.31	0.82
Loggerhead turtle	0.00	0.45	1.89	0.00	0.00	0.49	0	0.56	2.91	0	0.03	0.55
Green turtle	0.00	0.50	2.11	0.00	0.00	0.66	0	1.48	3.61	0	0.19	0.67

Source: Summarized from Tables I-47 through I-54, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
Beh. = behavior; Inj. = injury

Table J-19 Exposure Ranges ($ER_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Sea Turtles Due to Sound from Impact Pile Driving of One and Two 11-meter U3 Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Species	Range (kilometers)											
	One Monopile per Day						Two Monopiles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p
Kemp's ridley turtle	0	0.15	1.41	0	0	0.45	0	0.21	1.45	0	0	0.33
Leatherback turtle	0	0.68	1.65	0	0	0.15	0	0.70	1.76	0	0	0.58
Loggerhead turtle	0	0	1.37	0	0	0.44	0	0.03	1.38	0	0	0.21
Green turtle	0	0.17	1.75	0	0	0.35	0	0.36	1.60	0	0	0.38

Source: Summarized from Tables I-55 through I-58, Appendix I, *Animal Movement and Exposure Modeling* , to COP Appendix M-2 (Empire 2023)
Beh. = behavior; Inj. = injury

Table J-20 Exposure Ranges ($ER_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Sea Turtles Due to Sound from Impact Pile Driving of One and Two 11-meter T1 Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Species	Range (kilometers)											
	One Monopile per Day						Two Monopiles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p
Kemp's ridley turtle	0	0.34	2.21	0	0	0.44	0	0.38	1.99	0	0	0.59
Leatherback turtle	0	0.70	2.50	0	0	0.74	0	0.76	2.47	0	0	0.81
Loggerhead turtle	0	0	2.00	0	0	0.39	0	0.45	2.02	0	0	0.59
Green turtle	0	0.16	2.32	0	0	0.81	0	0.64	2.29	0	0	0.75

Source: Summarized from Tables I-59 through I-62, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
Beh. = behavior; Inj. = injury

Table J-21 Exposure Ranges ($ER_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Sea Turtles Due to Sound from Impact Pile Driving of One and Two 11-meter R3 Monopile WTG Foundations per Day with 0 and 10 dB of Noise Attenuation

Species	Range (kilometers)											
	One Monopile per Day						Two Monopiles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p
Kemp's ridley turtle	0	0.37	1.79	0	<0.01	0.53	0	0.34	1.84	0	0	0.51
Leatherback turtle	0	0.57	2.20	0	0	0.71	0	0.51	2.15	0	0	0.75
Loggerhead turtle	0	0	1.66	0	0	0.39	0	0.14	1.81	0	0	0.45
Green turtle	0	0.16	2.05	0	0	0.61	0	0.47	1.99	0	0	0.58

Source: Summarized from Tables I-63 through I-66, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
Beh. = behavior; Inj. = injury

Table J-22 Exposure Ranges ($ER_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Sea Turtles Due to Sound from Impact Pile Driving of OSS1 Jacket Foundations per Day with 0 and 10 dB of Noise Attenuation

Species	Range (kilometers)											
	Two Pin Piles per Day						Three Pin Piles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}
Kemp's ridley turtle	0	0	0.35	0	0	0.11	0	0	0.35	0	0	0.10
Leatherback turtle	0	0	0.52	0	0	0	0	0	0.57	0	0	0
Loggerhead turtle	0	0	0.38	0	0	0	0	0	0.37	0	0	0
Green turtle	0	0	0.46	0	0	0	0	0	0.45	0	0	0

Source: Summarized from Tables I-67 through I-70, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
Beh. = behavior; Inj. = injury

Table J-23 Exposure Ranges ($ER_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Sea Turtles Due to Sound from Impact Pile Driving of OSS2 Jacket Foundations per Day with 0 and 10 dB of Noise Attenuation

Species	Range (kilometers)											
	Two Pin Piles per Day						Three Pin Piles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_{p}
Kemp's ridley turtle	0	0	0.37	0	0	0.07	0	0	0.40	0	0	0.07
Leatherback turtle	0	0	0	0	0	0	0	0	0	0	0	0
Loggerhead turtle	0	0	0.20	0	0	0	0	0	0.19	0	0	0
Green turtle	0	0	0.27	0	0	0	0	0	0.30	0	0	0

Source: Summarized from Tables I-71 through I-74, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
Beh. = behavior; Inj. = injury

Table J-24 Acoustic Ranges (R_{max}) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Impact Pile Driving of Typical 9.6-meter Monopile WTG Foundations with 0 and 10 dB of Noise Attenuation

Faunal Group	Range (kilometers)					
	0 dB			10 dB		
	Injury L_{pk}	Injury $L_{E,\ 24h}$	Behavior L_p	Injury L_{pk}	Injury $L_{E,\ 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	0.19	7.22	14.36	0.05	2.78	5.90
Fish less than 2 grams	0.19	9.24	14.36	0.05	3.87	5.90
Fish without swim bladder	0.09	0.37	--	--	0.07	--
Fish with swim bladder not involved in hearing	0.16	1.95	--	0.05	0.50	--
Fish with swim bladder involved in hearing	0.16	1.95	--	0.05	0.50	--
Sea turtles	--	1.78	2.42	--	0.44	0.72

Source: Summarized from Appendix H, *Acoustic Ranges*, to COP Appendix M-2 (Empire 2023)

Table J-25 Acoustic Ranges (R_{max}) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Impact Pile Driving-of-Difficult to Drive 9.6-meter Monopile WTG Foundations with 0 and 10 dB of Noise Attenuation

Faunal Group	Range (kilometers)					
	0 dB			10 dB		
	Injury L_{pk}	Injury $L_{E,\ 24h}$	Behavior L_p	Injury L_{pk}	Injury $L_{E,\ 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	0.46	9.34	17.00	0.11	5.20	9.28
Fish less than 2 grams	0.46	12.03	17.00	0.11	6.64	9.28
Fish without swim bladder	0.15	0.85	--	0.02	0.16	--
Fish with swim bladder not involved in hearing	0.41	3.39	--	0.09	1.27	--
Fish with swim bladder involved in hearing	0.41	3.39	--	0.09	1.27	--
Sea turtles	--	3.06	4.01	--	1.08	1.67

Source: Summarized from Appendix H, *Acoustic Ranges*, to COP Appendix M-2 (Empire 2023)

Table J-26 Acoustic Ranges (R_{max}) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Impact Pile Driving of 11-meter (R3, T1, and U3) Monopile WTG Foundations with 0 and 10 dB of Noise Attenuation

Faunal Group	Range (kilometers)					
	0 dB			10 dB		
	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	0.30	6.53	12.24	0.07	3.18	7.51
Fish less than 2 grams	0.30	8.46	13.72	0.07	4.39	7.51
Fish without swim bladder	0.11	0.34	--	0.01	0.07	--
Fish with swim bladder not involved in hearing	0.19	1.83	--	0.06	0.52	--
Fish with swim bladder involved in hearing	0.19	1.83	--	0.06	0.52	--
Sea turtles	--	1.67	2.57	--	0.44	0.87

Source: Summarized from Appendix H, *Acoustic Ranges*, to COP Appendix M-2 (Empire 2023)

Table J-27 Acoustic Ranges (R_{max}) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Impact Pile Driving of OSS1 Jacket Foundations (One Pin Pile per Day) with 0 and 10 dB of Noise Attenuation

Faunal Group	Range (kilometers)					
	0 dB			10 dB		
	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	0.02	2.87	6.31	0.01	0.92	2.67
Fish less than 2 grams	0.02	4.24	6.31	0.01	1.57	2.67
Fish without swim bladder	0.01	0.05	--	--	--	--
Fish with swim bladder not involved in hearing	0.02	0.42	--	0.01	0.11	--
Fish with swim bladder involved in hearing	0.02	0.42	--	0.01	0.10	--
Sea turtles	--	0.34	0.44	--	0.10	0.12

Source: Summarized from Appendix H, *Acoustic Ranges*, to COP Appendix M-2 (Empire 2023)

Table J-28 Acoustic Ranges (R_{max}) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Impact Pile Driving of OSS1 Jacket Foundations (Two and Three Pin Piles per Day) with 0 and 10 dB of Noise Attenuation

Faunal Group	Range (kilometers)											
	2 Pin Piles per Day						3 Pin Piles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p
Fish ≥ 2 grams	0.02	3.91	6.31	0.01	1.41	2.66	0.02	4.51	6.31	0.01	1.72	2.66
Fish < 2 grams	0.02	5.35	6.31	0.01	2.19	2.66	0.02	6.08	6.31	0.01	2.59	2.66
Fish without swim bladder	0.01	0.11	--	--	0.01--		0.01	0.13	--	--	0.02	--
Fish with swim bladder not involved in hearing	0.02	0.64	--	0.01	0.16		0.02	0.82	--	0.01	0.20	--
Fish with swim bladder involved in hearing	0.02	0.64	--	0.01	0.16		0.02	0.82	--	0.01	0.20	--
Sea turtles	--	0.54	0.44	--	0.13	0.12	--	0.70	0.44	--	0.18	0.12

Source: Summarized from Appendix H, *Acoustic Ranges*, to COP Appendix M-2 (Empire 2023)
≥ = greater than or equal to; < = less than; Beh. = behavior; Inj. = injury

Table J-29 Acoustic Ranges (R_{max}) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Impact Pile Driving of OSS2 Jacket Foundations (One Pin Pile per Day) with 0 and 10 dB of Noise Attenuation

Faunal Group	Range (kilometers)					
	0 dB			10 dB		
	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	0.02	3.01	6.78	--	0.93	2.60
Fish less than 2 grams	0.02	4.64	6.78	--	1.60	2.66
Fish without swim bladder	--	0.05	--	--	--	--
Fish with swim bladder not involved in hearing	--	0.39	--	--	0.06	--
Fish with swim bladder involved in hearing	--	0.39	--	--	0.06	--

Faunal Group	Range (kilometers)					
	0 dB			10 dB		
	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p	Injury L_{pk}	Injury $L_{E, 24h}$	Behavior L_p
Sea turtles	--	0.35	0.42	--	0.06	0.10

Source: Summarized from Appendix H, *Acoustic Ranges*, to COP Appendix M-2 (Empire 2023)

Table J-30 Acoustic Ranges (R_{max}) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Impact Pile Driving of OSS2 Jacket Foundations with 0 and 10 dB of Noise Attenuation

Faunal Group	Range (kilometers)											
	2 Pin Piles per Day						3 Pin Piles per Day					
	0 dB			10 dB			0 dB			10 dB		
	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p	Inj. L_{pk}	Inj. $L_{E, 24h}$	Beh. L_p
Fish ≥ 2 grams	0.02	4.25	6.78	--	1.41	2.60	0.02	4.97	6.78	--	1.74	2.66
Fish < 2 grams	0.02	6.01	6.78	--	2.28	2.66	0.02	6.95	6.78	--	2.73	2.66
Fish without swim bladder	--	0.09	--	--	--	--	--	0.11	--	--	0.02	--
Fish with swim bladder not involved in hearing	0.02	0.61	--	--	0.13	--	0.02	0.79	--	--	0.18	--
Fish with swim bladder involved in hearing	0.02	0.61	--	--	0.13	--	0.02	0.79	--	--	0.18	--
Sea turtles	--	0.50	0.42	--	0.11	0.10	--	0.66	0.42	--	0.15	0.10

Source: Summarized from Appendix H, *Acoustic Ranges*, to COP Appendix M-2 (Empire 2023)
≥ = greater than or equal to; < = less than; Beh. = behavior; Inj. = injury

J.6.1.2. Vibratory Pile Driving for Cofferdam Installation

The results of acoustic modeling for vibratory pile driving are presented in Appendix M-1 of the COP (Empire 2023) for the multiple modeled locations. Summaries of ranges to acoustic thresholds for marine mammals, sea turtles, and fish are presented herein and are based on the maximum acoustic range to the 95^{th} maximum percentile ($R_{95\%}$) among the modeled scenarios (Table J-31 and Table J-32).

Table J-31 Maximum Acoustic Ranges ($R_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Marine Mammals Due to Sound from Vibratory Pile Driving without Noise Attenuation

Functional Hearing Group	Range (meters)	
	Level A $L_{E, 24h}$	Level B L_p
LFC	122	2,191
MFC	0	
HFC	52	
PW	62	

Source: Summarized from Tables M-1-8 and M-1-11 in COP Appendix M-1 (Empire 2023).
PW = phocid pinniped in water

Table J-32 Acoustic Ranges (R_{95}%) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Vibratory Pile Driving without Noise Attenuation

Faunal Group	Range (meters)	
	Injury $L_{E, 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	260	268
Fish less than 2 grams	304	
Sea turtles	0	53

Source: Summarized from Tables M-1-9 through M-1-11 in COP Appendix M-1 (Empire 2023).

J.6.1.3. Impact Pile Driving for Goal Post Installation

The results of acoustic modeling for goal post pile driving are presented in Appendix M-1 of the COP (Empire 2023) for the multiple modeled locations. Summaries of ranges to acoustic thresholds for marine mammals, sea turtles, and fish are presented herein and are based on the maximum acoustic range to the 95^{th} maximum percentile ($R_{95\%}$) among the modeled scenarios (Table J-33 and Table J-34).

Table J-33 Acoustic Ranges ($R_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Marine Mammals Due to Sound from Goal Post Pile Driving without Noise Attenuation

Functional Hearing Group	Range (meters)	
	Level A $L_{E, 24h}$	Level B 160 L_p
LFC	632.1	398.1
MFC	22.5	
HFC	752.9	
PW	338.3	

Source: Summarized from Tables M-1-13 and M-1-16 in COP Appendix M-1 (Empire 2023)
PW = phocid pinniped in water

Table J-34 Acoustic Ranges ($R_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Goal Post Pile Driving without Noise Attenuation

Faunal Group	Range (meters)	
	Injury $L_{E, 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	342	1,847.8
Fish less than 2 grams	631	
Sea turtles	18.3	39.8

Source: Summarized from Tables M-1-14 and M-1-15 in COP Appendix M-1 (Empire 2023)

J.6.1.4. Vibratory Pile Driving for Sheetpile Installation and Berthing Pile Removal

The results of acoustic modeling for vibratory pile driving associated with marina bulkhead repairs and berthing pile removal are presented in Appendix M-1 of the COP (Empire 2023). Summaries of ranges to acoustic thresholds for marine mammals, sea turtles, and fish are presented herein and are based on the maximum acoustic range to the 95th maximum percentile ($R_{95\%}$) among the modeled scenarios (Table J-35 through Table J-38).

Table J-35 Acoustic Ranges ($R_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Marine Mammals Due to Sound from Vibratory Pile Driving for Marina Bulkhead Repairs without Noise Attenuation

Functional Hearing Group	Range (meters)	
	Level A $L_{E, 24h}$	Level B 120 L_p
LFC	43.2	1,000
MFC	3.8	
HFC	63.8	
PW	26.2	

Source: Summarized from Tables M-1-17 and M-1-20 in COP Appendix M-1 (Empire 2023)
PW = phocid pinniped in water

Table J-36 Acoustic Ranges ($R_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Vibratory Pile Driving for Marina Bulkhead Repairs without Noise Attenuation

Faunal Group	Range (meters)	
	Injury $L_{E, 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	68.8	46.4
Fish less than 2 grams	37.2	
Sea turtles	2.0	1.0

Source: Summarized from Tables M-1-18 through M-1-19 in COP Appendix M-1 (Empire 2023)

Table J-37 Acoustic Ranges ($R_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Marine Mammals Due to Sound from Vibratory Pile Driving for Marina Berthing Pile Removal without Noise Attenuation

Functional Hearing Group	Range (meters)	
	Level A $L_{E, 24h}$	Level B 120 L_p
LFC	43.5	1,600
MFC	3.9	
HFC	64.3	
PW	26.5	

Source: Summarized from Tables M-1-21 and M-1-24 in COP Appendix M-1 (Empire 2023)
PW = phocid pinniped in water

Table J-38 Acoustic Ranges ($R_{95\%}$) to Injury and Behavioral Disturbance Thresholds for Fish and Sea Turtles Due to Sound from Vibratory Pile Driving for Marina Berthing Pile Removal without Noise Attenuation

Faunal Group	Range (meters)	
	Injury $L_{E, 24h}$	Behavior L_p
Fish greater than or equal to 2 grams	45.5	90.0
Fish less than 2 grams	84.0	
Sea turtles	2.4	1.9

Source: Summarized from Tables M-1-22 and M-1-23 in COP Appendix M-1 (Empire 2023)

J.6.2 Animal Exposure Estimates

J.6.2.1. Marine Mammals

The numbers of individual marine mammals predicted to receive sound levels above threshold criteria during impact pile driving for foundation installation were determined using animal movement modeling, as described in Section J.3.3. The modeled results for impact pile driving, with 0 and 10 dB of noise attenuation, for four 2-year construction schedules are presented in Table J-39 through Table J-42.

Table J-39 Number of Marine Mammals Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 1 (one monopile per day/two pin piles per day)

Marine Mammal Species	Year 1								Year 2							
	0 dB				10 dB				0 dB				10 dB			
	Level A		Level B		Level A		Level B		Level A		Level B		Level A		Level B	
	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]
LFC																
Fin whale	0.0	7.66	36.81	34.87	0	1.63	12.19	14.09	0	3.62	18.53	17.55	0	0.74	5.75	6.95
Minke whale	0.02	2.91	16.74	59.19	0	0.42	7.10	30.57	0.01	1.94	11.09	35.72	0	022	4.79	19.25
Humpback whale[3]	<0.01	1.81	13.60	59.12	<0.01	0.23	5.10	28.15	0	0.99	7.69	35.84	0	0.10	2.86	16.60
NARW	0.00	3.28	24.04	123.85	0	0.38	9.27	52.54	0	2.40	18.91	89.03	0	0.24	7.23	39.55
Sei whale	<0.01	0.19	1.06	4.20	<0.01	0.04	0.41	2.14	<0.01	0.14	0.82	3.12	0	0.03	0.30	1.60
MFC																
Atlantic white sided dolphin	0.00	0.00	453.10	159.80	0	0	179.81	61.88	0	0	261.87	86.48	0	0	103.87	35.11
Atlantic spotted dolphin	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-beaked common dolphin	0.00	0.00	2202.9	839.14	0	0	937.74	305.77	0	0	1392.62	520.43	0	0	581.15	184.17
Bottlenose dolphin	0.00	0.00	430.90	166.36	0	0	182.59	60.82	0	0	216.30	81.55	0	0	91.59	29.67
Risso's dolphin	0.00	0.00	3.73	1.39	0	0	1.30	0.51	0	0	2.18	0.80	0	0	0.71	0.29
Long-finned pilot whale	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-finned pilot whale	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sperm whale	0.00	0.00	4.42	1.61	0	0	1.55	0.53	0	0	2.3	0.81	0	0	0.78	0.26
HFC																
Harbor porpoise	9.63	0.15	656.15	7850.26	0.15	0	220.61	2318.93	5.80	0	484.13	5524.89	0	0	153.84	1667.90
PW																
Gray seal	0.23	0.55	129.97	95.97	0	0.04	42.26	32.26	0.22	0.44	107.04	77.37	0	0	33.92	26.16
Harbor seal	0.52	1.12	313.14	216.93	0	0	92.53	74.04	0.50	0.50	254.28	170.71	0	0	69.71	58.27

Source: Summarized from Table I-3 and Table I-4, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
[1] Unweighted criterion from NMFS 2005
[2] Frequency-weighted criteria from Wood et al. 2012.
[3] Given protected species observer sightings in the Project area from 2018 to 2021, behavioral exposure estimates for this species are likely underestimates. Therefore, this value was adjusted based on protected species observer data, and Empire requested take of 86 humpback whales by Level B harassment in its Letter of Authorization application.
PW = phocid pinniped in water

Table J-40 Number of Marine Mammals Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 2 (one monopile per day/three pin piles per day)

Marine Mammal Species	Year 1								Year 2							
	0 dB				10 dB				0 dB				10 dB			
	Level A		Level B		Level A		Level B		Level A		Level B		Level A		Level B	
	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]
LFC																
Fin whale	0	7.69	36.57	34.43	0	1.63	12.18	13.97	0	3.62	18.53	17.55	0	0.74	5.75	6.95
Minke whale	0.02	2.92	16.95	58.74	0	0.42	7.17	30.47	0.01	1.94	11.09	35.72	0	0.22	4.79	19.25
Humpback whale	<0.01	1.81	13.73	57.91	<0.01	0.23	5.15	28.05	0	0.99	7.69	35.84	0	0.10	2.86	16.60
NARW	0	3.28	24.27	123.07	0	0.38	9.32	52.69	0	2.40	18.91	89.03	0	0.24	7.23	39.55
Sei whale	<0.01	0.20	1.07	4.16	<0.01	0.04	0.41	2.13	<0.01	0.14	0.82	3.12	0	0.03	0.30	1.60

Marine Mammal Species	Year 1								Year 2							
	0 dB				10 dB				0 dB				10 dB			
	Level A		Level B		Level A		Level B		Level A		Level B		Level A		Level B	
	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]
MFC																
Atlantic white sided dolphin	0	0	452.5	159.05	0	0	179.82	61.85	0	0	261.87	86.48	0	0	103.87	35.11
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-beaked common dolphin	0	0	2227.21	849.12	0	0	945.64	308.78	0	0	1392.62	520.43	0	0	581.15	184.17
Bottlenose dolphin	0	0	429.53	165.33	0	0	182.91	60.64	0	0	216.30	81.55	0	0	91.59	29.67
Risso's dolphin	0	0	3.74	1.38	0	0	1.31	0.51	0	0	2.18	0.80	0	0	0.71	0.29
Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sperm whale	0	0	4.42	1.60	0	0	1.56	0.53	0	0	2.30	0.81	0	0	0.78	0.26
HFC																
Harbor porpoise	9.63	0.15	661.97	7712.44	0.15	0	222.30	2294.06	5.80	0	484.13	5524.89	0	0	153.84	1667.90
PW																
Gray seal	0.23	0.55	129.30	93.71	0	0.04	42.23	31.86	0.22	0.44	107.04	77.37	0	0	33.92	26.16
Harbor seal	0.52	1.12	312.29	212.97	0	0	92.62	73.46	0.50	0.50	254.28	170.71	0	0	69.71	58.27

Source: Summarized from Table I-5 and Table I-6, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
[1] Unweighted criterion from NMFS 2005
[2] Frequency-weighted criteria from Wood et al. 2012
PW = phocid pinniped in water

Table J-41 Number of Marine Mammals Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 3 (two monopiles per day/two pin piles per day)

Marine Mammal Species	Year 1								Year 2							
	0 dB				10 dB				0 dB				10 dB			
	Level A		Level B		Level A		Level B		Level A		Level B		Level A		Level B	
	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]
LFC																
Fin whale	0.03	7.59	28.72	24.98	0	1.58	11.17	10.92	0.02	3.65	14.52	12.30	0	0.68	5.45	5.33
Minke whale	0.02	2.97	16.2	47.58	0	0.35	6.84	26.13	<0.01	1.97	10.45	27.14	0	0.16	4.51	15.72
Humpback whale	<0.01	1.95	14.23	51.38	<0.01	0.18	5.36	26.60	0	1.09	7.95	30.45	0	0.07	2.93	15.26
NARW	0	3.34	23.66	114.79	0	0.37	9.28	49.32	0	2.49	17.96	71.46	0	0.20	7.12	34.19
Sei whale	<0.01	0.19	0.89	3.20	<0.01	0.03	0.37	1.67	<0.01	0.14	0.64	1.93	0	0.02	0.27	1.06
MFC																
Atlantic white sided dolphin	0	0	397.32	147.02	0	0	171.14	55.69	0	0	224.05	9.68	0	0	98.24	30.79
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-beaked common dolphin	0.73	0	2037.33	784.12	0	0	866.31	299.54	0.53	0	1228.35	456.45	0	0	522.05	175.52
Bottlenose dolphin	0	0	385.79	144.60	0	0	159.12	57.47	0	0	192.88	69.86	0	0	78.97	27.68
Risso's dolphin	<0.01	0	3.13	1.18	0	0	1.27	0.45	<0.01	0	1.77	0.65	0	0	0.70	0.24
Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sperm whale	0	0	3.86	1.37	0	0	1.46	0.49	0	0	2.00	0.67	0	0	0.74	0.24

Marine Mammal Species	Year 1								Year 2							
	0 dB				10 dB				0 dB				10 dB			
	Level A		Level B		Level A		Level B		Level A		Level B		Level A		Level B	
	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]
HFC																
Harbor porpoise	13.22	0.69	559.88	6319.98	0.89	0	203.99	1868.04	9.02	0.54	396.87	3476.65	0.64	0	141.46	1100.75
PW																
Gray seal	0.12	0.28	105.61	69.68	0	0.12	36.46	24.31	0.11	0.22	85.34	53.09	0	0.11	28.49	18.61
Harbor seal	036	1.48	261	171.76	0	0	97.72	65.06	0.25	0.74	204.39	129.78	0	0	76.19	49.65

Source: Summarized from Table I-7 and Table I-8, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
[1] Unweighted criterion from NMFS 2005
[2] Frequency-weighted criteria from Wood et al. 2012
PW = phocid pinniped in water

Table J-42 Number of Marine Mammals Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 4 (two monopiles per day/three pin piles per day)

Marine Mammal Species	Year 1								Year 2							
	0 dB				10 dB				0 dB				10 dB			
	Level A		Level B		Level A		Level B		Level A		Level B		Level A		Level B	
	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]	L_{pk}	$L_{E, 24h}$	L_p[1]	L_p[2]
LFC																
Fin whale	0.03	7.62	28.45	24.50	0	1.58	11.15	10.78	0.02	3.65	14.52	12.30	0	0.68	5.45	5.33
Minke whale	0.02	2.98	16.17	46.16	0	0.35	6.84	25.53	<0.01	1.97	10.45	27.14	0	0.16	4.51	15.72
Humpback whale	<0.01	1.95	14.21	50.69	<0.01	0.18	5.37	26.40	0	1.09	7.95	30.45	0	0.07	2.993	15.26
NARW	0	3.34	23.60	108.26	0	0.37	9.27	48.01	0	2.49	17.96	71.46	0	0.20	7.12	34.19
Sei whale	<0.01	0.20	0.88	2.97	<0.01	0.03	0.37	1.58	<0.01	0.14	0.64	1.93	0	0.02	0.27	1.06
MFC																
Atlantic white sided dolphin	0	0	395.42	145.67	0	0	170.84	55.49	0	0	224.05	79.68	0	0	98.24	30.79
Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-beaked common dolphin	0.73	0	2031.30	775.97	0	0	866.80	298.06	0.53	0	1228.35	456.45	0	0	522.05	175.52
Bottlenose dolphin	0	0	383.89	143.29	0	0	159.35	57.21	0	0	192.88	69.86	0	0	78.97	27.68
Risso's dolphin	<0.01	0	3.11	1.16	0	0	1.26	0.44	<0.01	0	1.77	0.65	0	0	0.70	0.24
Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sperm whale	0	0	3.84	1.36	0	0	1.46	0.49	0	0	2.00	0.67	0	0	0.74	0.24
HFC																
Harbor porpoise	13.22	0.69	558.14	5706.38	0.89	0	204.03	1738.98	9.02	0.54	396.87	3476.65	0.64	0.11	141.46	1100.75
PW																
Gray seal	0.12	0.28	103.91	67.37	0	0.12	36.30	23.77	0.11	0.22	85.34	53.09	0	0	28.49	18.61
Harbor seal	0.36	1.48	257.19	167.54	0	0	97.18	63.82	0.25	0.74	204.39	129.78	0	0	76.19	49.65

Source: Summarized from Table I-9 and Table I-10, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)
[1] Unweighted criterion from NMFS 2005
[2] Frequency-weighted criteria from Wood et al. 2012
PW = phocid pinniped in water

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J.6.2.2. Sea Turtles

The numbers of individual sea turtles predicted to receive sound levels above threshold criteria were also determined using animal movement modeling. The model results for impact pile driving, with 0 and 10 dB of noise attenuation are presented in Table J-43 through Table J-46.

Table J-43 Number of Sea Turtles Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 1 (one monopile per day/two pin piles per day)

Sea Turtle Species	Year 1						Year 2					
	0 dB			10 dB			0 dB			10 dB		
	Injury		Behavior	Injury		Behavior	Injury		Behavior	Injury		Behavior
	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p
Kemp's ridley sea turtle	2.69	0	21.81	0.33	0	5.48	1.01	0	11.84	0.14	0	2.74
Leatherback sea turtle	1.70	0	14.61	0.03	0	1.65	0.53	0	7.49	0	0	0.42
Loggerhead sea turtle	4.99	0	292.48	0	0	29.57	0	0	160.11	0	0	11.72
Green sea turtle	0.08	0	0.67	<0.01	0	0.10	0.03	0	0.36	0	0	0.04

Source: Summarized from Table I-11 and Table I-12, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)

Table J-44 Number of Sea Turtles Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 2 (one monopile per day/three pin piles per day)

Sea Turtle Species	Year 1						Year 2					
	0 dB			10 dB			0 dB			10 dB		
	Injury		Behavior	Injury		Behavior	Injury		Behavior	Injury		Behavior
	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p
Kemp's ridley sea turtle	2.69	0	21.81	0.33	0	5.48	1.01	0	11.84	0.14	0	2.74
Leatherback sea turtle	1.70	0	14.62	0.03	0	1.65	0.53	0	7.49	0	0	0.42
Loggerhead sea turtle	4.99	0	293.70	0	0	29.57	0	0	160.11	0	0	11.72
Green sea turtle	0.08	0	0.67	<0.01	0	0.10	0.03	0	0.36	0	0	0.04

Source: Summarized from Table I-13 and Table I-14, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)

Table J-45 Number of Sea Turtles Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 3 (two monopiles per day/two pin piles per day)

Sea Turtle Species	Year 1						Year 2					
	0 dB			10 dB			0 dB			10 dB		
	Injury		Behavior	Injury		Behavior	Injury		Behavior	Injury		Behavior
	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p	$L_{E, 24h}$	L_{pk}	L_p
Kemp's ridley sea turtle	3.35	0.02	21.15	0.05	0	5.14	1.65	<0.01	11.91	<0.01	0	2.67

Sea Turtle Species	Year 1						Year 2					
	0 dB			10 dB			0 dB			10 dB		
	Injury		Behavior	Injury		Behavior	Injury		Behavior	Injury		Behavior
	$L_{E,24h}$	L_{pk}	L_p	$L_{E,24h}$	L_{pk}	L_p	$L_{E,24h}$	L_{pk}	L_p	$L_{E,24h}$	L_{pk}	L_p
Leatherback sea turtle	1.70	0	12.42	0.04	0	1.26	0.63	0	6.15	0	0	0.32
Loggerhead sea turtle	9.52	0	334.58	0.46	0	62.83	7.91	0	202.22	0	0	32.77
Green sea turtle	0.14	0	0.74	<0.01	0	0.16	0.08	0	0.43	0	0	0.09

Source: Summarized from Table I-15 and Table I-16, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)

Table J-46 Number of Sea Turtles Predicted to Receive Sound Levels Above Regulatory Criteria for Impact Pile Driving Construction Schedule 4 (two monopiles per day/three pin piles per day)

Sea Turtle Species	Year 1						Year 2					
	0 dB			10 dB			0 dB			10 dB		
	Injury		Behavior	Injury		Behavior	Injury		Behavior	Injury		Behavior
	$L_{E,24h}$	L_{pk}	L_p	$L_{E,24h}$	L_{pk}	L_p	$L_{E,24h}$	L_{pk}	L_p	$L_{E,24h}$	L_{pk}	L_p
Kemp's ridley sea turtle	3.35	0.02	21.16	0.05	0	5.14	1.65	0	11.91	<0.01	0	2.67
Leatherback sea turtle	1.70	0	12.42	0.04	0	1.26	0.63	0	6.15	0	0	0.32
Loggerhead sea turtle	9.52	0	335.80	0.46	0	62.83	1.91	0	202.22	0	0	32.77
Green sea turtle	0.14	0	0.74	<0.01	0	0.16	0.08	0	0.43	0	0	

Source: Summarized from Table I-17 and Table I-18, Appendix I, *Animal Movement and Exposure Modeling*, to COP Appendix M-2 (Empire 2023)

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