Appendix J. Underwater Sound and Acoustic Modeling Results

J.1. Introduction

This appendix provides an overview of underwater sound sources, summarizes the regulation of underwater sound for marine mammals and fish/invertebrates, and identifies thresholds for explosives. In addition, this appendix summarizes the methods, assumptions, and results of the technical acoustic modeling report prepared for the Project.

J.2. Sources of Underwater Sound

Ocean sounds originate from a variety of sources. Some come from non-biological sources such as wind and waves, while others come from the movements or vocalizations of marine life (Hildebrand 2009). In addition, humans introduce sound into the marine environment through activities like oil and gas exploration, construction, military sonars, and vessel traffic (Hildebrand 2009). The acoustic environment or "soundscape" of a given ecosystem comprises all such sounds—biological, non-biological, and anthropogenic (Pijanowski et al. 2011). Soundscapes are highly variable across space, time, and water depth, among other factors, due to the properties of sound transmission and the types of sound sources present in each area. A soundscape is sometimes called the "acoustic habitat," as it is a vital attribute of a given area where an animal may live (i.e., habitat) (Hatch et al. 2016).

J.3. Physics of Underwater Sound

Sounds are created by the vibration of an object within its medium (Figure J-1). This movement generates kinetic energy, which travels as a propagating wave away from the sound source. As this wave moves through the medium, the particles undergo tiny back-and-forth movements ("particle motion") along the axis of propagation, but the particles themselves do not travel with the wave. Instead, they oscillate in roughly the same location, transferring their energy to surrounding particles. Instead, the vibration is transferred to adjacent particles, which are pushed into areas of high pressure (compression) and low pressure (rarefaction). Acoustic pressure is a non-directional (scalar) quantity, whereas particle motion is an inherently directional quantity (a vector) taking place in the axis of sound transmission. The total energy of the sound wave includes the potential energy associated with the sound pressure as well as the kinetic energy from particle motion.

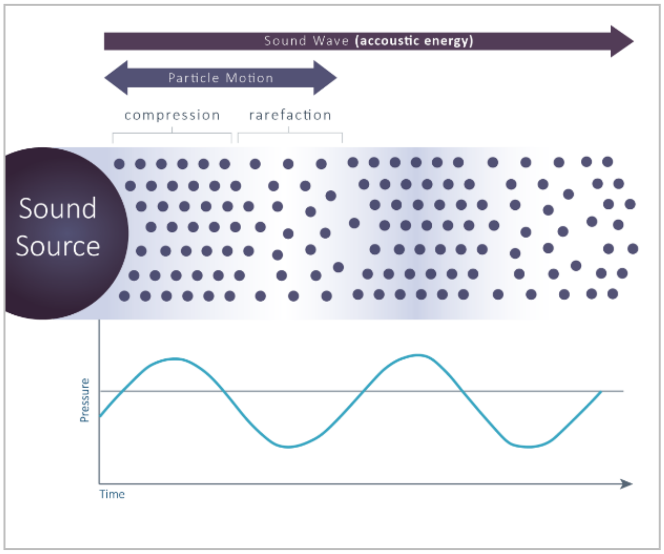
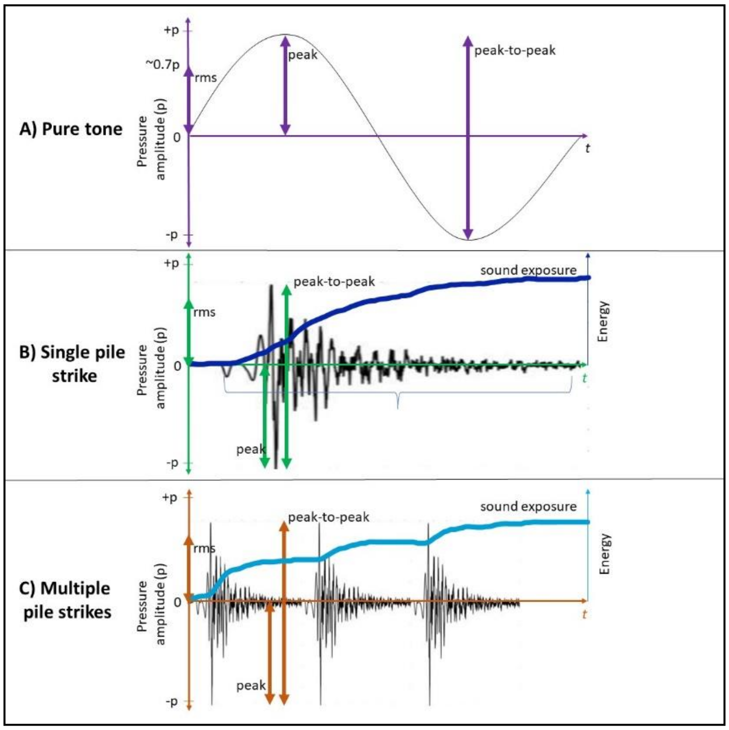


Figure J-1 Basic Mechanics of a Sound Wave

J.3.1 Units of Measurement

Sound can be quantified and characterized based on a number of physical parameters. A complete description of the units can be found in ISO 18405:2017. Some of the major parameters and their units (in parentheses) are:

Acoustic pressure (pascal): The values used to describe the acoustic (or sound) pressure are peak pressure (L_{pk}), peak-to-peak pressure ($L_{pk\text{-}pk}$), and RMS pressure (L_{RMS} or SPL) deviation. The peak sound pressure is defined as the maximum absolute sound pressure deviation within a defined time period and is considered an instantaneous value. The peak-to-peak pressure is the range of pressure change from the most negative to the most positive pressure amplitude of a signal (Figure J-2), whereas the RMS sound pressure represents a time-averaged pressure and is calculated as the square root of the mean (average) of the time-varying sound pressure over a given period (Figure J-2). The L_{pk}, $L_{pk\text{-}pk}$, and SPL are computed by multiplying the logarithm of the ratio of the peak or RMS pressures to a reference pressure (1 μPa in water) by a factor of 20 and are reported in dB; see sound levels described below.



A) A sine wave of a pure tonal signal with equal positive and negative peaks, so peak-to-peak is exactly twice the peak and RMS is approximately 0.7 x peak. B) A single pile-driving strike with one large positive pulse and a large negative pulse that is not necessarily the same magnitude. In this example, the negative pulse is more extreme so the reported peak value and peak-to-peak are less than double that. Sound exposure is shown as it accumulates across the time window. The final sound exposure would be considered the "single-shot" exposure and the RMS value is that divided by the duration of the pulse. C) Three consecutive pile-driving strikes with peak and peak-to-peak assessed the same way as in B). Sound exposure is shown accumulating across all three strikes and RMS is the total sound exposure divided by the entire time window shown. The cumulative sound exposure for this series of signals would be considered the total energy from all three pile-strikes.

Figure J-2 Sound Pressure Wave Representations of Four Metrics: Root-mean-square (L_{RMS}), Peak (L_{pk}), Peak-to-peak (L_{pk-pk}), and Sound Exposure (SEL)

Particle velocity (m/s): Particle velocity describes the change in position of the oscillating particles about its origin over a unit of time. Similar to sound pressure, particle velocity is dynamic and changes as the particles move back and forth. Therefore, peak particle velocity and RMS particle velocity can be used to describe this physical quantity. One major difference between sound pressure and particle velocity is that the former is a scalar (i.e., without the directional component) and the latter is a vector (i.e., includes both magnitude and direction). Particle acceleration can also be used to describe particle motion, and is defined as the rate of change of velocity of a particle with respect to time. It is measured in units of meters per second squared, or m/s^2.

Sound exposure (pascal-squared second): Sound exposure is proportional to the acoustic energy of a sound. It is the time-integrated squared sound pressure over a stated period or acoustic event (see Figure J-2). Unlike sound pressure, which provides an instantaneous or time-averaged value of acoustic pressure, sound exposure is cumulative over a period of time.

Acoustic intensity (watts per square meter): Acoustic or sound intensity is the amount of acoustic energy that passes through a unit area normal to the direction of propagation per second. It is the product of the sound pressure and the sound velocity. With an idealized constant source, the pressure and particle velocity will vary in proportion to each other at a given location, but the intensity will remain constant.

Sound levels: There is an extremely wide dynamic range of values when measuring acoustic pressure in pascals, so it is customary to use a logarithmic scale to compress the range of values. Aside from the ease it creates for comparing a wide range of values, animals (including humans) perceive sound on a logarithmic scale. These logarithmic acoustic quantities are known as *sound levels* and are expressed in dB, which is the logarithmic ratio of the measurement in question to a fixed reference value. Underwater acoustic SPLs are referenced to a pressure of 1 μPa (equal to 10^{-6} pascals or 10^{-11} bar). Note: airborne SPLs have a different reference pressure: 20 μPa.

The metrics previously described (sound pressure, sound exposure, and intensity) can also be expressed as levels, and are commonly used in this way:

- RMS sound pressure level (L_{RMS} or SPL, units of dB re 1 μPa)
- peak pressure level (L_{pk}, units of dB re 1 μPa)
- peak-to-peak pressure level ($L_{pk\text{-}pk}$, units of dB re 1 μPa)
- SEL (units of dB re 1 μPa^2s)

There are a few commonly used time periods used for SEL, including a 24 hour period (used in the U.S. for the regulation of noise impacts on marine mammals [SEL_{24}]), or the duration of a single event, such as a single pile-driving strike or an airgun pulse, called the single-strike SEL (SEL_{ss}). A sound exposure for some other period of time, such as the entire installation of a pile, may be written without a subscript (SEL) but, in order to be meaningful, should always denote the duration of the event.

Source Level: Another commonly discussed concept is source level. Source level is a representation of the amount of acoustic power radiated from the sound source being described. It describes how loud a particular source is in a way that can inform expected received levels at various ranges. It can be conceptualized as the product of the pressure at a particular location and the range from that location to a spherical (omnidirectional) source in an idealized infinite lossless medium. The source level is the sum of the received level and the propagation loss to that receiver. It is often discussed as what the received level would be 1 meter from the source, but this can lead to confusion as an actual measurement at 1 meter is likely to be impossible for large or non-spherical sources. The most common type is an SPL source level in units of dB re 1 µPa-m, although in some circumstances a SEL source level (in dB re 1 $\mu Pa^2 s\text{-}m^2$) may be expressed; peak source level (in units of dB re 1 µPa-m) may also be appropriate for some sources.

J.3.2 Propagation of Sound in the Ocean

Underwater sound can be described through a source-path-receiver model. An acoustic source emits sound energy that radiates outward and travels through the water and the seafloor. The sound level decreases with increasing distance from the acoustic source as the sound travels through the environment. The amount by which the sound levels decrease between the theoretical source level and a receiver is called *propagation loss*. Among other things, the amount of propagation loss that occurs depends on the source-receiver separation, the geometry of the environment the sound is propagating through, the frequency of the sound, the properties of the water column, and the properties of the seafloor and sea surface.

When sound waves travel through the ocean, they may encounter areas with different physical properties that will likely alter the propagation pathway of the sound, compared to a homogenous and boundaryless environment. For example, near the ocean's surface, water temperature is usually higher, resulting in relatively fast sound speeds. As temperature decreases with increasing depth, the sound speed decreases. Sounds bend toward areas with lower speeds (Urick 1983). Ocean sound speeds are often slowest at mid-latitude depths of about 1,000 meters and, because of sound's preference for lower speeds, sound waves above and below this "deep sound channel" often bend toward it. Sounds originating in this layer can travel great distances. Sounds can also be trapped in the mixed layer near the ocean's surface (Urick

1983). Latitude, weather, and local circulation patterns influence the depth of the mixed layer, and the propagation of sounds near the surface is highly variable and difficult to predict.

At the boundaries near the sea surface and the sea floor, acoustic energy can be scattered, reflected, or attenuated depending on the properties at the surface (e.g., roughness, presence of wave activity, or bubbles) or seafloor (e.g., bathymetric features, substrate heterogeneity). For example, fine-grain sediments tend to absorb sounds well, while hard-bottom substrates reflect much of the acoustic energy back into the water column. The presence of ice on the ocean's surface can also affect sound propagation. For example, the presence of solid ice may dampen sound levels by blocking surface winds. The presence of ice can also increase sound levels when pieces of ice break or scrape together (Urick 1983). The effect will also depend on the thickness and roughness of the ice, among many other factors related to the ambient conditions. As a sound wave moves from a source to a receiver (i.e., an animal), it may travel on multiple pathways that may be direct, reflected, refracted, or a combination of these mechanisms, creating a complex pattern of transmission across range and depth. The patterns may become even more complicated in shallow waters due to repeated interactions with the surface and the bottom, frequency-specific propagation, and more heterogenous seafloor properties. All of these variables contribute to the difficulty in reliably predicting the sound field in a given marine environment at any particular time.

J.3.3 Sound Source Classification

In the current regulatory context, anthropogenic sound sources are divided into four types: impulsive, non-impulsive, continuous, and intermittent, based on their differing potential to affect marine species (NMFS 2018). Specifically, when it comes to potential damage to marine mammal hearing, sounds are classified as either impulsive or non-impulsive, and when considering the potential to affect behavior or acoustic masking, sounds are classified as either continuous or intermittent.

Impulsive noises are characterized as having (ANSI S1.13-2005 [Finneran 2016]):

- Broadband frequency content
- Fast rise times and rapid decay times
- Short durations (i.e., less than 1 second)
- High peak sound pressures

The characteristics of non-impulsive sound sources are less clear but may:

- Be variable in spectral composition, i.e., broadband, narrowband, or tonal
- Have longer rise time/decay times and total durations compared to an impulsive sound
- Be continuous (e.g., vessel engine radiated noise) or intermittent (e.g., echosounder pulses)

It is generally accepted that sources like explosions, airguns, sparkers, boomers, and impact pile driving are impulsive and have a greater likelihood of causing hearing damage than non-impulsive sources (explosions are further considered for non-auditory injury; see Section J.5.3, *Thresholds for Non-auditory Injury for Explosives*). At close distances to impulsive sounds, physiological effects on an animal are likely, including TTS and PTS. This binary, at-the-source classification of sound types, therefore, provides a conservative framework upon which to predict potential adverse hearing impacts on marine mammals.

For behavioral effects of anthropogenic sound on marine mammals, NMFS classifies sound sources as either intermittent or continuous (NMFS 2018). Continuous sounds, such as drilling or vibratory pile-driving, remain "on," i.e., above ambient noise, for a given period of time, although this is not well defined. An intermittent sound typically consists of bursts or pulses of sound on a regular on/off pattern, also called the duty-cycle. Examples of intermittent sounds are those from scientific echosounders, sub-bottom profilers, and even pile driving. It is important to recognize that these delineations are not always practical in application, as a continuous yet moving sound source (such as a vessel passing over a fixed receiver) could be considered intermittent from the perspective of the receiver.

In reality, animals will encounter many signals in their environment that may contain many or all of these sound types, called complex sounds. Eeven for sounds that are impulsive at the source, as the signal propagates through the water, the degree of impulsiveness decreases (Martin et al. 2020). While there is evidence, at least in terrestrial mammals (Hamernik and Hsueh 1991), that complex sounds can be more damaging than continuous sounds, there is not currently a regulatory category for this type of sound. One current approach for assessing the impulsiveness of a sound that has gained attention is to compute the kurtosis of that signal. Kurtosis is a statistical measure that describes the prevalence of extreme values within a distribution of observations, in other words the “spikiness” of the data. Martin et al. (2020) showed that a sound with a kurtosis value of 3 or less has very few extreme values and is generally considered Gaussian (i.e., normally distributed) noise, whereas a kurtosis value greater than 40 represents a distribution of observations with many extreme values and is very spiky. This generally describes an impulsive noise. A distribution of sound level observations from a time series with a kurtosis value somewhere in between these two values would be considered a complex sound.

J.4. Sound Sources Related to Offshore Wind Development

J.4.1 Geophysical and Geotechnical Surveys

G&G surveys are conducted to characterize the bathymetry, sediment type, and benthic habitat characteristics of the marine environment. They may also be used to identify archaeological resources or obstacles on the seafloor. These types of surveys occur in the site assessment phase in order to inform the placement of offshore wind foundations but may also occur intermittently during and after turbine construction to identify, guide, and confirm the locations of turbine foundations. The suite of HRG sources that may be used in geophysical surveys includes side-scan sonars, multibeam echosounders, magnetometers and gradiometers, parametric sub-bottom profilers, compressed high-intensity radiated pulse sub-bottom profilers, boomers, or sparkers. Seismic airguns are not expected to be used for offshore wind applications. These HRG sources may be towed behind a ship, mounted on a ship’s hull, or deployed from remotely operated vehicles or autonomous underwater vehicles.

All HRG sources are active acoustic sources, meaning they produce sound deliberately in order to obtain information about the environment. With the exception of some multibeam echosounder and side-scan sonar, they produce sounds below 180 kilohertz and therefore may be audible to marine species. Source levels vary widely depending on source type and operational power level used, from approximately 145 dB re 1 µPa-m for towed sub-bottom profilers up to 245 dB re 1 µPa-m for some multibeam echosounders (Crocker and Fratantonio 2016). Generally speaking, sources that emit sound in narrow beams directed at the seafloor are less likely to affect marine species because they ensonify a small portion of the water column, thereby reducing the likelihood that an animal encounters the sound. While sparkers are omnidirectional, most other HRG sources have narrow beamwidths (e.g., multibeam echosounders: up to 6 degrees, parametric sub-bottom profilers: 30 degrees, boomers: 30–90 degrees) (Crocker and Fratantonio 2016). Most HRG sources emit short pulses of sound, with periods of silence in between. This means that only several “pings” emitted from a vessel towing an active acoustic source would reach an animal below, even if the animal was stationary (Ruppel et al. 2022). HRG surveys may occur throughout the construction area with the potential for greater effort in some areas.

Geotechnical surveys may use vibracores, jet probes, bottom-grab samplers, deep borings, or other methods to obtain samples of sediments at each potential turbine location and along the cable route. For most of these methods, source levels have not been measured, but it is generally assumed that low-frequency, low-level noise would be introduced as a byproduct of these actions. It is likely that the sound of the vessel would exceed that generated by the geotechnical method itself.

J.4.2 Unexploded Ordnance Detonations

UXO may be discovered on the seabed in offshore wind lease areas or along export cable routes. While non-explosive methods may be employed to lift and move these objects, some may need to be detonated. Underwater explosions of this type create a shock wave with a nearly instantaneous rise in pressure, followed by a series of symmetrical bubble pulses. Shock waves are supersonic, so they travel faster than the speed of sound. The explosive sound field extremely is complex, especially in shallow waters. In 2015, von Benda-Beckmann et al. measured received levels of explosions in shallow waters at distances ranging from 100–2,000 meters from the source in water depths ranging from 6–22 meters. The measured SEL from the explosive removal of a 263-kilogram charge was 216 dB re 1 $\mu Pa^2 s$ at a distance of 100 meters and 196 dB re 1 $\mu Pa^2 s$ at 2,000 meters. They found that SELs were lower near the surface than near the seafloor or in the middle of the water column, suggesting that if an animal is near the surface, the effects may be less damaging. Most of the acoustic energy for underwater explosions is below 1,000 Hz.

As an alternative to traditional detonation, a newer method called deflagration allows for the controlled burning of underwater ammunition. Typically, a remotely operated vehicle uses a small, targeted charge to initiate rapid burning of the ordnance; once this process is complete, the remaining debris can be cleared away. Recent work has demonstrated that both peak sound pressure (L_{pk}) and SEL measured from deflagration events may be as much as 20 dB lower than equivalently sized high-order detonations (Robinson et al. 2020).

J.4.3 Construction and Installation

J.4.3.1. Impact and Vibratory Pile Driving

At present, the installation of turbine foundations is largely done using pile driving. There are several techniques, including impact and vibratory driving, and many pile designs and sizes, including monopile and jacket foundations. Impact pile driving employs a hammer to strike the pile head and force the pile into the sediment with a typical hammer strike rate of approximately 30–50 strikes/minute. Typically, force is applied over a period of less than 20 milliseconds, but the pile can generate sound for upward of 0.5 second. Pile-driving noise is characterized as impulsive because of its high peak pressure, short duration, and rapid onset time. Underwater sound levels generated during pile driving depend on many factors including the pile material and size, characteristics of the substrate, penetration of the pile in the seabed, hammer energy and size, and water depth. Currently the design envelope for most offshore wind turbine installations anticipates hammer energy between 2,500 and 4,000 kilojoules (kJ) but, generally speaking, with increasing pile diameter, greater hammer energy is used. The propagation of pile-driving sounds depends on factors such as the sound speed in the water column (influenced by temperature, salinity, and depth), the bathymetry, and the composition of sediments in the seabed and will therefore vary among sites. Due to variation in these features, sounds may not radiate symmetrically outward from a pile.

Measurements of impact-pile driving are generally derived from measurements at facilities in Europe; see Bellman et al. (2020) for a complete report of expected sound levels and a discussion of noise abatement methods. In the U.S. OCS, BOEM has invested in the Realtime Opportunity for Development of Environmental Observations efforts to measure sound installation and operation of two wind farms: Block Island Wind Farm and Coastal Virginia Offshore Wind. At Block Island Wind Farm, 50-inch-diameter jacket foundations were installed in 30-meter water depth. Jacket foundations typically use using pin piles, which are generally substantially smaller than monopiles, but more pin piles are needed per foundation. The sound levels generated will vary depending on the pile material, size, substrate, hammer energy, and water depth. At Block Island Wind Farm, Amaral et al. (2018) measured sound levels at various distances during pile driving and reported SPL received levels between 150–160 dB re 1 µPa at approximately 750 meters from the piles. It should be noted that the slant range of the jacket piles influenced the measurements, so caution is encouraged with interpretation. At Coastal Virginia Offshore Wind, two monopiles (7.8-meter diameter) were installed off in 27-meter water depth in 2020. Dominion Energy (2020) recorded sounds during this process; without noise mitigation, L_{pk} source levels were back-calculated to be 221 dB re 1 µPa-m, but with a double bubble curtain, L_{pk} source levels were around 212 dB re 1 µPa-m because a good portion of energy greater than 200 Hz was attenuated by the bubble curtain. The unmitigated SPL source level was 213 dB re 1 µPa-m; the mitigated SPL source level was 204 dB re 1 µPa-m.

Vibratory hammers may be used as an alternative to impact pile driving. The vibratory hammer continuously exerts vertical vibrations into the pile, which causes the sediment surrounding the pile to liquefy, allowing the pile to penetrate the substrate. The vibratory hammer typically oscillates at a frequency of 20–40 Hz (Matuschek and Betke 2009) and produces most of its acoustic energy below 2 kilohertz. While measurements of vibratory pile driving of large monopiles have not been reported, Buehler et al. (2015) measured sound levels at 10 meters distance from a 72-inch steel pile, and found them to be 185 dB re 1 µPa. Vibratory pile driving is a non-impulsive sound source but, because the hammer is on continuously, underwater sound introduced would be into the water column for a longer period of time than with impact pile driving.

A technique that is quickly gaining use for installation in hard rock substrates is down-the-hole pile driving, which uses a combination of percussive and drilling mechanisms, with a hammer acting directly on the rock to advance a hole into the rock and also advance the pile into that hole (Guan et al. 2022). Noise characteristics for down-the-hole pile driving include both impulsive and non-impulsive components. The impulsive component of the down-the-hole pile driving is the result of a percussive hammer striking the bedrock, while the non-impulsive component is from drilling and air lifting of cuttings and debris from the pile. While only limited studies have been conducted on down-the-hole pile-driving noise, its characteristics strongly resemble those of impact pile driving but with a higher hammer striking rate (approximately 10–15 Hz). The dominant frequencies from down-the-hole pile driving are below 2 kilohertz, similar to those of conventional impact pile driving. Due to the high rate of hammer striking along with the sounds of drilling and debris clearing out, sound levels in between the pulses are much higher than for conventional impact pile driving (Guan et al. 2022).

Various noise abatement technologies, such as bubble curtains, arrays of enclosed air resonators, or segmented nets of rubber or foam, may be employed to reduce noise from impact pile driving. Measurements from European wind farms have shown that a single noise abatement system can reduce broadband sound levels by 10–15 dB, while using two systems together can reduce sound levels as much as 20 dB (Bellmann et al. 2020). Based on Realtime Opportunity for Development of Environmental Observations measurements from Coastal Virginia Offshore Wind, double big bubble curtains are shown to be most effective for frequencies above 200 Hz, and greater noise reduction was seen in measurements taken in the middle of the water column compared to those near the seabed. Approximate sound level reduction is 3–5 dB below 200 Hz and 8–20 dB above 200 Hz, depending on the characteristics of the bubble curtain (Amaral et al. 2020).

J.4.3.2. Vessels

During construction, vessels and aircraft may be used to transport crew and equipment. See Section J.4.4, *Operations and Maintenance*, for further detail about sounds related to those activities. Large vessels would also be used during the construction phase to conduct pile driving and may use dynamic positioning systems. Dynamic positioning is the process by which a vessel holds station over a specific seafloor location for some time period using input from gyrocompasses, motion sensors, global positioning systems, active acoustic positioning systems, and wind sensors to determine relative movement and environmental forces at work. Generally speaking, most acoustic energy is less than 1,000 Hz, often below 50 Hz, with tones related to engine and propeller size and type. The sound can also vary directionally, and this directionality is much more pronounced at higher frequencies. Because this is a dynamic operation, the sound levels produced will vary based on the specific operation, dynamic positioning system used (e.g., jet or propeller rotation versus a rudder or steering mechanism), and factors such as the blade rate and cavitation, in some cases. Representative sound field measurements from the use of dynamic positioning are difficult to obtain because the sound transmitted is often highly directional and context specific. The direction of sound propagation may change as different dynamic positioning needs requiring different configurations are applied.

Many studies have found that the measured sound levels of dynamic positioning alone are, counterintuitively, higher than those of dynamic positioning combined with the intended activities such as drilling (Jiménez-Arranz et al. 2020; Kyhn et al. 2011; Nedwell and Edwards 2004) and coring (Warner and McCrodan 2011). Nedwell and Edwards (2004) reported that dynamic positioning thrusters of the semi-submersible drill rig Jack Bates produced periodic noise (corresponding to the rate of the thruster blades) with most energy between 3–30 Hz. The received SPL measured at 100 meters from the vessel was 188 dB re 1 µPa. Warner and McCrodan (2011) found that most dynamic positioning related sounds from the self-propelled drill ship R/V Fugro Synergy were in the 110–140 Hz range, with an estimated source level of 169 dB re 1 µPa-m. Sounds in this frequency range varied by 12 dB during dynamic positioning, while the broadband levels, which also included diesel generators and other equipment sounds, varied by only 5 dB over the same time period. All of the above sources report high variability in levels with time. This is due in part to the intermittent usage and relatively slow rotation rates of thrusters used in dynamic positioning. It is also difficult to provide a realistic range of source levels from the data thus far because most reports do not identify the direction from which sound was measured relative to the vessel, and dynamic positioning thrusters are highly directional systems.

The active acoustic positioning systems used in dynamic positioning can be additional sources of high-frequency sound. These systems usually consist of a transducer mounted through the vessel's hull and one or more transponders affixed to the seabed. Kongsberg High-Precision Acoustic Positioning systems produce pings in the 10–32-kilohertz frequency range. The hull-mounted transducers have source levels of 188–206 dB re 1 µPa-m depending on adjustable power settings (Kongsberg Maritime AS 2013). The fixed transponders have maximum source levels of 186–206 dB re 1 µPa-m depending on model and beam width settings from 15 to 90 degrees (Jiminez-Arranz et al. 2020). These systems have high source levels, but beyond 2 kilometers they are generally quieter than other components of the sound from dynamic positioning vessels for various reasons, including that their pulses are produced in narrowly directed beams, each individual pulse is very short, and their high-frequency content leads to faster attenuation.

J.4.3.3. Dredging, Trenching, and Cable Laying

The installation of cables can be done by towing a tool behind the installation vessel to simultaneously open the seabed and lay the cable, or by laying the cable and following with a tool to embed the cable. Possible installation methods for these options include jetting, vertical injection, controlled-flow excavation, trenching, and plowing. Burial depth of the cables is typically 1–2 meters. Cable installation vessels may use utilize dynamic positioning to lay the cables (see Section J.4.3.2, *Vessels*).

Nedwell and Edwards (2004) measured sounds from a 130-meter-long trenching vessel and found that sound levels were similar to those produced during pipeline laying in the same area (see below), with the exception of a 20-kilohertz tonal sound, which they attributed to the vessel's dynamic positioning thrusters. Source levels for trenching were not reported. Nedwell et al. (2003) recorded underwater sound

160 meters from trenching activity with the hydrophone 2 meters below the surface (and water depth 7–11 meters) and back-calculated the SPL source level of trenching to be 178 dB re 1 µPa-m (assuming propagation loss of 22logR). They describe the sound as generally spanning a wide range of frequencies, variable over time, and accompanied by some tonal machinery noise and transients associated with rock breakage.

Mechanical dredges mechanically dig or gather sediment from the bottom using a bucket. They may also be called backhoe dredges, grab dredges, bucket dredges, bucket ladder dredges, or clamshells. These dredges are usually fixed via anchoring or dynamic positioning systems. Material is scraped off the bottom and lifted up to the ship using a winch. Mechanical dredging is widely used in the research community to sample hard materials from the seafloor for studies of volcanic areas (e.g., mid-ocean ridges) and deep-sea minerals. These dredges may be used in offshore wind projects to reach cable-burying depths in problematic areas where simple jetting cannot be used.

Dredging produces distinct sounds during each specific phase of operation: excavation, transport, and placement of dredged material (Central Dredging Association 2011; Jiménez-Arranz et al. 2020). Engines, pumps, and support vessels used throughout all phases may introduce low-level, continuous noise into the marine environment. The sounds produced during excavation vary depending on the sediment type—the denser and more consolidated the sediment is, the more force the dredger needs to impart, and the higher sound levels that are produced (Robinson et al. 2011). Hydraulic dredges (with cutterheads or drag arms in continuous contact with the seabed) produce nearly continuous sounds during the excavation process. On the other hand, sounds from mechanical dredges occur in intervals as the dredge lowers a bucket, digs, and raises the bucket with a winch. During the sediment transport phase, many factors—including the load capacity, draft, and speed of the vessel—influence the sound levels that are produced (Reine et al. 2014b). Sounds are also produced during pump-out operations when dredge plant pumps are operated (Central Dredging Association 2011). Dredging activities as a whole generally produce low-frequency sounds; most energy is below 1,000 Hz, with peaks typically occurring between 150–300 Hz (McQueen et al. 2018).

McQueen et al. (2018) summarized results from several studies that measured sounds during dredging operations. For cutterhead suction dredges, SPL source levels were 168–175 dB re 1 µPa-m (Greene 1987; Reine et al. 2012b, 2014a). Trailing suction hopper dredges were slightly louder, with SPL source levels ranging from 172–190 dB re 1 µPa-m (McQueen et al. 2018). Dickerson et al. (2001) recorded a maximum SPL of 124 dB re 1 µPa at 154 meters during the moment when the grab hit the seabed; during other phases of operation (e.g., raising and lowering of grab dredge, dumping sediment on barge), the received SPL was closer to approximately 110–115 dB re 1 µPa at 154 meters. Finally, SPL source levels during backhoe dredge operations ranged from 163–179 dB re 1 µPa-m (Nedwell et al. 2008; Reine et al. 2012a). Hydraulic dredges are generally louder than mechanical dredges, and dredging of coarser sediments usually produces more noise than softer sediments (Jiménez-Arranz et al. 2020). Additional detail and measurements of dredging sounds can be found in Jiménez-Arranz et al. (2020), McQueen et al. (2018), and Robinson et al. (2011).

J.4.4 Operations and Maintenance

J.4.4.1. Aircraft

Manned aircraft consist of propeller and jet engines, fixed-wing craft, and helicopters. Unmanned systems also exist. For jet engine aircraft, the engine is the primary source of sound. For propeller-driven aircraft and helicopters, the propellors and rotors also produce noise. Aircraft generally produce low-frequency sound below 500 Hz (Richardson et al. 1995). While aircraft noise can be substantial in air, penetration of aircraft noise into the water is limited because much of the noise is reflected off the water’s surface (Richardson et al. 1995). The noise that does penetrate into the water column does this via a critical incident angle or cone. With an idealized flat sea surface, the maximum critical incident angle is approximately 13 degrees (Urick 1983); beyond this, sound is reflected off the surface. When the sea surface is not flat, there may be some additional penetration into the water column in areas outside of this 13-degree cone. Nonetheless, the extent of noise from passing aircraft is more localized in water than it is in air.

Jiménez-Arranz et al. (2020) reviewed Richardson et al.'s (1995) sound measurements recorded below passing aircraft of various models. These SPL measurements included 124 dB re 1 µPa (dominant frequencies between 56–80 Hz) from a maritime patrol aircraft with an altitude of 76 meters, 109 dB re 1 µPa (dominant frequency content below 22 Hz) from a utility helicopter with an altitude of 152 meters, and 107 dB re 1 µPa (tonal, 82 Hz) from a turbo propeller with an altitude of 457 meters. Recent published levels associated with unmanned aircraft (Christiansen et al. 2016; Erbe et al. 2017) indicate source levels around or below 100 dB re 1 µPa-m.

J.4.4.2. Vessels in Transit

During operations, small vessels may be used to transport crew and supplies. Noise from vessel transit is considered to be continuous, with a combination of broadband and tonal sounds (Richardson et al. 1995; Ross 1976). Transiting vessels generate continuous sound from their engines, propeller cavitation, onboard machinery, and hydrodynamics of water flows (Ross 1976). The actual radiated sound depends on several factors, including the type of machinery on the ship, the material conditions of the hull, how recently the hull has been cleaned, interactions with the sea surface, and shielding from the hull, which reduces sound levels in front of the ship.

In general, vessel noise increases with ship size, power, speed, propeller blade size, number of blades, and rotations per minute. Source levels for large container ships can range from 177 to 188 dB re 1 µPa-m (McKenna et al. 2013) with most energy below 1 kilohertz. Smaller vessels typically produce higher-frequency sound concentrated in the 1–5 kilohertz range. Kipple and Gabriele (2003) measured underwater sound from vessels ranging from 14 to 65 feet long (25 to 420 horsepower) and back-calculated source levels to be 157–181 dB re 1 µPa-m. Similar levels are reported by Jiménez-Arranz et al. (2020), who provide a review of measurements for support and crew vessels, tugs, rigid-hull inflatable boats, icebreakers, cargo ships, oil tankers, and more.

During transit to and from shore bases, survey vessels typically travel at speeds that optimize efficiency, except in areas where transit speed is restricted. The vessel strike speed restrictions in place along the Atlantic OCS are expected to offer a secondary benefit of underwater noise reduction. For example, recordings from a speed reduction program in the Port of Vancouver (210–250-meter water depths) showed that reducing speeds to 11 knots reduced vessel source levels by 5.9–11.5 dB, depending on the vessel type (MacGillivray et al. 2019). Vessel noise is also expected to be lower during G&G surveys, as they typically travel around 5 knots when towing instruments.

J.4.4.3. Turbine Operations

Once wind farms are operational, low-level sounds are generated by each WTG, but sound levels are much lower than during construction. This type of sound is considered to be continuous, omnidirectional radially from the pile, and non-impulsive. Most of the energy associated with operations is below 120 Hz. Sound levels from WTG operations are likely to increase somewhat with increasing generator size and power ratings, as well as with wind speeds. Recordings from Block Island Wind Farm indicated that there was a correlation between underwater sound levels and increasing wind speed, but this was not clearly influenced by turbine machinery; rather it may have been explained by the natural effects that wind and sea state have on underwater sound levels (Elliott et al. 2019; Urick 1983).

A recent compilation (Tougaard et al. 2020) of operational noise from several wind farms, with turbines up to 6.15 MW in size, showed that operational noise generally attenuates rapidly with distance from the turbines (falling to near-ambient sound levels within approximately 1 kilometer from the source), and the combined noise levels from multiple turbines is lower or comparable to that generated by a small cargo ship. Tougaard et al. (2020) developed a formula predicting a 13.6-dB increase for every tenfold increase in WTG power rating. This means that operational noise could be expected to increase by 13.6 dB when increasing in size from a 0.5-MW turbine to a 5-MW one, or from 1 MW to 10 MW. The least squares fit of that dataset would predict that the SPL measured 100 meters from a hypothetical 15-MW turbine in operation in 10-m/s (19-knot or 22-mile-per-hour) wind would be 125 dB re 1 µPa. However, all of the 46 data points in that dataset—with the exception of the two from Block Island Wind Farm—were from WTGs operated with gear boxes of various designs rather than the newer use of direct-drive technology, which is expected to lower underwater noise levels substantially. Stöber and Thomsen (2021) make predictions for source levels of 10-MW turbines based on a linear extrapolation of maximum received levels from WTGs with ratings up to 6.15 MW. The linear fit is likely inappropriate, and the resulting predictions may be exaggerated. Tougaard et al. (2020) point out that received level differences among different pile types could be confounded by differences in water depth and turbine size. In any case, additional data are needed to fully understand the effects of size, foundation type properties (e.g., structural rigidity and strength), and drive type on the amount of sound produced during turbine operation.

J.4.5 Decommissioning

The methods that may be used for decommissioning are not well understood at this time. It is possible that explosives may be used (see Section J.4.2, *Unexploded Ordnance Detonations*). However, given the general trend of reducing the use of underwater explosives that has been observed in the oil and gas industry, it is likely that offshore wind structures will instead be removed by cutting. While it is difficult to extrapolate directly, we can glean some insights from a recent study that measured received sound levels during the mechanical cutting of well conductor casings on oil and gas platforms in California. The cutters operated at 60–72 revolutions per minute, and the cutting time varied widely between cuts (on the order of minutes to hours). At distances of 106–117 meters from the cutting, received SPLs were 120–130 dB re 1 µPa, with most acoustic energy falling between 20 and 2,000 Hz (Fowler et al. 2022). This type of sound is considered to be non-impulsive and intermittent (i.e., continuous while cuts are actually being made, with quieter periods between cuts). Additional noise from vessels (see Section J.4.3.2, *Vessels*) and other machinery may also be introduced throughout the decommissioning process.

J.5. Regulation of Underwater Sound for Marine Mammals

The MMPA prohibits the “take” of marine mammals, defined as the harassment, hunting, capturing, killing, or an attempt of any of those actions on a marine mammal. This act requires that an incidental take authorization be obtained for the incidental take of marine mammals as a result of anthropogenic activities. MMPA regulators divide the effects on marine mammals that could result in a take into Level A and Level B, defined as follows:

- Level A: Any act of pursuit, torment, or annoyance that has the potential to <u>injure</u> a marine mammal or marine mammal stock in the wild
- Level B: Any act of pursuit, torment, or annoyance that has the potential to <u>disturb</u> a marine mammal or marine mammal stock in the wild by causing a disruption of behavioral patterns including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but that does not have the potential to injure a marine mammal or marine mammal stock in the wild (16 USC 1362)

With respect to anthropogenic sounds, Level A takes generally include injury impacts like PTS, whereas Level B takes include behavioral effects as well as TTS. The current regulatory framework used by

NMFS for evaluating an acoustic take of a marine mammal involves assessing whether the animal's received sound level exceeds a given threshold. For Level A, this threshold differs by functional hearing group, but for Level B, the same threshold is used across all marine mammals.

J.5.1 Thresholds for Injury

The current NMFS (2018) injury (Level A) thresholds consist of dual criteria of L_{pk} and 24-hour cumulative SEL thresholds (Figure J-1). These criteria are used to predict the potential range from the source within which injury may occur. The criterion that results in the larger physical impact range is generally used to be most conservative. The SEL thresholds are frequency weighted, which means that the sound is essentially filtered based on the animal's frequency-specific hearing sensitivity, de-emphasizing the frequencies at which the animal is less sensitive (see Section J.17 for the frequency range of hearing for each group). The frequency weighting functions are described in detail in Finneran (2016).

Table J-1 The Acoustic Thresholds for Onset of Permanent Threshold Shift and Temporary Threshold Shift for Marine Mammals for Both Impulsive and Non-impulsive Sound Sources

Marine Mammal Functional Hearing Group	Effect	Impulsive Source		Non-impulsive Source
		L_{pk} (dB re 1 μPa)	Weighted SEL_{24h} (dB re 1 μPa²s)	Weighted SEL_{24h} (dB re 1 μPa²s)
LFC	PTS	219	183	199
	TTS	213	168	179
MFC	PTS	230	185	198
	TTS	224	170	178
HFC	PTS	202	155	173
	TTS	196	140	153
Phocid pinnipeds underwater	PTS	218	185	201
	TTS	212	170	181
Otariid pinnipeds underwater	PTS	232	203	199
	TTS	226	188	199

Source: NMFS 2018
Note: L_{pk} values are unweighted within the generalized hearing range of marine mammals (i.e., 7 Hz to 160 kilohertz): Values presented for SEL use a 24-hour accumulation period unless stated otherwise, and are weighted based on the relevant marine mammal functional hearing group (Finneran 2016).
dB re 1 µPa = decibels relative to 1 µPa; dB re 1 µPa^{2}s = decibels relative to 1 µPa^{2}s.

J.5.2 Thresholds for Behavioral Disturbance

NMFS currently uses a threshold for behavioral disturbance (Level B) of 160 dB re 1 μPa SPL for non-explosive impulsive sounds (e.g., airguns, impact pile driving) and intermittent sound sources (e.g., scientific and non-tactical sonar), and 120 dB re 1 μPa SPL for continuous sounds (e.g., vibratory pile driving, drilling (NMFS 2022). This is an "unweighted" criterion that is applicable for all marine mammal species. In-air behavioral thresholds exist for harbor seals and non-harbor seal pinnipeds at 90 dB re 20 μPa SPL and 100 dB re 20 μPa SPL, respectively (NMFS 2022). Unlike with SEL-based thresholds, the accumulation of acoustic energy over time is not relevant for this criterion, meaning that a Level B take can occur even if an animal experiences a received SPL of 160 dB re 1 μPa very briefly just once.

While the Level B criterion is generally applied in a binary fashion, as alluded to previously, there are numerous factors that determine whether an individual will be affected by a sound, resulting in substantial variability even in similar exposure scenarios. In particular, it is recognized that the context in which a sound is received affects the nature and extent of responses to a stimulus (Ellison et al. 2012; Southall et al. 2007). Therefore, a "step function" concept for Level B harassment was introduced by Wood et al. (2012) whereby proportions of exposed individuals experience behavioral disturbance at different received levels, centered at an SPL of 160 dB re 1 μPa. These probabilistic thresholds reflect the higher sensitivity that has been observed in beaked whales and migrating mysticete whales (Table J-2). At the moment, this step function provides additional insight to calculating Level B takes for certain species groups. The M-weighting functions, described by Southall et al. (2007) and used for the Wood et al. (2012) probabilistic disturbance step thresholds, are different from the weighting functions by Finneran (2016) previously mentioned. The M-weighting was specifically developed for interpreting the likelihood of audibility, whereas the Finneran weighting functions were developed to predict the likelihood of auditory injury.

Table J-2 Probabilistic disturbance SPL_{RMS} thresholds (M-weighted) used to predict a behavioral response. Probabilities are not additive and reflect single points on a theoretical response curve

Marine Mammal Group	Probabilistic Disturbance RMS Thresholds M-weighted dB re: 1 µPa RMS			
	120	140	160	180
Porpoises/beaked whales	50%	90%	--	--
Migrating mysticetes whales	10%	50%	90%	--
All other species/behaviors	--	10%	50%	90%

Source: Wood et al. 2012

J.5.3 Thresholds for Non-auditory Injury for Explosives

Shock waves associated with underwater detonations can induce non-auditory physiological effects, including mortality and direct tissue damage (i.e., severe lung injury, slight lung injury, and gastrointestinal tract injury). To predict non-auditory lung injury and mortality, the acoustic impulse, measured in pascal-seconds, is the integral of the pressure shock pulse over time and serves as the threshold. Because lung capacity or size is generally directly related to the size of an animal, body mass is one parameter used to predict the likelihood of lung injury. In addition, the depth of the animal is used, as this represents the ambient pressure conditions of the animal and its vulnerability to a rapid change in pressure. Gastrointestinal tract injury potential is identified using the peak SPL and is considered to occur beginning at levels of 237 dB re 1 µPa. The U.S. Navy established thresholds to identify to assess the potential for mortality and slight lung injury from explosive sources based on a modified Goertner equation; this assessment adopts and applies these thresholds (Navy 2017). Table J-3 provides an estimate of mass of the different marine mammal species covered in this assessment. Table J-4 lists the equations used to calculate thresholds based on effects observed in 1 percent of animals.

Table J-3 Representative Calf/Pup and Adult Mass Estimates Used for Assessing Impulse-based Onset of Lung Injury and Mortality Threshold Exceedance Distances

Impulse Animal Group	Representative Species	Calf/Pup Mass (kilograms)	Adult Mass (kilograms)
Baleen whales and sperm whale	Sei whale (*Balaenoptera borealis*), sperm whale (*Physeter macrocephalus*)	650	16,000
Pilot and minke whales	Minke whale (*Balaenoptera acutorostrata*)	200	4,000

Impulse Animal Group	Representative Species	Calf/Pup Mass (kilograms)	Adult Mass (kilograms)
Beaked whales	Gervais' beaked whale (*Mesoplodon europaeus*)	49	366
Dolphins, Kogia, pinnipeds, and sea turtles	Harbor seal (*Phoca vitulina*)	8	60
Porpoises	Harbor porpoise (*Phocoena phocoena*)	5	40

Table J-4 Marine Mammal Acoustic Thresholds used by NMFS for Non-auditory Injury and Mortality from Explosives

Mammals	Mortality (Severe Lung Injury) (Pa·s)	Slight Lung Injury (Pa·s)	G.I. Tract Injury (L_{pk}, dB re 1 μPa)
All marine mammals	$I=103M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$	$I=47.5M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$	237

Impulse thresholds for mortality and slight lung injury are calculated using the modified Goertner equation presented in Navy 2017, equations 11 (slight lung injury) and 12 (mortality), where *M* is the animal's mass in kilograms and *D* is the depth of the animal at exposure in meters.
Lung injury (severe and slight) thresholds are dependent on animal's mass, *M, in* kilograms (see Table C.9 in Navy 2017) and the animal's depth, *D,* in meters.
G.I. = gastrointestinal; Pa s = pascal-second

J.6. Thresholds for Auditory Injury for Explosives

The supersonic shock wave from an explosion transitions to normal pressure wave at a range determined by the weight and type of the explosive used. The range to the TTS and PTS threshold are outside of these radii, and the normal impulsive TTS and PTS thresholds (Table J-1) are applicable for determining auditory injury impacts (NMFS 2018).

J.7. Thresholds for Behavioral Disturbance for Explosives

Single blast events within a 24-hour period are not presently considered by NMFS to produce behavioral effects if they are below the onset of TTS thresholds for frequency-weighted SEL and peak pressure level. Only short-term startle responses are expected as far as behavioral responses. For multiple detonations, the threshold applied for behavioral effects is that same TTS threshold minus 5 dB.

J.7.1 Approach to Acoustic Exposure Modeling

In order to predict the number of individuals of a given species that may be exposed to harmful levels of sound from a specific activity, a series of modeling exercises are conducted. First, the sound field of a sound-generating activity is modeled based on characteristics of the source and the physical environment. From the sound field, the range to the U.S. regulatory acoustic threshold isopleths can be predicted. This approach is referred to as *acoustic modeling*. By overlaying the marine mammal density information for a certain species or population in the geographical area of the activity, the number of animals exposed within the acoustic threshold isopleths is then predicted. This is called *exposure modeling*. Some models further incorporate animal movement to make more realistic predictions of exposure numbers. Animal movement models may incorporate behavioral parameters including swim speeds, dive depths, course changes, or reactions to certain sound types, among other factors. Exposure modeling may be conducted for a range of scenarios including different seasons, energy (e.g., pile-driving hammers), mitigation strategies (e.g., 6 dB versus 10 dB of attenuation), and levels of effort (e.g., number of piles per day).

J.8. Regulation of Underwater Sound for Fishes and Invertebrates

J.8.1 Thresholds for Injury

During construction of the Bay Bridge in California, researchers observed dead fish near pile-driving operations, suggesting that fish could be killed when in very close proximity (less than 10 meters) to the pile (Caltrans 2004). Further work around this construction project led to the formation of dual interim criteria by the Fisheries Hydroacoustic Working Group (2008), which were later adopted by NMFS. With these interim criteria, the maximum permitted peak SPL for a single pile-driving strike is 206 dB re 1 µPa, and the maximum accumulated SEL is 187 dB re 1 µPa^{2}s for fishes greater than 2 grams, and 183 dB re 1 µPa^{2}s for fishes below 2 grams (Table J-5). These criteria are still being used by NMFS but, given the new information obtained since 2008, the appropriateness of these thresholds is being reconsidered (Popper et al. 2019).

These early findings prompted a suite of laboratory experiments in which a special testing apparatus was used to simulate signals from pile driving that a fish would encounter around 10 meters from a pile (Casper et al. 2012, 2013a, 2013b; Halvorsen et al. 2011, 2012a, 2012b). An important component of this work was the ability to simulate both the pressure and particle motion components of the sound field, which is rarely done in laboratory experiments. These studies showed that effects are greater in fishes with swim bladders than those without, and that species with closed swim bladders experienced greater damage than those with open swim bladders. Evidence of barotrauma was observed starting at peak pressures of 207 dB re 1 µPa (Halvorsen et al. 2012a). Larger animals seem to have a higher susceptibility to injury than smaller animals (Casper et al. 2013a). The researchers found that most of the species tested showed recovery from injury within 10 days of exposure, but they note that injured animals may be more vulnerable to predation while they are recovering, and these secondary effects have not been studied. The authors also conclude that SEL alone is not enough to predict potential impacts on fishes; the energy in a given strike and the total number of strikes are also important factors. These studies formed the foundation of the *Guidelines for Fish and Sea Turtles* by Popper et al. (2014), which became ANSI standard (#ASA S3/SC1.4 TR-2014) and have become widely accepted hearing thresholds for fishes and turtles.

No studies have directly measured TTS in fishes as a result of exposure to pile-driving noise. Popper et al. (2005) exposed caged fish to sounds of seismic airguns (an impulsive signal that can serve as a proxy) and tested their hearing sensitivity afterward. Three species with differing hearing capabilities were exposed to five pulses at a mean received L_{pk} of 207 dB re 1 µPa (186 dB re 1 µPa^{2}s SEL). None of the fish showed evidence of barotrauma or tissue damage, and there was no damage to the hearing structures (Song et al. 2008). The species with the least-sensitive hearing—the broad whitefish—showed no evidence of TTS. The northern pike and lake chub, species with more sensitive hearing, did exhibit TTS after exposure to seismic pulses but showed recovery after 18 hours. The findings suggest that there is a relationship between hearing sensitivity and level of impact, and that species without a connection between the swim bladder and ear are unlikely to experience TTS. Nonetheless, Popper et al. (2014) propose 186 dB re 1 µPa^{2}s SEL as a conservative TTS threshold for all fishes exposed to either seismic airguns or pile driving, regardless of hearing anatomy. They acknowledge that research is needed on potential TTS due to exposure to pile-driving noise and that future work should measure particle motion as the relevant cue.

A handful of studies have directly investigated the effects of impulsive sounds on eggs and larvae of marine fishes and invertebrates, and most have taken place in the laboratory. Bolle et al. (2012) used a device similar to that used by Halvorsen et al. (2012a) to simulate pile-driving sounds and found no damage to larvae of common sole (which has a swim bladder at certain larval stages) from an SEL of 206 dB re 1 uPa^2s, which the authors surmise is equivalent to the received level at approximately 100 meters from a 4-meter-diameter pile. Further work by Bolle et al. (2014) tested larvae of seabass and herring (both species have swim bladders). Several different life stages were tested, but none of the species showed a difference in mortality between control and exposed animals. The seabass were exposed to SELs up to 216 dB re 1 μPa^2s and maximum L_{pk} of 217 dB re 1 μPa, while herring were exposed to SELs up to 212 dB re 1 μPa^2s and maximum L_{pk} of 207 dB re 1 μPa. Together, the tested larvae represent the entire range of swim bladder shape types described by Popper et al. (2014). There was no difference in impacts experienced by species with and without a swim bladder or between those with open or closed swim bladders. Based on this work, Popper et al. (2014) use 210 dB re 1 uPa^2s SEL as a threshold for mortality after exposure to both pile driving and seismic airguns.

Popper et al. (2014) provide thresholds for non-recoverable injury, recoverable injury (i.e., mild forms of barotrauma), and TTS for the three hearing groups, plus an additional category for eggs and larvae (Table J-5). Unlike with marine mammals, Popper et al. (2014) do not distinguish between impulsive and non-impulsive sounds; instead they provide thresholds for each sound type (explosions, pile-driving, seismic airguns, sonars, and continuous sounds). That said, studies focused on pile-driving are sometimes used to draw conclusions about impacts from seismic airguns, and vice versa. This is simply due to a lack of comprehensive data for each source type. The thresholds are all given in terms sound pressure, not particle motion, though many have acknowledged that these would be more appropriate (Popper and Hawkins 2018). Currently, there are no underwater noise thresholds for invertebrates, but the effect ranges are expected to be similar to those predicted for fishes in Group 1.

Table J-5 Acoustic Thresholds for Exposure to Pile-driving Sound

Fish Hearing Group	Mortality and Non-Recoverable injury		Recoverable Injury		TTS
	L_{pk}	SEL	L_{pk}	SEL	SEL
Fish without swim bladder (Group 1)[1]	>213	>219	>213	>216	>>186
Fish with swim bladder not involved in hearing (Group 2)[1]	>207	210	>207	203	>186
Fish with swim bladder involved in hearing (Group 3)[1]	>207	207	>207	203	186
Eggs and Larvae[1]	>207	>210	--	--	--
Fish ≥ 2 grams[2]	--	--	206	187	--
Fish < 2 grams[2]	--	--	206	183	--

[1] Popper et al. (2014) Sound Exposure Guidelines. Note that Popper et al. (2014) use the notation "SEL_{cum}," but SEL without a subscript is the preferred nomenclature, used here to describe the energy that would be accumulated over an entire pile-driving event (i.e., installation of a pile).
[2] Fisheries Hydroacoustic Working Group (2008)

J.8.2 Thresholds for Behavioral Disturbance

NOAA Fisheries currently uses an SPL criterion of 150 dB re 1 μPa for the onset of behavioral effects in fishes (GARFO 2020). The scientific rationale for this criterion is not well supported by the data (Hastings 2008), and there has been criticism about its use (Popper et al. 2019). Most notably, the differences in hearing anatomy among fishes suggest the use of a single criterion may be too simplistic. Furthermore, a wide range of behavioral responses have been observed in the empirical studies thus far (ranging from startle responses to changes in schooling behavior), and it is difficult to ascertain which, if any, of those responses may lead to significant biological consequences. Interestingly, several recent studies on free-ranging fishes (e.g., Hawkins et al. 2014; Roberts et al. 2016) have observed the onset of different behavioral responses at similar received levels ($L_{pk\text{-}pk}$ of 152–167 dB re 1 µPa), and Popper et al. (2019) suggest that a received level of 163 dB re 1 µPa $L_{pk\text{-}pk}$ might be more appropriate than the current criterion of 150 re 1 µPa L_{RMS}. Finally, given that most species are more sensitive to particle motion and not acoustic pressure, the criteria should, at least in part, be expressed in terms of particle motion. However, until there is further empirical evidence to support a different criterion, the 150 dB re 1 µPa L_{RMS} threshold remains in place as the interim metric that regulatory agencies have agreed upon.

J.8.3 Thresholds for Explosives

Popper et al. (2014) present criteria for mortality and non-recoverable injury as a result of exposure to detonations. They note that it is difficult to disentangle the effects of the compressive forces of the shock wave (very close to the explosion) versus the decompressive effect (area of negative pressure, farther from the explosion), but either can lead to barotrauma or mortality in fishes. Several studies (e.g., Goertner 1978; Yelverton 1975) have worked with different species, with different charge sizes and water depths, all of which are important factors in predicting the effects of explosives. Yet Popper et al. (2014) derive their thresholds using data from an older study that represent the lowest amplitude that caused consistent mortality across species (Hubbs and Rechnitzer 1952). Therefore, for all fishes, regardless of hearing anatomy, the threshold for mortality and non-recoverable injury is given as a range: 229–234 dB re 1 µPa L_{pk} by Popper et al. (2014), but in practice, 229 dB is likely used.

J.9. Short Project Description

This section is focused on providing an overview of the methods, assumptions, and results of the technical acoustic modeling report prepared for the Project (Ocean Wind 2022; Küsel et al. 2022; Hannay and Zykov 2022; JASCO 2021). Readers who may be less familiar with acoustic terminology are recommended to refer to the glossary (COP Volume III, Appendix R-2; Ocean Wind 2023).

The Project would consist of up to 98 WTGs, up to three OSS, and interconnection and export cables. The Project would be on the OCS offshore New Jersey in BOEM Lease Area OCS-A 0498. The major underwater noise-producing activities of this Project would include impact pile driving during construction. The piles to be driven would include large (11-meter-diameter at the mudline) monopiles and 2.44-meter-diameter pin piles. This appendix summary focuses on the quantitative modeling of the impact pile driving, vibratory pile driving, HRG surveys, and UXO detonations. Qualitative assessments of lower noise level activities (dredging, vessel movements etc.) were also provided in the technical acoustic modeling report (COP Volume III, Appendix R-2; Ocean Wind 2023).

For the quantitative modeling assessment of impact pile driving, predicted sound fields were generated for one representative deep-water location for the monopiles and for one shallow-water location for the jacket foundation with pin piles (Figure 2 and Table 3; Küsel et al. 2022). Sound field predictions were made for both summertime and wintertime conditions. To predict sound fields, the sound produced at the pile as the hammer strikes it must be characterized. The propagation of the hammer-strike sound through the water column and the sediment is then predicted. The result is a set of predicted broadband sound fields, which are used to predict the ranges to U.S. regulatory isopleths as well as the number of marine animals that could be exposed to sound levels that exceed regulatory thresholds. Finally, the effects of sound source mitigation (e.g., bubble curtains) on impact pile-driving effects were explored.

A practical spherical spreading model was used by JASCO (JASCO 2021) to estimate the extent of potential underwater noise effects as a result of vibratory driving of sheet piles. The sound level of the vibratory pile driver at 10 meters was assumed to be 165 dB re 1 µPa^2. The modeling assumed that the installation and removal of cofferdams would require 18 hours over 2 days to complete, with vibratory pile driving taking place for no longer than 12 hours each 24-hour period over the installation period.

A total of 31,375 kilometers of HRG surveys are estimated to be required in the Offshore Project area and export cable route area, with a single vessel being able to cover 43.5 miles (70 kilometers) per day. For purposes of analysis, a single vessel survey day is assumed to cover the maximum 70 kilometers. In years 1, 4, and 5, 88 survey days per year are expected. It is estimated that a total of 6,110 linear kilometers would be needed within the Wind Farm Area and export cable route area during this time. Survey effort would be split between the Wind Farm Area and the export cable route area: 3,000 kilometers for the array cable, 2,300 kilometers for the Oyster Creek export cable, 510 kilometers for the BL England export cable, and 300 kilometers for the OSS interconnector cable. During years 2 and 3 (when construction would occur), 180 survey days per year would be required. HRG surveys during WTG and OSS construction and operation would include up to 11,000 kilometers of export cable surveys, 10,500 kilometers of array cable surveys, 1,065 kilometers of foundation surveys, 250 kilometers of WTG surveys, and up to 2,450 kilometers of monitoring and verification surveys. To cover the requirements of the Project, several HRG surveys were considered in the modeling:

- Shallow-penetration, non-impulsive, non-parametric sub-bottom profilers (compressed high-intensity radiated pulses), 2 to 20 kilohertz
- Medium-penetration, impulsive boomers, 3.5 Hz to 10 kilohertz
- Medium-penetration, impulsive sparkers, 50 Hz to 4 kilohertz

For HRG surveys, the NMFS User Spreadsheet Tool and transmission loss equations were used to estimate the distances to thresholds. Source levels relied upon measurements recorded from equipment, the best available manufacturer specifications (representing maximum output), or the closest proxy source (Ocean Wind 2022).

A separate report (Hannay and Zykov 2022) explored the predicted effects of UXO removal by detonation at several locations. In this report, the ranges were calculated to a variety of regulatory thresholds for peak pressure, impulse, and SEL metrics. The modeling of acoustic fields generated by UXO detonations was performed using a combination of semi-empirical and physics-based computational models.

J.10. Acoustic Models and Assumptions

The acoustic assessment of Project activities relies upon a variety of models to predict the potential effect on marine animals. The models used in the quantitative analysis include:

1. GRLWEAP Model: to model the force applied to the pile by the hammer
2. Finite Difference Model: to compute pile vibrations after the hammer strikes the pile
3. Full Waveform Range-dependent Acoustic Model (FWRAM): to calculate the time-dependent sound field and PK sound levels
4. Marine Operation Noise Model (MONM): a parabolic equation model to calculate SEL values for both impulse pile driving and UXO detonations
5. JASMINE Model: the JASCO Applied Sciences animat[1] movement and exposure model
6. UXO Semi-empirical Models: to predict the shock pulse source waveform, the impulse amplitude, and their attenuation with range

[1] Animat = simulated animal

7. NMFS User Spreadsheet Tool (NMFS 2020): this tool, supplied by NMFS, is used to calculate distances to regulatory thresholds when more sophisticated modeling is not available or is not warranted; this tool was used for HRG modeling and assumes spherical spreading.

Both FWRAM and MONM predict the propagation of the source signal through the physical environment. As such, these models require accurate descriptions of the ocean bathymetry, seafloor sediment properties, water column sound velocity profile, and ocean surface roughness. The assumptions of these models and their inputs are critical to the accuracy of the model output.

J.10.1 Physical Environment

The bathymetry information used in the modeling was extracted from the General Bathymetric Chart of the Oceans (GEBCO Bathymetric Compilation Group 2020). A simplified model of the sediment properties (i.e., the Geoacoustic Model) was developed based on measurements made within the Project area. The water column properties (i.e., sound velocity profile) were extracted from the U.S. Navy's Generalized Digital Environmental Model (Carnes 2009). The water column properties change seasonally, and an average of all the summer months was used to represent the Project area for the times in which pile driving was expected to occur. Additional analyses using winter conditions were prepared in the technical acoustic modeling report (COP Volume III, Appendix R-2; Ocean Wind 2023) but were not used for exposure analysis because the proposed activities are intended to take place outside of the NARW seasonal closures.

J.10.2 Impact Pile Sound Source Details

Required inputs for the modeling are the assumed size and properties of the piles, as well as the hammer energy used to drive them into the sediment (Table J-6).

Table J-6 Key Assumptions About the Piles Used in the Underwater Acoustic Modeling

Foundation type	Modeled maximum impact hammer energy (kJ)	Number of Strikes	Strike Rate (min-1)	Pile diameter (m)	Pile wall thickness (mm)	Seabed penetra-tion (m)	Piles per day
Monopile	4,000	10,846	50	8 to 11	80	50	2
Jacket	2,500	13,191	50	2.44	75	70	2–3

m = meter; mm = millimeter

To estimate the number of marine animals likely to be exposed above the regulatory thresholds, a conservative construction schedule that maximized activity during the highest-density months for each species was assumed. Sixty WTG monopiles (two per day for 30 days) were assumed to be installed in the highest-density month of each species and an additional 38 WTG monopiles (two per day for 19 days) were assumed to be installed during the month with the second highest animal density. Two options are being considered for OSS foundations: either three monopiles (two per day for 1 day and one on a third day) or 48 pin piles (three per day for 16 days) in the highest-density month. Both options were modeled and evaluated.

Monopile installation was expected to begin with 500-kJ hammer strikes that would be scaled up to 4,000 kJ at the end of the pile progression. A total of 10,846 strikes are expected per pile, and the strike rate was estimated at 50 strikes per minute. Pin piles are expected to scale from 500 kJ to 2,500 kJ hammer strike energies during the piling progression. A total of 13,191 strikes are predicted for each pin pile, with a strike rate of 50 strikes per minute. Details of the pile progression are presented in the technical acoustic modeling report (COP Volume III, Appendix R-2, Tables 1 and 2; Ocean Wind 2023). No simultaneous pile driving was included in the modeling assumptions.

J.10.3 Vibratory Driving Source Details

The sound level of the vibratory pile driver was assumed to be 165 dB re 1 μPa^2 at 10 meters range. The NMFS (2020) practical spherical spreading model was used to estimate the range to regulatory thresholds. This modeling assumed that the installation and removal of cofferdams would each require 18 hours to complete over 2 days, with vibratory driving taking place for no longer than 12 hours each day.

J.10.4 UXO Sound Source Details

Five different charge sizes (Table J-7) were modeled at the four modeling sites with depths ranging from 12 meters to 45 meters in depth. The net explosive weights listed in Table J-7 include both the donor charge and UXO weights. Predictions for the range to thresholds were made with and without 10 dB of bubble curtain mitigation. As Ocean Wind has committed to attaining a 10-dB attenuation for all UXO detonation events, mitigated values are presented herein.

Table J-7 UXO Charge Sizes Used for Underwater Acoustic Modeling

Navy Bin	Maximum net equivalent weight TNT	
	kilograms	pounds
E4	2.3	5
E6	9.1	20
E8	45.5	100
E10	227	500
E12	454	1,000

TNT = trinitrotoluene

J.10.5 HRG Sound Source Details

Both non-impulsive and impulsive HRG sources were considered (Table J-8).

Table J-8 HRG Equipment Used for Underwater Acoustic Assessment

Equipment	Operating frequency (kHz)	SL_{RMS} (dB re 1 μPa-m)	$SL_{0\text{-}pk}$ (dB re 1 μPa-m)	Pulse duration (width) (mse)	Repetition rate (Hz)	Beam-width (degrees)	CF (2016) or MAN
Non-parametric shallow penetration SBPs (non-impulsive)							
ET 216 (2000DS or 3200 top unit)	2–16	195	--	20	6	24	MAN
	2–8	--	--	--	--	--	--
ET 424	4–24	176	--	3.4	2	71	CF
ET 512	0.7–12	179	--	9	8	80	CF
GeoPulse 5430A	2–17	196	--	50	10	55	MAN
Teledyne Benthos Chirp III - TTV 170	2–7	197	--	60	15	100	MAN
Medium penetration SBPs (impulsive)							
AA, Dura-spark UHD (400 tips, 500 J)	0.3–1.2	203	211	1.1	4	Omni	CF

Equipment	Operating frequency (kHz)	SL_{RMS} (dB re 1 μPa-m)	$SL_{0\text{-}pk}$ (dB re 1 μPa-m)	Pulse duration (width) (mse)	Repetition rate (Hz)	Beam-width (degrees)	CF (2016) or MAN
AA, triple plate S-Boom (700–1,000 J)	0.1–5	205	211	0.6	4	80	CF

CF = Crocker and Fratantonio; dB re 1 μPa = decibel referenced to 1 micropascal; kHz = kilohertz; m = meter; MAN = manufacturer; $SL_{0\text{-}pk}$ = zero to peak source level; SL_{RMS} = root-mean-square source level; SBP = sub-bottom profilers

J.11. Details of Attenuation (Bubble Curtain) Method

As described in Ocean Wind's Application for MMPA Rulemaking and Letter of Authorization, Ocean Wind is proposing use of a dual noise mitigation system (e.g., bubble curtain system and an additional system) to achieve broadband noise attenuation during impact pile installation (Ocean Wind 2022). The same or a different noise mitigation system would be used during UXO detonations.

No specific sound source attenuation method was specified in the modeling report. However, the effect of sound source attenuation at 0, 6, 10, 15, and 20 dB for winter and summer conditions was presented in the report for the marine mammal regulatory SEL isopleths (COP Volume III, Appendix R-2, Tables H-45 and H-46; Ocean Wind 2023). These sound source attenuation effects are summarized for LFC (Figure J-3) to provide an illustration of the general effectiveness of different levels of sound source attenuation. An attenuation of 10 dB produces about a 50-percent reduction in the ranges to injury thresholds or isopleths. All the predicted exposures and ranges to thresholds were calculated using 10 dB of sound source attenuation.

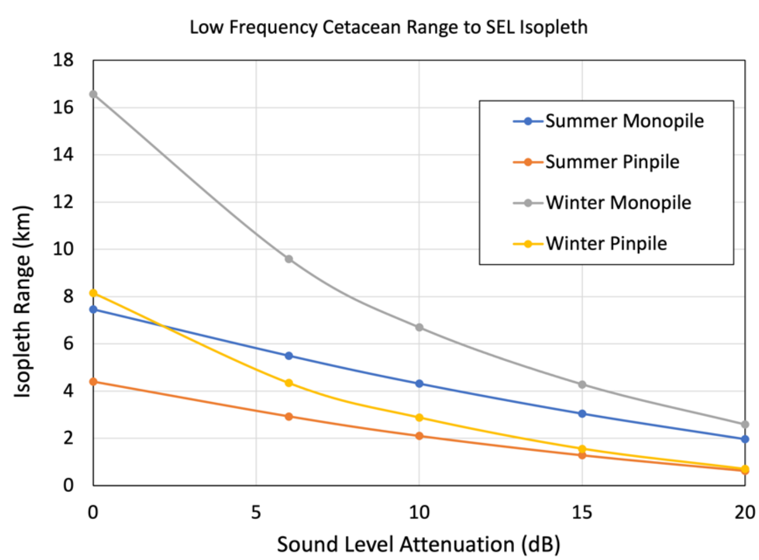


Figure J-3 Effect of Sound Source-Attenuation Levels on Ranges to SEL Isopleths for LFC in Summer and Winter Conditions

The effects of the five levels of sound attenuation on the distances to fish regulatory isopleths for the large monopoles were presented in the technical acoustic modeling report (COP Volume III, Appendix R-2; Ocean Wind 2023), Tables H-47 to H-54, with pin pile values presented in Tables H-55 to H-62.

J.12. Propagation Modeling Methods

To model the sound from the pile driving, 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 is simulated using a vertical array of discrete point sources. Their amplitudes 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.

J.12.1 SEL Modeling

MONM was used to compute received SEL (L_E) for impact pile driving and UXO detonations. MONM uses a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model that has been modified to account for a solid seabed (Zhang and Tindle 1995). Like all parabolic equation models, MONM requires environmental inputs such as bathymetry, the water sound speed profile, and seabed properties.

J.12.2 PK and SPL Modeling for Impact Pile Driving

Time-domain predictions of the pressure waves generated in the water are required for calculating SPL and PK pressure levels for impulsive sounds from impact pile driving. Furthermore, the pile must be represented as a distributed source to accurately characterize vertical directivity effects in the near-field zone. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments (Figure J-4), and it requires the same environmental inputs as MONM. Synthetic pressure waveforms were modeled over the frequency range 10 to 2,048 Hz, inside a 0.5-second window. The synthetic pressure waveforms were post-processed, after applying a travel time correction, to calculate standard SPL and SEL metrics versus range and depth from the source.

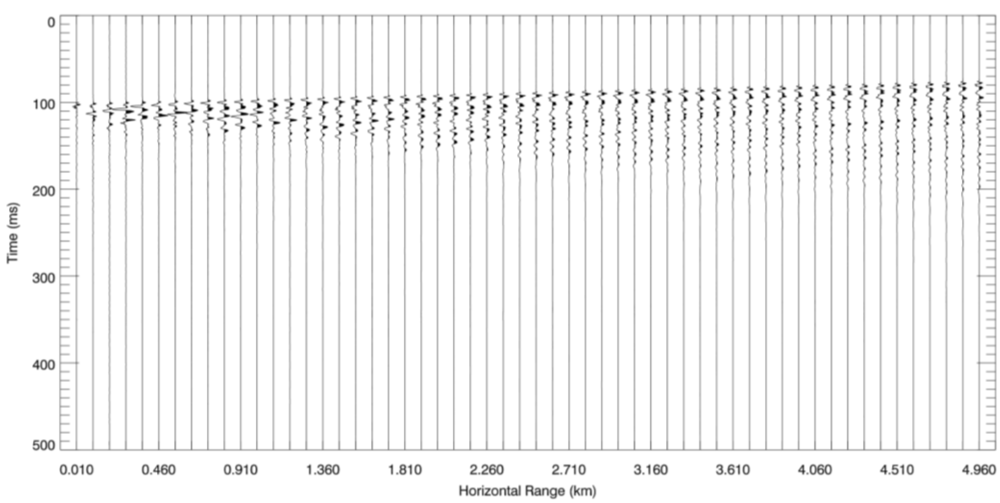


Figure J-4 Example of Synthetic Pressure Waveforms Computed by FWRAM at Multiple Range Offsets

J.12.3 Vibratory Pile-driving Modeling

Vibratory driving hammers are assumed to have a sound level of 165 dB re 1 μPa^2 at 10 meters range. Because the source level is so low, the simple NMFS (2020) practical spherical spreading model was used to predict the ranges to regulatory thresholds, which is a reasonable approach.

J.12.4 Peak Pressure and Impulse Modeling for UXO Detonations

The waveform of UXO detonations was predicted using the methodology of Arons and Yennie (1948, Küsel et. al. citing Arons and Yennie 1949). The shock wave peak pressure as a function of range was predicted using weak shock theory (Rogers 1977). These are both well-established prediction methods that have been validated.

J.12.5 HRG Acoustic Propagation Methods

Ranges to level A regulatory isopleths for the HRG sources were calculated using the NMFS (2020) User Spreadsheet Tool. This tool accounts for the source level, the speed of the vessel, the repetition rate of the source, the pulse duration, and frequency weighting for each source/animal hearing group combination. Ranges to behavioral thresholds were calculated using the NMFS (2020) practical spherical spreading model. Finally, isopleth distances for HRG sources with beamwidths less than 180° were calculated following NMFS Office of Protected Resources interim guidance (Guan 2020).

J.13. Animal Movement Model Methodology

The combination of the predicted sound fields and animal movements was used to derive the animal exposures. Movement predictions are typically created using an animat-based model (Dean 1998; Frankel et al. 2002). Such modeling is typically conducted for individual species, when sufficient data are available, or representative species groups. Animat models require the input of a variety of behavioral parameter values that reproduce the "behavioral envelope" of each species or group. Examples include the range of swimming speeds, dive depths, and course changes. The output can be thought of as a table of latitude, longitude, depth, and time values that represent the four-dimensional movements of the animat; the input values were not included in the report.

The JASMINE animat modeling program was used to simulate animal movement through the predicted sound fields. JASMINE simulates full four-dimensional movement (space and time). The direction of animats was predicted using either a random walk, correlated random walk, or correlated random walk with directional bias (used for migratory animals). The underwater acoustic and exposure modeling report (COP Volume III, Appendix R-2; Ocean Wind 2023) did not specify which directional model was used in the simulations they conducted.

Animat tracks begin with an initial position. The animal's direction is based on the input behavioral parameters, which, along with its speed and diving behavioral values, are used to create an individual movement leg (i.e., the course between two three-dimensional locations). The model then repeats the individual movement leg process to build a full track for the duration of the simulation.

Within each modeled species or species group, JASMINE can simulate different behavioral states (e.g., foraging, resting, or directed travel). A set of transition probabilities is used to control when or if an individual animat will switch behavioral states. However, the details of which behavioral states and the transition probabilities used in the animat modeling were not provided in the report.

JASMINE can include behavioral aversion to sound sources as a behavioral state. Aversion is used to explore how the predicted exposures of animals may differ between simulations where aversion to sound sources is included or not. The underwater acoustic and exposure modeling report (COP Volume III, Appendix R-2; Ocean Wind 2023) focused on exploring the differences caused by aversion in NARWs (a critically endangered species) and harbour porpoises (a common species in coastal waters known to have strong behavioral reactions to sound). Aversion for these two marine mammal species was implemented by allowing the animats to change course away from the sound source, with low levels of aversion at low sound received levels, moderate aversions at moderate sound levels, and strong aversion at higher sound levels. The specific values are shown in the underwater acoustic and exposure modeling report (COP Volume III, Appendix R-2, Tables J-1 and J-2; Ocean Wind 2023).

J.14. Ranges to Regulatory Thresholds Methods

The standard approach of taking the maximum sound received level across all depths was used to reduce the three-dimensional sound field to a two-dimensional plan view. The physical environment often produces an oddly shaped sound field. The 95th percentile of all the maximum ranges (R_{max}) for each direction from the source that exceeded the isopleth ($R_{95\%}$) was used to represent the range to regulatory isopleths (Figure J-5).

Two approaches were used to determine the ranges to regulatory level isopleths. The first was simply the $R_{95\%}$ value for the sound field, which is applied for fish. The second approach was based on the results of the animat modeling for marine mammals and sea turtles. This approach is called the Exposure Range. For each animat, the range to the closest point of approach that exceeds an acoustic threshold was determined, producing a distribution of ranges. The 95th percentile of this distribution was taken as the $ER_{95\%}$ and used to estimate the range to regulatory thresholds for the species represented by that animat.

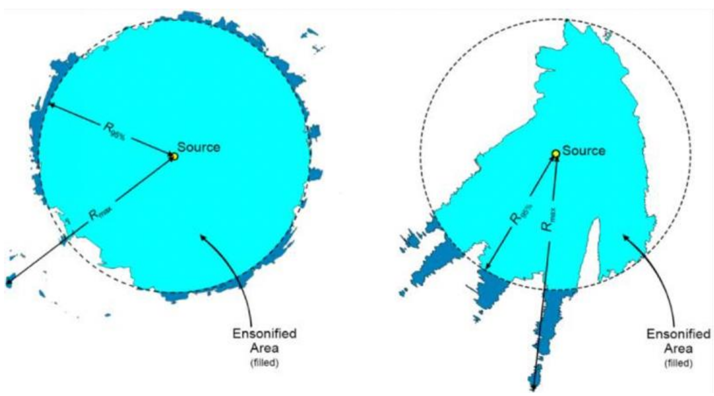


Figure J-5 Two Demonstrations of the Comparison Between the Maximum Range to the Regulatory Threshold (R_{max}) and the 95th percentile of All Maximum Threshold Ranges ($R_{95\%}$)

J.15. Marine Species Present in the Project Area

Thirty-nine marine mammal stocks (37 species) and four species of sea turtles potentially occur in the Offshore Project area (Table J-9). All the sea turtle species and six marine mammal species are listed under the ESA. Species with sufficient density to be potentially affected were modeled quantitatively. Rare species were not modeled because their low densities ensured that risks would approach zero.

Table J-9 Summarized List of Marine Mammal and Sea Turtle Species Present in the Project Area and their Abundance (rare species not modeled)

Species	Abundance	Modeled (Y/N)
Mysticetes		
Blue whale	402	Y
Fin whale	6,802	Y
Humpback whale	1,396	Y
Minke whale	21,968	Y
NARW	368	Y
Sei whale	6,292	Y

Species	Abundance	Modeled (Y/N)
Odontocetes		
Atlantic spotted dolphin	39,921	N
Atlantic white-sided dolphin	93,233	Y
Bottlenose dolphin (offshore)	62,851	Y
Bottlenose dolphin (coastal)	6,639	Y
Clymene dolphin	4,237	N
False killer whale	1,791	N
Fraser's dolphin	Unknown	N
Killer whale	Unknown	N
Melon-headed whale	Unknown	N
Pan tropical spotted dolphin	6,593	N
Pilot whale, long-finned	39,215	Y
Pilot whale, short-finned	28,924	Y
Pygmy killer whale	Unknown	N
Risso's dolphin	35,215	Y
Rough-toothed dolphin	136	N
Short-beaked common dolphin	172,974	Y
Sperm whale	4,349	Y
Spinner dolphin	4,102	N
Striped dolphin	67,036	N
Beaked Whales		
Cuvier's beaked whale	5,744	N
Blainville's beaked whale	10,107	N
Gervais' beaked whale		N
Sowerby's beaked whale		N
True's beaked whale		N
Northern bottlenose whale	Unknown	N
***Kogia* spp.**		
Dwarf sperm whale	7,750	N
Pygmy sperm whale	7,750	N
Porpoises		
Harbour porpoise	95,543	Y
Pinnipeds		
Gray seal	27,300	Y
Harbor seal	61,136	Y
Harp seal	Unknown	N
Hooded seal	Unknown	N
Sirenians		
Florida Manatee	4,834	N
Sea Turtles		
Leatherback sea turtle	--	Y
Loggerhead sea turtle	--	Y

Species	Abundance	Modeled (Y/N)
Kemp's ridley sea turtle	--	Y
Green sea turtle	--	N

Source: NMFS 2021.

J.15.1 Marine Mammal Seasonality and Densities for Project Duration

Mean monthly density estimates (animals per km^2) of all the marine mammal species in the Project area were derived using the Duke University Marine Geospatial Ecology Laboratory model results, which were updated on June 20, 2022 (Roberts and Halpin 2022). The new models resulted in updated density estimates for all taxa for which Ocean Wind is requesting take and serve as a complete replacement for the Roberts et al. (2016a) models and subsequent updates (Roberts et al. 2016b, 2017, 2018, 2021a, 2021b). Refer to Attachment J-1, *Updates to the Application for Marine Mammal Protection Act Rulemaking and Letter of Authorization*, for revised densities and take estimates.

J.15.2 Turtle Seasonality and Densities for Project Duration

At-sea density estimates for sea turtles are extremely limited, particularly in the Project area. For this reason, Küsel et al. (2022) used sea turtle densities estimated for a different geographic region as surrogates for the Project area. A multi-year series of seasonal aerial surveys was conducted in the New York Bight region by Normandeau Associates and APEM for the New York State Energy Research and Development Authority (Normandeau Associates and APEM 2018a, 2018b, 2019a, 2019b, 2020). Four sea turtle species were reported as being present in the area during these surveys: loggerhead, leatherback, Kemp's ridley, and green turtles. The Normandeau Associates and APEM density estimates were used in the Küsel et al. analysis of sea turtle impacts rather than the older Department of the Navy (2007) sea turtle density estimates.

To obtain the densities used in the current study, the maximum seasonal abundance for each species was extracted. The abundance was corrected to represent the abundance in the entire offshore planning area and then scaled by the full offshore planning area to obtain a density in units of animals per km^2. Two categories listed in the reports included more than one species: one combined loggerhead and Kemp's ridley turtles, and the other included turtles that were observed but not identified to the species level. The counts within the two categories that included more than one species were distributed amongst the relevant species with a weighting that reflected the recorded counts for each species. For example, loggerhead turtles were identified far more frequently than any other species; therefore, more of the unidentified counts were assigned to them. The underlying assumption is that a given sample of unidentified turtles would have a distribution of species that was similar to the observed distribution within a given season.

The New York State Energy Research and Development Authority study (Normandeau Associates and APEM 2018a, 2018b, 2019a, 2019b, 2020) reported that in the survey area, most of the sea turtles recorded were loggerhead sea turtles, by an order of magnitude. Seasonal sea turtle densities used in animal movement modeling are listed in Table J-10 for loggerhead, leatherback, Kemp's ridley, and green sea turtles.

Table J-10 Sea Turtle Density Estimates Derived from New York State Energy Research and Development Authority Annual Reports

Common name	Density (animals/100 km^2)			
	Spring	Summer	Fall	Winter
Kemp's ridley turtle	0.05	0.991	0.19	0

Common name	Density (animals/100 km²)			
	Spring	Summer	Fall	Winter
Leatherback turtle	0	0.331	0.789	0
Loggerhead turtle	0.254	26.799	0.19	0.025
Green turtle	0	0.038	0	0

J.15.3 Seasonal Restrictions

There are two NARW seasonal management areas to the north and south of the Project area. Restrictions associated with these dynamic management areas are in effect between November 1 and April 30 annually. Vessels transiting these areas must comply with NMFS regulations and speed restrictions as applicable for NARWs.

J.16. Acoustic Impact Criteria

Marine mammal acoustic criteria used for the modeling effort were derived from the current U.S. regulatory acoustic criteria (Table J-11). PK pressure levels (L_{pk}) and frequency weighted accumulated SELs ($L_{E,24h}$) were taken from the NOAA Technical Guidance (2018) for marine mammal injury thresholds. SPL (L_p) for marine mammal behavioral thresholds were based on the unweighted NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria.

Table J-11 NMFS Regulatory Levels for Marine Mammals in dB for MMPA Level A and Level B Acoustic Threshold-Level Exposure from Impulsive and Non-impulsive Sources

Functional Hearing Group	Sound Source Type				
	Impulsive			Non-Impulsive	
	Level A SEL_{cum}	Level A SEL_{peak}	Level B dB_{RMS}	Level A SEL_{cum}	Level B dB_{RMS}
Low-frequency cetaceans	183	219	160	199	120
Mid-frequency cetaceans	185	230		198	
High-frequency cetaceans	155	202		173	
Phocid pinnipeds underwater	185	218		201	

Sources: NOAA 2005; Wood et al. 2012; NMFS 2018
SEL_{cum} = cumulative sound exposure level

Fish injury thresholds (PK and SEL) were derived from the Fisheries Hydroacoustic Working Group (2008) and Stadler and Woodbury (2009) for fish that are equal to, greater than, or less than 2 grams. Injury thresholds (PK and SEL) were obtained from Popper et al. (2014) for fish without swim bladders, fish with swim bladders not involved in hearing, and fish with swim bladders involved in hearing.

Behavioral thresholds for fish were developed by the NMFS Greater Atlantic Regional Fisheries Office (Andersson et al. 2007; Wysocki et al. 2007; Mueller-Blenkle et al. 2010; Purser and Radford 2011) (Table J-12).

Table J-12 Acoustic Metrics and Thresholds for Fish or Sea Turtles Currently Used by NMFS Greater Atlantic Regional Fisheries Office and BOEM for Impulsive Pile Driving

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

[1] PTS thresholds are applicable only to sea turtles; physical injury thresholds are provided for fish.
L_E = SEL (dB re 1 µPa^{2}s); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

PK pressure levels (L_{pk}) and frequency-weighted accumulated SEL ($L_{E,24h}$) from Finneran et al. (2017) were used for the onset of PTS and TTS in sea turtles (Table J-12). Behavioral response thresholds for sea turtles were obtained from McCauley et al. (2000).

J.17. Marine Animal Exposure Estimates

J.17.1 Marine Mammals

The numbers of individual marine mammals predicted to receive sound levels above threshold criteria were determined using animal movement modeling. The modeled results assumed broadband attenuation of 10 dB and a summer sound speed profile. The modeling used to produce these results does not include aversion behavior in the animats. Refer to Attachment J-1 for marine mammal exposure estimates.

J.17.2 Sea Turtles

The same type of animat modeling was also conducted for the sea turtle species in the Project area to determine the numbers of individual sea turtles predicted to receive sound levels above threshold criteria (Table J-13 to Table J-16). These animat modeling results assumed broadband attenuation of 10 dB, calculated in the same way as the marine mammal exposures.

J.18. Acoustic Exposures and Ranges to Acoustic Regulatory Thresholds for Impact Pile-driving Scenarios

The results in the acoustic modeling report of the multiple combinations of the two modeled seasons, varying levels of sound source attenuation, Acoustic Range method, and Exposure Range method are too numerous to replicate here but several marine mammal exposure and harassment take estimates are presented in Attachment J-1 for various impact pile-driving scenarios while exposure estimates for sea turtles for various pile-driving scenarios are included herein (Table J-13 to Table J-16).

Table J-13 WTG Monopile Foundations: Number of Sea Turtles Predicted to Receive Sound Levels Above Exposure Criteria with 10 dB Attenuation for a Total of 98 Monopiles

Sea Turtle Species	Injury		Behavior
	$L_{E,\ 24h}$	L_{pk}	L_p
Kemp's ridley turtle	0.83	0	15.00
Leatherback turtle	0.25	0	6.61
Loggerhead turtle	7.50	0	168.84
Green turtle	0.06	0	0.47

Source: COP Volume III, Appendix R-2, Table 19; Ocean Wind 2023
L_E = SEL (dB re 1 µPa^{2}s); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

Table J-14 OSS Monopile Foundations: Number of Sea Turtles Predicted to Receive Sound Levels Above Exposure Criteria with 10 dB Attenuation for a Total of Three Monopiles

Sea Turtle Species	Injury		Behavior
	$L_{E,\ 24h}$	L_{pk}	L_p
Kemp's ridley turtle	0.02	0	0.43
Leatherback turtle	<0.01	0	0.18
Loggerhead turtle	0.23	0	5.97
Green turtle	<0.01	0	0.01

Source: COP Volume III, Appendix R-2, Table 20; Ocean Wind 2023
L_E = SEL (dB re 1 µPa^{2}s); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

Table J-15 Pin Piles Supporting OSS Jacket Foundation: Number of Sea Turtles Predicted to Receive Sound Levels Above Exposure Criteria with 10 dB Attenuation for a Total of 48 Pin Piles

Sea Turtle Species	Injury		Behavior
	$L_{E,\ 24h}$	L_{pk}	L_p
Kemp's ridley turtle	0	0	0.31
Leatherback turtle	0	0	0.44
Loggerhead turtle	0	0	14.70
Green turtle	0	0	0.02

Source: COP Volume III, Appendix R-2, Table 21; Ocean Wind 2023
L_E = SEL (dB re 1 µPa^{2}s); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

Table J-16 Exposure Ranges ($ER_{95\%}$) in Meters to Marine Mammal Threshold Criteria with 10-dB Sound Attenuation: Monopile Foundation (tapered 8- to 11-meter-diameter monopiles, two piles per day)

Species	$ER_{95\%}$ Injury (PTS) Threshold $L_{E\ 24h}$/ $SEL_{cum,\ 24h}$ (meters)		$ER_{95\%}$ Behavioral Threshold L_p/SPL_{RMS} (meters)	
	Summer (May through November)	Winter (December only)	Summer (May through November)	Winter (December only)
LFC	1,650	2,490	3,130	3,450
MFC	0	0	3,090	3,410
HFC	880	1,430	3,070	3,370
Pinnipeds in water	80	240	3,090	3,420
Sea turtles	300	440	1,060	1,260

J.19. Ranges to Acoustic Regulatory Thresholds for Vibratory Pile-driving Installation and Cofferdams Removal

Küsel et al. (2022) presented distance ranges to regulatory isopleths by marine mammal hearing groups for the vibratory installation and removal of cofferdams (Table J-17). The maximum distances to the Level A thresholds ranged from 7.7 meters for MFC to 128.2 meters for HFC. The maximum ranges to the Level B thresholds were 10,000 meters for all marine mammal hearing groups.

Table J-17 Distances to Weighted MMPA Level A Cumulative Sound Exposure Level Acoustic Thresholds (NMFS 2018) and Unweighted Level B root-mean-square Sound Pressure Level Acoustic Thresholds (NMFS 2012) for Marine Mammals Associated with Vibratory Pile Installation and Removal of Cofferdams

Marine Mammal Hearing Group	Level A Threshold SEL_{cum} (dB re 1 μPa^{2}s)	Maximum Distance (m) to Level A Threshold	Level B Threshold SPL_{RMS} (dB re 1 μPa^2)	Maximum Distance (m) to Unweighted Level B Threshold
Low-frequency cetaceans	199	86.7	120	10,000
Mid-frequency cetaceans	198	7.7	120	10,000
High-frequency cetaceans	173	128.2	120	10,000
Phocid pinnipeds in water	201	52.7	120	10,000

Source (thresholds): NMFS 2012, 2018; source (distances): Küsel et al. 2022.
dB re 1 μPa^2 = decibel referenced to 1 micropascal squared; m = meter; SEL_{cum} = cumulative sound exposure level; SPL_{RMS} = root-mean-square sound pressure level

J.20. Ranges to Acoustic Regulatory Thresholds for UXO Detonations

Hannay and Zykov (2022; Tables 9 to 36) present ranges to regulatory isopleths for the various sites, explosive weights, body sizes, and species groups of marine mammals, sea turtles, and marine fishes. Information on the total number of marine mammal takes for UXO surveys, maximum ranges to the regulatory thresholds for any site, and body size of marine mammals and sea turtles is summarized herein (Table J-18 and Table J-19) for mitigated (10-dB reduction) scenarios. The ranges for fish injury peak pressure were 290 meters with 10 dB of mitigation.

Determining the maximum UXO ranges to regulatory thresholds for impulse signals required assessing body size. A set of representative animal masses for smaller and larger animals in several species categories of marine mammals and sea turtles was selected (Hannay and Zykoy 2022, Section 7.1). Five body mass categories of marine mammals and sea turtles were developed, with high and low body mass ranges (Hannay and Zykoy 2022, Table 7), with turtles included in the group with HFC, with the body size masses ranging from 5 kilograms (harbour porpoise calf) to 16,000 kilograms (adult sperm whale).

Table J-18 Summary of Maximum UXO Ranges (meters) to Regulatory Thresholds for Auditory Injury in Marine Mammals and Sea Turtles for Peak Pressure and SEL Metrics ($R_{95\%}$) for Mitigated Scenario

Functional Hearing Group	Injury Type	Metric	
		Peak Pressure	SEL
LFC	Level A (PTS)	846	3,780
	Level B (TTS)	1,618	11,900
MFC	Level A (PTS)	258	4,61

Functional Hearing Group	Injury Type	Metric	
		Peak Pressure	SEL
	Level B (TTS)	4,94	2,550
HFC	Level A (PTS)	5,369	62,00
	Level B (TTS)	10,367	14,100
PW	Level A (PTS)	942	1,600
	Level B (TTS)	1,802	7,020
Turtle	Level A (PTS)	210	472
	Level B (TTS)	398	2,250

Note: Maximum ranges are based on worst-case scenario modeling results for charge size E12 (454 kilograms) and site (S1, S2, S3, S4) (Hannay and Zykov 2022).
PW = phocid pinnipeds in water

Table J-19 Summary of Maximum UXO Ranges (meters) to Regulatory Thresholds for Non-Auditory Injury and Mortality in Marine Mammals and Sea Turtles for Peak Pressure for Mitigated Scenario

Injury Type	Marine Mammal Species	Adult	Pup/Calf
Mortality	Baleen whale/sperm whale	34	109
	Minke whale	58	162
	Beaked whale	135	234
	Dolphins, kogia, pinnipeds, turtles	224	332
	Porpoise	243	353
Lung Injury	Baleen whale/sperm whale	237	81
	Minke whale	132	330
	Beaked whale	282	448
	Dolphins, kogia, pinnipeds, turtles	429	606
	Porpoise	465	648
Onset Gastrointestinal Injury		125	125

Note: Maximum ranges are based on worst-case scenario modeling results for charge size E12 (454 kilograms) and deepest water depth (45 meters) based on 1% of animals exposed (mortality/lung injury) (Hannay and Zykov 2022).

J.21. Ranges to Acoustic Regulatory Thresholds for HRG Survey Sources

Summarized here are the distances to the regulatory thresholds for marine mammal hearing groups associated with use of nine types of shallow and medium sound sources or comparable sound source categories during HRG surveys (Table J-20), which were presented in the MMPA Letter of Authorization application for the Project (Ocean Wind 2022).

Table J-20 Distance to Weighted MMPA Level A and Unweighted MMPA Level B Marine Mammal Hearing Group Thresholds Associated with Use of Each Type of HRG Sound Source or Comparable Sound Source Category

HRG Sound Source	Distance to MMPA Level A Threshold (meters)					Distance to MMPA Level B (meters)
	LFC (SEL_{cum} threshold)	MFC (SEL_{cum} threshold)	HFC (SEL_{cum} threshold)	HFC (SPL_{0-pk} threshold)	PW (SEL_{cum} threshold)	All (SPL_{RMS} threshold)
Shallow Sub-Bottom Profilers						
ET 216 CHIRP	<1	<1	2.9	NA	0	9
ET 424 CHIRP	0	0	0	NA	0	4
ET 512i CHIRP	0	0	<1	NA	0	6
GeoPulse 5430	<1	<1	36.5	NA	<1	21
TB CHIRP III	1.5	<1	16.9	NA	<1	48
Medium Sub-Bottom Profilers						
AA Triple plate S-Boom (700/1,000J)	<1	0	0	4.7	<1	34
AA Dura-spark UHD (500J/400 tip)	<1	0	0	2.8	<1	141
AA Dura-spark UHD 400+400	<1	0	0	2.8	<1	141
GeoMarine Geo-Source Dual 400 Tip Sparker	<1	0	0	2.8	<1	141

Source: Application for MMPA Letter of Authorization, Ocean Wind 2022: Table 1-30
AA = Applied Acoustics; CHIRP = Compressed High-Intensity Radiated Pulse; ET = EdgeTech; NA=not applicable; PW = phocid pinnipeds in water; SEL_{cum} = cumulative sound exposure level; SPL_{0-pk} = zero to peak source level; TB = Teledyne Benthos; UHD = Ultra-high Definition

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ATTACHMENT J-1
UPDATES TO THE APPLICATION FOR MARINE MAMMAL PROTECTION ACT RULEMAKING AND LETTER OF AUTHORIZATION

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Ocean Wind 1
An Ørsted & PSEG project

Ocean Wind 1 Offshore Wind Farm

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

Submitted to:
National Marine Fisheries Service
Office of Protected Resources

Prepared for:
Ocean Wind LLC

Prepared by:
HDR, Inc.

August 2022

Purpose and Need

Ocean Wind LLC (Ocean Wind), a subsidiary of Orsted Wind Power North America LLC (Orsted) (Applicant), and joint venture partner Public Service Enterprise Group Renewable Generation LLC (PSEG), is proposing to install up to 98 wind turbine generators (WTGs) and three associated offshore substations (OSSs), each supported by a steel pipe monopile (OSSs may have jacket pile (pin pile) foundations); install and remove cofferdams at landfall sites; detonate unexploded ordnances (UXO); and conduct high-resolution site characterization surveys during construction and operation, all to support the construction of an offshore wind farm. The Ocean Wind Offshore Wind Farm Project (OCW01, Offshore Wind Farm, or Project) is being developed pursuant to the Bureau of Ocean Energy Management (BOEM) requirements for the Ocean Wind BOEM Lease Area Outer Continental Shelf (OCS)-A-0498 Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf.

Ocean Wind submitted a request for a rulemaking and Letter of Authorization (LOA) pursuant to Section 101(a)(5) of the Marine Mammal Protection Act (MMPA) and 50 Code of Federal Regulations (CFR) § 216 Subpart I to allow for the incidental harassment of small numbers of marine mammals resulting from the installation of WTGs and OSSs; installation and removal of cofferdams at locations of export cable route (ECR) to landfall transitions; potential detonations of UXO; and performance of high-resolution geophysical (HRG) site characterization surveys operating at less than 180 kHz which was deemed complete on February 11, 2022. A Notice of Receipt of the LOA application was published in the Federal Register on March 7, 2022 (87 FR 12666).

The take requests included in Section 6 of the OCW01 LOA application, submitted to NMFS in February 2022, were based primarily on a collection of Roberts et al. (2016a, 2016b, 2017, 2018, 2020, 2021a, 2021b) density estimates. On June 20, 2022, the Duke Marine Geospatial Ecology Lab released a comprehensive new set of marine mammal density models for the U.S. east coast, available at https://seamap.env.duke.edu/models/-Duke/EC/. **The new models result in updated density estimates for all taxa for which OCW01 is requesting take** and serve as a complete replacement for the Roberts et al. (2016) models and subsequent updates. Although our LOA application was deemed complete in February 2022, OCW01 voluntarily agreed to provide NMFS and the Public with updated take estimates resulting from this update in the density models.

Additionally, OCW01 has committed to mitigating all potential unexploded ordnance (pUXO) detonations since the submittal of the LOA application. Therefore, we are presenting an updated take request for that activity based on a mitigated scenario of up to 10 pUXO detonations assuming 10 dB of mitigation.

The tables presented in this document have been updated and are intended to replace the corresponding tables contained within the LOA application. Only tables that have been updated due to the new Roberts et al. (2022) models or the mitigated pUXO detonation scenarios are included herein, otherwise tables within the LOA application remain valid.

Updates to Methodology

- Each proposed activity resulting in potential marine mammal take (WTG/OSS installation, cofferdam installation, HRG surveys, and UXO detonation) is associated with unique animal density estimates defined by the anticipated extent of that activity's "footprint", which includes the activity location plus a perimeter that corresponds to maximum extent of the Level B isopleth, rounded up to the nearest 5-km increment (Figure 1 through Figure 4).
- All density grid cells which overlapped with the activity footprint were included in the analysis (Figure 1).

- For all activities, coastal migratory and offshore stocks of bottlenose dolphins were delineated using the 20-m isobath. For WTG/OSS installation (i.e., impact piling), coastal and offshore bottlenose dolphins were rerun using animal movement modeling in order to have coastal bottlenose dolphins seeded only in less than 20 m water depth and offshore bottlenose dolphins seeded only in greater than 20 m water depth.
- Harbor seal, gray seal, short-finned pilot whale, and long-finned pilot whale densities have now been scaled based on relative abundance in the project area, vs. in the LOA application where densities were applied equally to both species present and not adjusted by abundance.
- The 2022 updates to the North Atlantic right whale (NARW) and humpback whale density models resulted in datasets with three different time spans for each species. We have selected the most recent of these for this analysis: 2009-2019 for humpbacks, and 2010-2019 for NARW.
- As stated above, OCW01 has committed to mitigating every potential unexploded ordnance (pUXO) detonation with a minimum 10 dB noise reduction. We have therefore revised all take estimates to reflect the 10 dB-mitigated scenario. Potential exposures for all marine mammal taxa were modeled using frequency-weighted sound exposure level (SEL) values. In the LOA application, SPL_{pk} values were used to model exposures for high-frequency cetaceans because these distances were larger than SEL distances for the unmitigated scenario.
- Because cofferdam installation may take place at any time between October and May (no cofferdams will be installed from June through September), requested take is based on the average density for the months October through May (vs. using the maximum monthly density to estimate take)[1]. This averaging approach avoids potential overestimation of take and aligns with the take estimation approach for HRG surveys, which assumes density averaged across all months in which activities may take place.
- Estimated takes resulting from HRG surveys have been better aligned with the proposed schedule as outlined in the COP; namely, an annual total of 88 survey days for years 1, 4, and 5 with approximately 47.5 survey days in the wind farm area (WFA) and 40.5 survey days in the export cable route (ECR) area, and 180 survey days for years 2 and 3 with approximately 101.5 survey days in the WFA and 78.5 survey days in the ECR. Likewise the activity footprint and associated animal densities have been parsed to separate the ECR cable route from the WFA in order to more accurately represent the spatial resolution of proposed survey effort (Fig. 3; Tables 6-3 and 6-X).

All other methods outlined within the LOA application remain unchanged.

[1] Note that the mean density values were selected during the density extraction process, consistent with what was done in the LOA application.

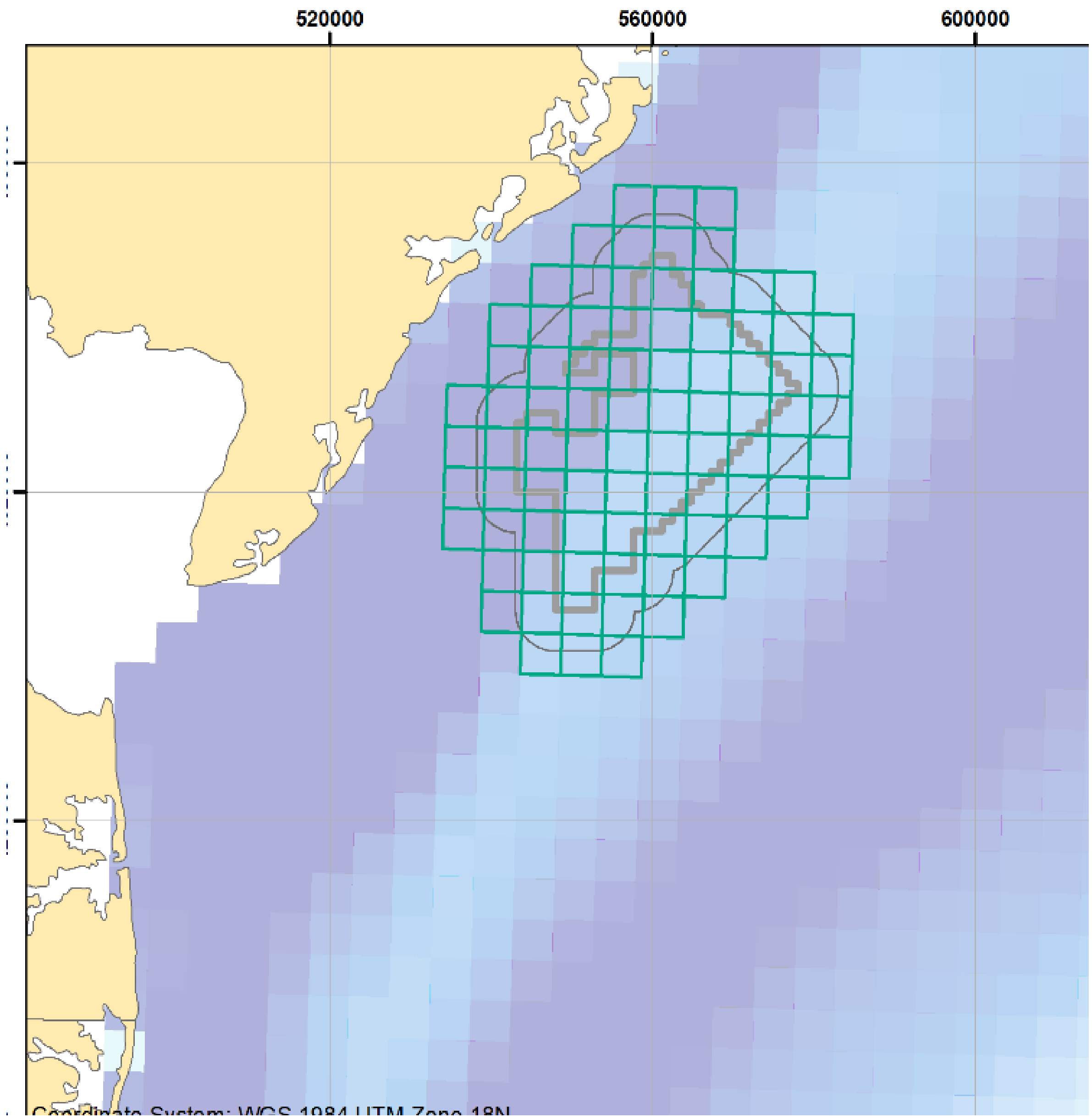

Figure 1. Marine mammal (e.g., NARW) density map showing highlighted grid cells used to calculate mean monthly species exposure estimates for WTG and OSS installation within a 5 km perimeter around the full OCS-A 0498 lease area (Roberts et al. 2016, 2022)

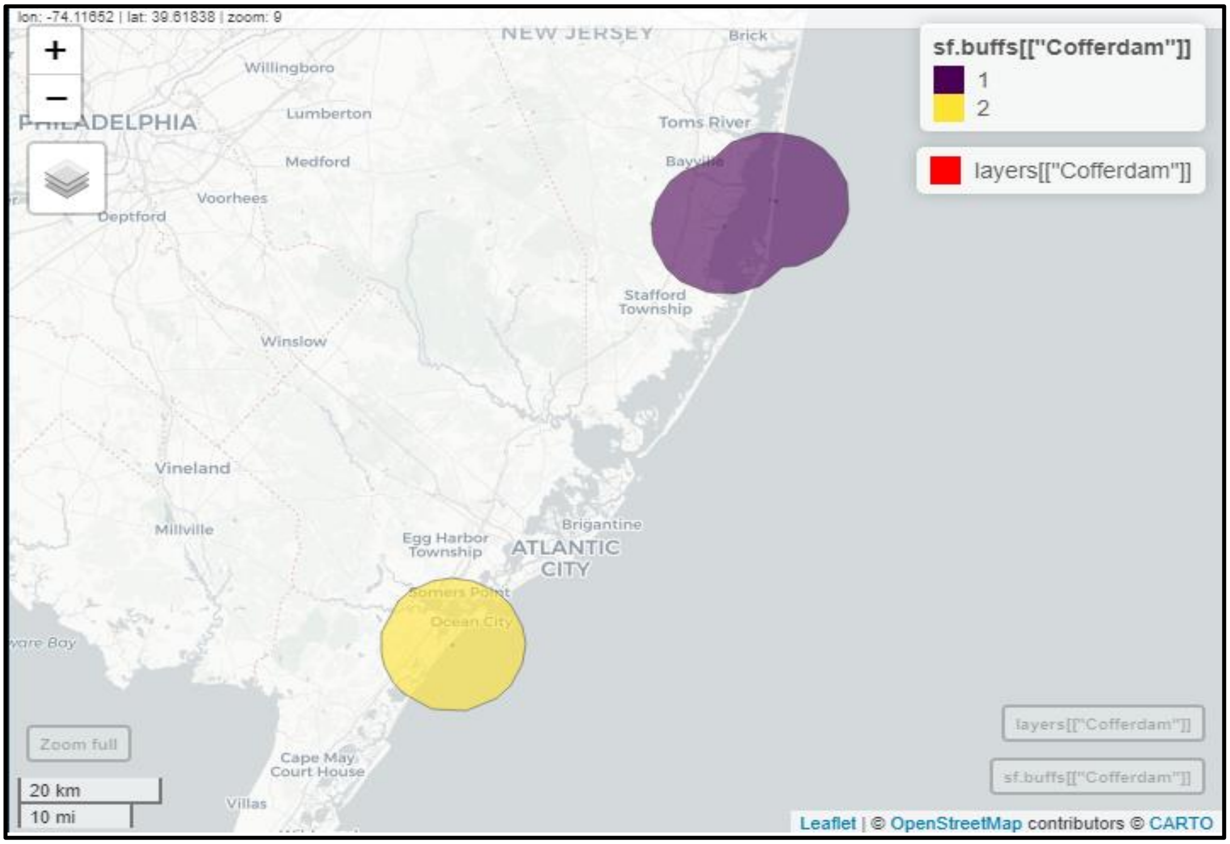

Figure 2. Activity footprint associated with cofferdam Installation (10 km perimeter)

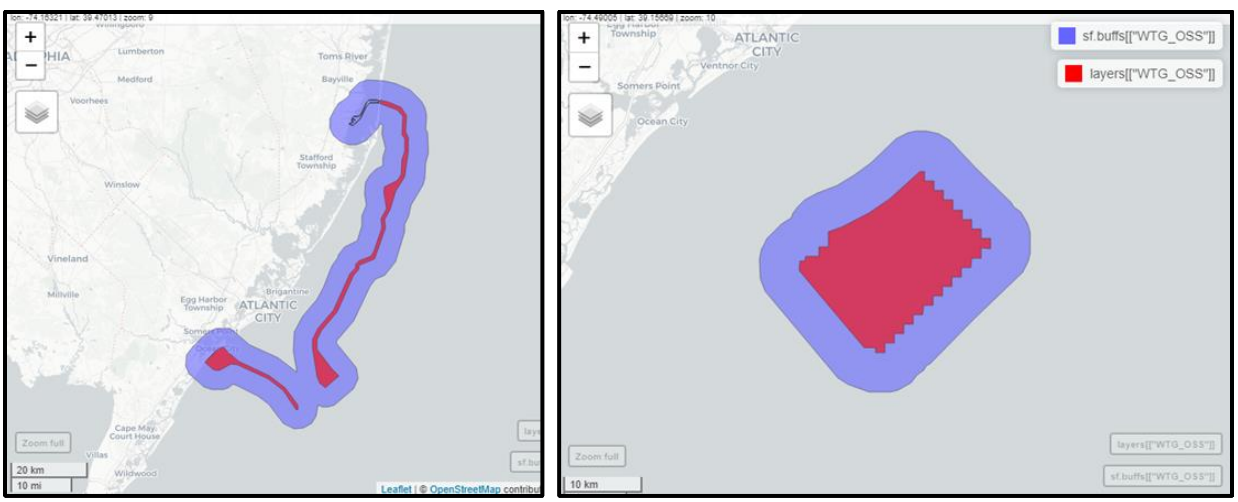

Figure 3. Activity footprint associated with HRG Surveys (5 km perimeter; ECR survey area shown in L panel; WFA surveys shown in R panel)

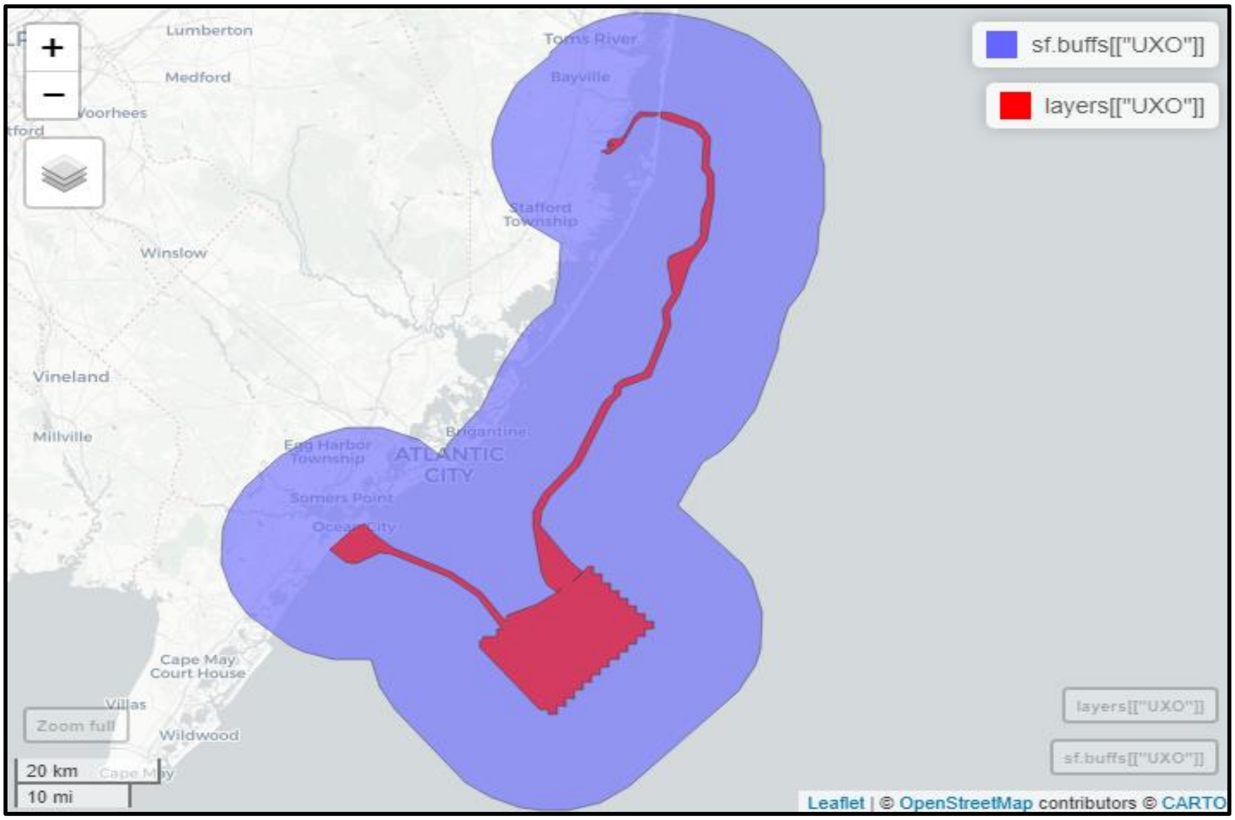

Figure 4. Activity footprint associated with pUXO Detonations (15 km perimeter)

Updated Tables

Table 6-1. Estimated Densities (Animals/km^2) Used for Modeling Marine Mammal Exposures to WTG and OSS Installation Within a 5 km Buffer Around Ocean Wind Farm OCS-A 0498 Lease Area for All Months within the Planned Construction Schedule.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Density
North Atlantic right whale [a]					0.00010	0.00003	0.00001	0.00001	0.00002	0.00004	0.00012	**0.00045**	
Fin whale [a]			--	--	0.00080	0.00067	0.00041	0.00023	0.00027	0.00030	0.00038	**0.00141**	--
Sei whale [a]		--	--	--	0.00021	0.00005	0.00001	0.00001	0.00002	0.00007	0.00021	**0.00042**	--
Minke whale		--	--	--	**0.00674**	0.00154	0.00044	0.00020	0.00012	0.00061	0.00014	0.00041	--
Humpback whale	--	--	--	--	0.00085	0.00051	0.00010	0.00005	0.00018	0.00062	0.00081	**0.00126**	--
Sperm whale [a]	--	--	--	--	**0.00008**	0.00003	0.00001	0.00000	0.00000	0.00000	0.00003	0.00004	--
Atlantic white-sided dolphin	--	--	--	--	**0.00643**	0.00475	0.00018	0.00003	0.00043	0.00474	0.00539	0.00488	--
Bottlenose dolphin, offshore [b]	--	--	--	--	0.07555	0.09293	0.11089	**0.11352**	0.10079	0.09563	0.11146	0.06987	--
Bottlenose dolphin, coastal [b]	--	--	--	--	0.33333	0.39124	0.42611	0.47620	**0.51100**	0.45149	0.44875	0.23091	--
Short-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00011**
Long-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00015**
Risso's dolphin	--	--	--	--	0.00024	0.00006	0.00006	0.00007	0.00006	0.00012	0.00063	**0.00096**	--
Common dolphin	--	--	--	--	0.02902	0.01382	0.00831	0.00355	0.00059	0.00862	0.04682	**0.05157**	--
Harbor porpoise	--	--	--	--	0.00801	0.00010	0.00006	0.00005	0.00001	0.00003	0.00010	**0.02456**	--
Harbor seal	--	--	--	--	0.08433	0.01299	0.00319	0.00194	0.00391	0.01947	0.05067	**0.09830**	--
Gray seal	--	--	--	--	0.03017	0.00465	0.00114	0.00069	0.00140	0.00697	0.01813	**0.03517**	--

[a] Listed as Endangered under the ESA.

[b] Density adjusted by their relative abundance (see Section 3.1 of Appendix A for more information).

Note: Exposure modeling for the Atlantic spotted dolphin and the blue whale was not conducted because impacts on these species approach zero due to their low predicted densities in the Project; therefore, these species were excluded from all quantitative analyses and tables based on modeling results.

Note: Gray cells with **Bold** values indicate highest monthly density May – December. Gray cells with Underlined values represent the second highest monthly density May – December. No pile installation is planned for January – April. Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts *et al.* 2022).

Table 6-2. Estimated Densities (Animals/km^2) of Marine Mammals Within a 10 km Buffer of the Affected Area of the Cofferdam Installation for All Months within the Planned Construction Schedule.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Density	Oct – May Average
North Atlantic right whale [a]	0.00066	0.00054	0.00030	0.00017	0.00004	--	--	--	--	0.00003	0.00013	0.00038	--	**0.00028**
Blue whale [a]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00075**	--
Fin whale [a]	0.00070	0.00021	0.00041	0.00052	0.00018	--	--	--	--	0.00017	0.00017	0.00081	--	**0.00039**
Sei whale [a]	0.00013	0.00008	0.00015	0.00019	0.00009	--	--	--	--	0.00003	0.00014	0.00029	--	**0.00014**
Minke whale	0.00013	0.00015	0.00021	0.00296	0.00234		--	--	--	0.00030	0.00004	0.00009	--	**0.00078**
Humpback whale	0.00071	0.00048	0.00072	0.00049	0.00026	--	--	--	--	0.00028	0.00067	0.00134	--	**0.00062**
Sperm whale [a]	0.00001	0.00001	0.00001	0.00002	0.00002	--	--	--	--	0.00000	0.00005	0.00003	--	**0.00002**
Atlantic white-sided dolphin	0.00047	0.00030	0.00046	0.00121	0.00067	--	--	--	--	0.00060	0.00128	0.00118	--	**0.00077**
Common bottlenose dolphin - Offshore [b]	0.03783	0.01201	0.01922	0.08214	0.20581	--	--	--	--	0.32131	0.29980	0.21115	--	**0.14866**
Common bottlenose dolphin - Coastal [b]	0.05088	0.01936	0.04322	0.21940	0.54984	--	--	--	--	0.74941	0.62651	0.33903	--	**0.32471**
Short-finned pilot whale [b]	--	--	--	--	--	--	-	--	--	--	--	--	**0.00001**	--
Long-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00001**	--
Risso's dolphin	0.00000	0.00000	0.00000	0.00001	0.00001	--	--	--	--	0.00001	0.00004	0.00007	--	**0.00002**
Common dolphin	0.00222	0.00096	0.00171	0.00411	0.00281	--	--	--	--	0.00197	0.01140	0.00757	--	**0.00409**
Harbor porpoise	0.01230	0.01081	0.01234	0.01637	0.00324	--	--	--	--	0.00006	0.00022	0.01297	--	**0.00854**
Harbor seal	0.09066	0.06456	0.07150	0.11609	0.07464	--	--	--	--	0.11182	0.16049	0.11575	--	**0.10069**
Gray seal	0.03244	0.02310	0.02558	0.04153	0.02670	--	--	--	--	0.04001	0.05742	0.04141	--	**0.03602**

[a] Listed as Endangered under the ESA.

[b] Density adjusted by their relative abundance (short-finned pilot whale = 0.00000133395 animals/km^2; long-finned pilot whale = 0.00000181 animals/km^2) (see Section 3.1 of **Appendix A** for more information).

Note: Grey cells with **Bold** values indicate density used in Cofferdam exposure estimates.

Table 6-3. Estimated Densities (Animals/km^2) of Marine Mammals Within a 5 km Buffer Around the Affected Area of the High-Resolution Geophysical Surveys (Export Cable Route) for All Months.

Species	January	February	March	April	May	June	July	August	September	October	November	December	Annual Density	Annual Average
North Atlantic right whale [a]	0.00088	0.00076	0.00047	0.00029	0.00007	0.00002	0.00001	0.00001	0.00001	0.00004	0.00014	0.00047	--	**0.00026**
Blue whale [a]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00001**	--
Fin whale [a]	0.00134	0.00053	0.00069	0.00082	0.00040	0.00042	0.00019	0.00011	0.00014	0.00027	0.00032	0.00122	--	**0.00054**
Sei whale [a]	0.00022	0.00013	0.00026	0.00038	0.00014	0.00005	0.00001	0.00001	0.00001	0.00004	0.00020	0.00043	--	**0.00016**
Minke whale	0.00027	0.00029	0.00036	0.00495	0.00432	0.00070	0.00013	0.00005	0.00007	0.00047	0.00008	0.00021	--	**0.00099**
Humpback whale	0.00084	0.00057	0.00080	0.00081	0.00045	0.00031	0.00009	0.00006	0.00014	0.00046	0.00091	0.00145	--	**0.00057**
Sperm whale [a]	0.00002	0.00002	0.00001	0.00004	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00006	0.00004	--	**0.00002**
Atlantic white-sided dolphin	0.00111	0.00069	0.00087	0.00266	0.00184	0.00124	0.00006	0.00001	0.00013	0.00164	0.00286	0.00247	--	**0.00130**
Common bottlenose dolphin – Offshore [b]	0.02538	0.00856	0.01571	0.06199	0.15746	0.21175	0.21513	0.22393	0.23224	0.22416	0.22789	0.13564	--	**0.14499**
Common bottlenose dolphin - Coastal [b]	0.04469	0.01658	0.03581	0.16624	0.41650	0.54059	0.53568	0.57866	0.65609	0.59458	0.53167	0.28456	--	**0.36680**
Short-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00001**	--
Long-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00002**	--
Risso's dolphin	0.00001	0.00000	0.00000	0.00005	0.00004	0.00001	0.00001	0.00001	0.00001	0.00003	0.00018	0.00023	--	**0.00005**
Common dolphin	0.00628	0.00277	0.00453	0.01061	0.00995	0.00203	0.00053	0.00014	0.00004	0.00409	0.02396	0.01937	--	**0.00702**
Harbor porpoise	0.02199	0.01958	0.01839	0.02454	0.00526	0.00014	0.00007	0.00002	0.00001	0.00005	0.00022	0.02073	--	**0.00925**
Harbor seal	0.09088	0.06190	0.05808	0.09051	0.08105	0.05305	0.00872	0.00522	0.01027	0.05957	0.10025	0.10656	--	**0.06051**
Gray seal	0.03252	0.02215	0.02078	0.03238	0.02900	0.01898	0.00312	0.00187	0.00367	0.02131	0.03587	0.03812	--	**0.02165**

[a] Listed as Endangered under the ESA.

[b] Density adjusted by their relative abundance (see Section 3.1 of Appendix A for more information).

Note: **Bold** values indicate densities used in HRG ECR exposure estimates.

Table 6-X NEW. Estimated Densities (Animals/km^2) of Marine Mammals Within a 5 km Buffer Around the Affected Area of the High-Resolution Geophysical Surveys (Wind Farm Area) for All Months.

Species	January	February	March	April	May	June	July	August	September	October	November	December	Annual Density	Annual Average
North Atlantic right whale [a]	0.00066	0.00073	0.00061	0.00049	0.00011	0.00003	0.00001	0.00001	0.00002	0.00004	0.00009	0.00037	--	**0.00026**
Blue whale [a]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00001**	--
Fin whale [a]	0.00187	0.00142	0.00106	0.00102	0.00093	0.00076	0.00051	0.00029	0.00031	0.00031	0.00038	0.00144	--	**0.00086**
Sei whale [a]	0.00026	0.00016	0.00034	0.00075	0.00025	0.00006	0.00001	0.00001	0.00002	0.00008	0.00025	0.00042	--	**0.00022**
Minke whale	0.00058	0.00059	0.00061	0.00673	0.00788	0.00187	0.00054	0.00025	0.00014	0.00066	0.00017	0.00050	--	**0.00171**
Humpback whale	0.00095	0.00066	0.00084	0.00103	0.00102	0.00061	0.00012	0.00006	0.00021	0.00071	0.00088	0.00113	--	**0.00069**
Sperm whale [a]	0.00004	0.00002	0.00001	0.00007	0.00010	0.00003	0.00001	0.00000	0.00000	0.00000	0.00003	0.00003	--	**0.00003**
Atlantic white-sided dolphin	0.00360	0.00231	0.00210	0.00674	0.00806	0.00607	0.00022	0.00004	0.00058	0.00585	0.00642	0.00589	--	**0.00399**
Common bottlenose dolphin – Offshore [b]	0.01615	0.00555	0.00786	0.02497	0.06586	0.08314	0.09932	0.09994	0.08669	0.08358	0.09841	0.06283	--	**0.06119**
Common bottlenose dolphin - Coastal [b]	0.03145	0.01108	0.02114	0.07735	0.20004	0.23634	0.27770	0.29394	0.29119	0.27197	0.29371	0.16292	--	**0.18073**
Short-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00014**	--
Long-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00018**	--
Risso's dolphin	0.00019	0.00003	0.00003	0.00032	0.00030	0.00008	0.00007	0.00008	0.00007	0.00015	0.00083	0.00127	--	**0.00029**
Common dolphin	0.02980	0.01260	0.01481	0.03048	0.03751	0.01786	0.01024	0.00416	0.00066	0.01046	0.05685	0.06472	--	**0.02418**
Harbor porpoise	0.03940	0.03782	0.02871	0.03842	0.00970	0.00015	0.00009	0.00007	0.00001	0.00003	0.00014	0.02757	--	**0.01518**
Harbor seal	0.11132	0.08232	0.05158	0.05694	0.09691	0.00776	0.00170	0.00107	0.00224	0.01127	0.03705	0.10569	--	**0.04715**
Gray seal	0.03983	0.02945	0.01846	0.02037	0.03467	0.00278	0.00061	0.00038	0.00080	0.00403	0.01325	0.03781	--	**0.01687**

[a] Listed as Endangered under the ESA.

[b] Density adjusted by their relative abundance (see Section 3.1 of Appendix A for more information).

Note: **Bold** values indicate densities used in HRG WFA exposure estimates

Table 6-Y (NEW). Estimated Densities (Animals/km^2) of Marine Mammals Within a 15 km Buffer Around the Affected Area of pUXO Detonations for All Months in which Detonations are Allowed (May through October).

Species	January	February	March	April	May	June	July	August	September	October	November	December	Annual Density
North Atlantic right whale [a]	--	--	--	--	**0.00008**	0.00002	0.00001	0.00001	0.00002	0.00004	--	--	--
Blue whale [a]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00001**
Fin whale [a]	--	--	--	--	**0.00068**	0.00061	0.00034	0.00019	0.00023	0.00029	--	--	--
Sei whale [a]	--	--	--	--	**0.00021**	0.00006	0.00001	0.00001	0.00002	0.00006	--	--	--
Minke whale	--	--	--	--	**0.00627**	0.00146	0.00037	0.00019	0.00012	0.00056	--	--	--
Humpback whale	--	--	--	--	**0.00081**	0.00056	0.00011	0.00007	0.00019	0.00063	--	--	--
Sperm whale [a]	--	--	--	--	**0.00008**	0.00003	0.00003	0.00001	0.00000	0.00000	--	--	--
Atlantic white-sided dolphin	--	--	--	--	**0.00545**	0.00415	0.00013	0.00003	0.00041	0.00392	--	--	--
Common bottlenose dolphin – Offshore [b]	--	--	--	--	0.09128	0.12148	0.12465	**0.12615**	0.12612	0.12511	--	--	--
Common bottlenose dolphin - Coastal [b]	--	--	--	--	0.45605	0.58021	0.56497	0.61742	**0.71100**	0.64462	--	--	--
Short-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00010**
Long-finned pilot whale [b]	--	--	--	--	--	--	--	--	--	--	--	--	**0.00013**
Risso's dolphin	--	--	--	--	**0.00021**	0.00007	0.00006	0.00006	0.00005	0.00009	--	--	--
Common dolphin	--	--	--	--	**0.02407**	0.01261	0.00759	0.00417	0.00095	0.00754	--	--	--
Harbor porpoise	--	--	--	--	**0.00789**	0.00024	0.00016	0.00008	0.00002	0.00007	--	--	--
Harbor seal	--	--	--	--	**0.09467**	0.04068	0.00659	0.00392	0.00774	0.04540	--	--	--
Gray seal	--	--	--	--	**0.03387**	0.01456	0.00236	0.00140	0.00277	0.01624	--	--	--

[a] Listed as Endangered under the ESA.

[b] Density adjusted by their relative abundance (see Section 3.1 of Appendix A for more information).
Note: **Bold** values indicate densities used in pUXO exposure estimates.

Table 6-7. Estimated Maximum Level A Exposures of Marine Mammals Resulting from WTG Foundation Monopile Impact Installation. Results indicate total potential exposures per stock modeled over the effective period of the LOA assuming 2 piles are installed per day.

Species	Estimated Level A Exposures (SEL_{cum})
North Atlantic right whale [a]	0.9 [b]
Fin whale [a]	3.69
Sei whale [a]	0.89
Minke whale	18.42
Humpback whale	4.24
Sperm whale [a]	0
Atlantic white-sided dolphin	0
Common bottlenose dolphins:	
Offshore	0
Coastal	0
Pilot whales:	
Short-finned pilot whale	0
Long-finned pilot whale	0
Risso's dolphin	0
Common dolphin	0
Harbor porpoise	51.31 [C]
Seals:	
Gray seal	3.04
Harbor seal	12.16

Note: Values taken from JASCO's density and exposure modeling update memo (August 2022). Exposure modeling for the blue whale and Atlantic spotted dolphin was not conducted because impacts on the species approach zero due to their low predicted densities in the Project area. These species are therefore excluded from quantitative analyses and tables.

[a] Listed as Endangered under the ESA.

[b] Level A exposures were estimated for this species, but due to mitigation measures in **Section 11**, no Level A takes are expected or requested. Level A exposure estimates are added to Level B take requests in **Section 6.2.3**.

[C] The calculated Level A exposures are likely an overestimate; the modeled 10 dB reduction due to NMS is assumed across all frequencies and does not take into account that the reduction is greater at higher frequencies, which are those heard best by harbor porpoise.

Table 6-8. Estimated Maximum Level A Exposures of Marine Mammals Resulting from OSS Foundation Monopile or Pin Pile Impact Pile Driving. Results indicate total potential exposures per stock modeled over the effective period of the LOA assuming 2 monopiles or 3 pin piles are installed per day.

Species	Estimated Level A Exposures (SEL_{cum}) 11-m Monopiles (3)	Estimated Level A Exposures (SEL_{cum}) 2.44-m Pin Piles (48)
North Atlantic right whale [a]	0.04 [b]	0.10 [b]
Fin whale [a]	0.15	0.48
Sei whale [a]	0.04	0.14
Minke whale	0.76	2.29
Humpback whale	0.18	0.54
Sperm whale [a]	0	0
Atlantic white-sided dolphin	0	0
Common bottlenose dolphins:		
Offshore	0	0
Coastal	0	0
Pilot whales:		
Short-finned pilot whale	0	0
Long-finned pilot whale	0	0
Risso's dolphin	0	0
Common dolphin	0	0
Harbor porpoise [c]	2.38	16.60
Seals:		
Gray seal	0.08	0.32
Harbor seal	0.37	0.43

Note: Values taken from JASCO's density and exposure modeling update memo (August 2022). Exposure modeling for the blue whale and Atlantic spotted dolphin was not conducted because impacts on the species approach zero due to their low predicted densities in the Project area. These species are therefore excluded from quantitative analyses and tables.

[a] Listed as Endangered under the ESA.

[b] Level A exposures were estimated for this species, but due to mitigation measures outlined in **Section 11**, no Level A takes are expected or requested. See **Section 6.2.3** for more information.

[C] The calculated Level A exposures are likely an overestimate; the modeled 10 dB reduction due to NMS is assumed across all frequencies and does not take into account that the reduction is greater at higher frequencies, which are those heard best by harbor porpoise.

Table 6-9. Estimated Level A Exposures by Month to Marine Mammal Species Resulting from Vibratory Pile Installation and Removal of Cofferdams.

Species	Jan	Feb	Mar	Apr	May	Oct	Nov	Dec	Average Exposures [a]
North Atlantic right whale [b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Blue whale [b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Fin whale [b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Sei whale [b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Minke whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Humpback whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Sperm whale [b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Atlantic white-sided dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Common bottlenose dolphins:									
Offshore	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Coastal	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Pilot whales:									
Short-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Long-finned pilot whale	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Risso's dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Common dolphin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**
Harbor porpoise	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	0.02	**0.01**
Seals:									
Gray seal	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01	**0.01**
Harbor seal	0.02	0.02	0.02	0.03	0.02	0.03	0.04	0.03	**0.02**

Note: **Bolded** values indicate estimates used in final take request.

[a] Average Exposure values were calculated using the October – May average density column from Table 6-2; all other monthly exposure methods remained the same.

[b] Listed as Endangered under the ESA.

Table 6-10. Estimated Potential Maximum Level A Exposures of Marine Mammals Resulting from the Possible Detonations of up to 10 UXOs assuming both 10 dB of Attenuation

Species	Estimated Level A Exposures (PTS SEL) 10 dB Attenuation
North Atlantic right whale [a,b]	0.03
Blue whale [a]	<0.01
Fin whale [a]	0.28
Sei whale [a]	0.08
Minke whale	2.53
Humpback whale	0.33
Sperm whale [a]	<0.01
Atlantic white-sided dolphin	0.03
Common bottlenose dolphins:	
Offshore	0.68
Coastal	3.84
Pilot whales:	
Short-finned pilot whale	<0.01
Long-finned pilot whale	<0.01
Risso's dolphin	<0.01
Common dolphin	0.13
Harbor porpoise	9.49
Seals:	
Gray seal	2.28
Harbor seal	6.39

[a] Listed as Endangered under the ESA.

[b] Level A exposures were estimated for this species, but due to mitigation measures outlined in **Section 11**, no Level A takes are expected or requested. See **Section 6.2.3** for more information.

Table 6-11. Estimated Annual Level A Exposures of Marine Mammals Resulting from HRG Surveys.

Species	Estimated Level A Exposures [b]	
	Years 1, 4, and 5 (88 days each of HRG surveys)	Years 2 and 3 (180 days each of HRG surveys)
North Atlantic right whale [a]	<0.01	0.01
Blue whale [a]	<0.01	<0.01
Fin whale [a]	0.01	0.02
Sei whale [a]	<0.01	<0.01
Minke whale	0.02	0.04
Humpback whale	0.01	0.02
Sperm whale [a]	<0.01	<0.01
Atlantic white-sided dolphin	0.03	0.05
Common bottlenose dolphins:		
Offshore	1.23	2.46
Coastal	3.28	6.60
Pilot whales:		
Short-finned pilot whale	<0.01	<0.01
Long-finned pilot whale	<0.01	<0.01
Risso's dolphin	<0.01	<0.01
Common dolphin	0.20	0.42
Harbor porpoise	5.60	11.59
Seals:		
Gray seal	0.23	0.48
Harbor seal	0.66	1.34

[a] Listed as Endangered under the ESA.

[b] Although Level A exposures were estimated for HRG surveys, due to mitigation measures outlined in **Section 11**, no Level A takes are expected or requested. See **Section 6.2** for more information.

Table 6-12. Estimated Level B Maximum Exposures of Marine Mammals Resulting from WTG Monopile Impact Installation based on the 160 dB rms Threshold.

Species	Estimated Level B Exposures
North Atlantic right whale [a]	3.11
Fin whale [a]	7.05
Sei whale [a]	2.00
Minke whale	52.25
Humpback whale	13.82
Sperm whale [a]	0
Atlantic white-sided dolphin	71.5
Common bottlenose dolphins:	
Offshore	935.91
Coastal	0
Pilot whales:	
Short-finned pilot whale	0.04
Long-finned pilot whale	0
Risso's dolphin	7.06
Common dolphin	1,229.37
Harbor porpoise	233.89
Seals:	
Gray seal	197.56
Harbor seal	554.22

Notes: Values taken from JASCO's density and exposure modeling update memo (August 2022). Exposure modeling for the blue whale and Atlantic spotted dolphin was not conducted because impacts on the species approach zero due to their low predicted densities in the Project area. These species are therefore excluded from quantitative analyses and tables.

[a] Listed as Endangered under the ESA.

Table 6-13. Estimated Maximum Level B Exposures of Marine Mammals Resulting from OSS Foundation Monopile or Pin Pile Impact Pile Driving.

Species	Estimated Level B Exposures 8/11-m Monopiles (3)	Estimated Level B Exposures 2.44-m Pin Piles (48)
North Atlantic right whale [a]	0.14	0.75
Fin whale [a]	0.27	1.20
Sei whale [a]	0.08	0.45
Minke whale	2.32	15.81
Humpback whale	0.51	3.63
Sperm whale [a]	0	0
Atlantic white-sided dolphin	2.37	16.20
Common bottlenose dolphins:		
Offshore	30.44	168.23
Coastal	0	0
Pilot whales:		
Short-finned pilot whale	<0.01	0
Long-finned pilot whale	0	0
Risso's dolphin	0.26	1.79
Common dolphin	40.51	293.89
Harbor porpoise	10.004	70.97
Seals:		
Gray seal	6.98	38.59
Harbor seal	19.76	99.14

Notes: Values taken from JASCO's density and exposure modeling update memo (August 2022). Exposure modeling for the blue whale and Atlantic spotted dolphin was not conducted because impacts on the species approach zero due to their low predicted densities in the Project area. These species are therefore excluded from quantitative analyses and tables.

[a] Listed as Endangered under the ESA.

Table 6-14. Estimated Level B Exposures by Month to Marine Mammal Species Resulting from Vibratory Pile Installation and Removal of Cofferdams.

Species	Jan	Feb	Mar	Apr	May	Oct	Nov	Dec	Average Exposures
North Atlantic right whale [a]	2.08	1.71	0.97	0.55	0.13	0.09	0.41	1.20	**0.89**
Blue whale [a]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**
Fin whale [a]	2.21	0.65	1.30	1.64	0.57	0.54	0.55	2.56	**1.25**
Sei whale [a]	0.40	0.26	0.48	0.61	0.29	0.09	0.44	0.91	**0.44**
Minke whale	0.42	0.48	0.68	9.40	7.42	0.94	0.12	0.28	**2.47**
Humpback whale	2.25	1.51	2.28	1.56	0.83	0.90	2.13	4.26	**1.96**
Sperm whale [a]	0.03	0.04	0.02	0.06	0.08	0.00	0.15	0.09	**0.06**
Atlantic white-sided dolphin	1.49	0.96	1.47	3.84	2.11	1.91	4.06	3.76	**2.45**
Common bottlenose dolphins:									
Offshore	120.06	38.12	60.99	260.70	653.27	1019.85	951.596	670.22	**471.85**
Coastal	161.51	61.44	137.20	696.39	1745.23	2378.69	1988.58	1076.10	**1030.64**
Pilot whales:									
Short-finned pilot whale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Long-finned pilot whale	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.01**
Risso's dolphin	0.01	0.00	0.00	0.03	0.02	0.02	0.11	0.21	**0.05**
Common dolphin	7.05	3.05	5.43	13.05	8.91	6.24	36.20	24.03	**12.99**
Harbor porpoise	39.03	34.32	39.17	51.95	10.28	0.18	0.69	41.18	**27.10**
Seals:									
Gray seal	102.96	73.31	81.20	131.83	84.76	126.98	182.25	131.44	**114.34**
Harbor seal	287.77	204.92	226.96	368.48	236.92	354.92	509.40	367.39	**319.59**

Note: **Bolded** values indicate estimates used in final take request.

[a] Average Exposure values were calculated using the October – May average density column from Table 6-2; all other monthly exposure methods remained the same.

[b] Listed as Endangered under the ESA.

Table 6-15. Estimated Maximum Level B Exposures of Marine Mammals Resulting from the Possible Detonations of up to 10 UXOs assuming both 10 dB of Attenuation

Species	Estimated Level B Exposures (TTS SEL)
	10 dB Attenuation
North Atlantic right whale [a]	0.35
Blue whale [a]	0.04
Fin whale [a]	2.87
Sei whale [a]	0.87
Minke whale	26.42
Humpback whale	3.41
Sperm whale [a]	0.01
Atlantic white-sided dolphin	1.05
Common bottlenose dolphins:	
Offshore	24.36
Coastal	137.31
Pilot whales:	
Short-finned pilot whale	0.02
Long-finned pilot whale	0.02
Risso's dolphin	0.04
Common dolphin	4.65
Harbor porpoise	46.50
Seals:	
Gray seal	50.98
Harbor seal	142.49

[a] Listed as Endangered under the ESA.

Table 6-16. Estimated Annual Maximum Level B Exposures of Marine Mammals Resulting from HRG Surveys.

Species	Estimated Annual Level B Exposures Per Year	
	Years 1, 4 and 5 (88 days each of HRG surveys)	Years 2 and 3 (180 days each of HRG surveys)
North Atlantic right whale [a]	0.46	0.94
Blue whale [a]	0.02	0.03
Fin whale [a]	1.24	2.56
Sei whale [a]	0.33	0.68
Minke whale	2.40	4.98
Humpback whale	1.10	2.27
Sperm whale [a]	0.04	0.09
Atlantic white-sided dolphin	4.79	10.04
Common bottlenose dolphins:		
Offshore	173.84	348.37
Coastal	464.18	933.46
Pilot whales:		
Short-finned pilot whale	0.14	0.29
Long-finned pilot whale	0.19	0.40
Risso's dolphin	0.31	0.65
Common dolphin	28.38	59.52
Harbor porpoise	21.69	44.88
Seals:		
Gray seal	33.23	67.56
Harbor seal	92.88	188.83

[a] Listed as Endangered under the ESA.

Table 6-17. Requested Level A and Level B Takes for Marine Mammals During Impact Pile Driving of WTG 8/11-m Monopiles for the Effective Period of the LOA (5-year total).

Species	Population Size	Level A Harassment Takes	Level B Harassment Takes	Max Percent Population
North Atlantic right whale [a]	368	0 [b]	4	1.09
Blue whale [a]	unknown	0	4 [c]	unknown
Fin whale [a]	6,802	4	8	0.18
Sei whale [a]	6,292	1	2 [d]	0.05
Minke whale	21,968	19	53	0.33
Humpback whale	1,396	5	14	1.36
Sperm whale [a]	4,349	0	3 [d]	0.07
Atlantic white-sided dolphin	93,233	0	72	0.08
Atlantic spotted dolphin	39,921	0	45 [d]	0.11
Common bottlenose dolphins:				
Offshore	62,851	0	936	1.49
Coastal	6,639	0	0	0.00
Pilot whales:				
Short-finned pilot whale	28,924	0	10 [d]	0.03
Long-finned pilot whale	39,215	0	10 [d]	0.03
Risso's dolphin	35,215	0	30 [d]	0.09
Common dolphin	172,974	0	1,230	0.71
Harbor porpoise	95,543	52	234	0.30
Seals:				
Gray seal	27,300	4	198	0.74
Harbor seal	61,336	13	555	0.93

Note: Values ≥0.5 from **Table 6-7** and **Table 6-12** have been rounded up to the nearest integer, values <0.5 rounded down to 0.

[a] Listed as Endangered under the ESA.

[b] 0.90 Level A exposures were estimated for North Atlantic right whale, but due to mitigation measures outlined in **Section** Error! Reference source not found., no Level A takes are expected or requested.

[c] No Level B exposures were estimated for blue whale, but up to 4 Level B takes not calculated through density estimates are requested in the unlikely event that 4 individuals, or two cow and calf pairs, approach monopile installation.

[d] The requested take for these species was adjusted based on mean group size:

- Sei whale: Kenney and Vigness-Raposa, 2010.
- Sperm whale: Barkaszi and Kelly, 2019.
- Atlantic spotted dolphin: Kenney and Vigness-Raposa, 2010.
- Pilot whales: Kenney and Vigness-Raposa, 2010.
- Risso's dolphin: Barkaszi and Kelly, 2019.

Table 6-18. Requested Level A and Level B Takes for Marine Mammals During Impact Pile Driving for Either OSS Scenario: 3 8/11-m Monopiles or 3 Jacket Foundations Composed of 16 2.44-m Pin Piles Each.

Species	Population Size	3 8/11-m Monopile Scenario			48 2.44-m Pin Pile Scenario		
		Level A Harassment Takes	Level B Harassment Takes	Max Percent Population	Level A Harassment Takes	Level B Harassment Takes	Max Percent Population
North Atlantic right whale [a]	368	0	0	0.00	0	1	0.27
Blue whale [a]	unknown	0	0	0.00	0	0	0.00
Fin whale [a]	6,802	0	0	0.00	0	2	0.03
Sei whale [a]	6,292	0	0	0.00	0	0	0.01
Minke whale	21,968	1	3	0.02	3	16	0.09
Humpback whale	1,396	0	1	0.07	1	4	0.36
Sperm whale [a]	4,349	0	0	0.00	0	3 [b]	0.07
Atlantic white-sided dolphin	93,233	0	3	0.01	0	17	0.02
Atlantic spotted dolphin	39,921	0	0	0.00	0	45 [b]	0.11
Common bottlenose dolphins:							
Offshore	62,851	0	31	0.05	0	169	0.27
Coastal	6,639	0	0	0.06	0	0	0.00
Pilot whales:							
Short-finned pilot whale	28,924	0	0	0.00	0	10 [b]	0.03
Long-finned pilot whale	39,215	0	0	0.00	0	10 [b]	0.03
Risso's dolphin	35,215	0	0	0.00	0	30 [b]	0.09
Common dolphin	172,974	0	41	0.02	0	294	0.17
Harbor porpoise	95,543	3	11	0.01	17	71	0.09
Seals:							
Gray seal	27,300	0	7	0.03	0	39	0.14
Harbor seal	61,336	0	20	0.03	0	100	0.16

Note: Values ≥0.5 from **Table 6-8** and **Table 6-13** have been rounded up to the nearest integer, values <0.5 rounded down to 0.

[a] Listed as Endangered under the ESA.

[b] The requested take for these species was adjusted based on mean group size:

- Sei whale: Kenney and Vigness-Raposa, 2010.
- Sperm whale: Barkaszi and Kelly, 2019.
- Atlantic spotted dolphin: Kenney and Vigness-Raposa, 2010.
- Pilot whales: Kenney and Vigness-Raposa, 2010.
- Risso's dolphin: Barkaszi and Kelly, 2019.

Table 6-19. Requested Level A and Level B Takes Resulting from Vibratory Installation and Removal of Cofferdams and the Percentage of Each Population or Stock Taken for the Effective Period of the LOA (5-year total).

Species	Population Size	Level A Harassment Takes	Level B Harassment Takes	Max Percent Population
North Atlantic right whale [a]	368	0	1	0.27
Blue whale [a]	unknown	0	0	0.00
Fin whale [a]	6,802	0	2	0.03
Sei whale [a]	6,292	0	1	0.02
Minke whale	21,968	0	3	0.01
Humpback whale	1,396	0	3	0.21
Sperm whale [a]	4,349	0	0	0.00
Atlantic white-sided dolphin	93,233	0	5	0.01
Atlantic spotted dolphin	39,921	0	45 [b]	0.11
Common bottlenose dolphins:				
Offshore	62,851	0	472	0.75
Coastal [f]	6,639	11 [c]	1,031	15.70
Pilot whales:				
Short-finned pilot whale	28,924	0	10 [d]	0.03
Long-finned pilot whale	39,215	0	10 [d]	0.03
Risso's dolphin	35,215	0	30 [d]	0.09
Common dolphin	172,974	0	13	0.01
Harbor porpoise	95,543	0	28	0.03
Seals:				
Gray seal	27,300	28 [e]	115	0.52
Harbor seal	61,336	28 [e]	320	0.57

[a] Listed as Endangered under the ESA.

[b] No Level B exposures were estimated for Atlantic spotted dolphin, but up to 45 Level B takes are requested in the unlikely event a pod of up to 45 individuals approaches cofferdam installation or removal (based on Kenney and Vigness-Raposa, 2010).

[c] No Level A exposures were estimated for coastal bottlenose dolphin, but up to 11 Level A takes are requested in the unlikely event a pod of dolphins approaches cofferdam installation or removal (based on Toth *et al.* 2011).

[d] Level B take of these species were adjusted to account for mean group size:

- Pilot whales: Kenney and Vigness-Raposa, 2010.
- Risso's dolphins: Barkaszi and Kelly, 2019.

[e] No Level B exposures were estimated for gray and harbor seals, but up to 28 Level A takes are requested in the event that up to 2 animals per day approach cofferdam installation or removal.

[f] Coastal bottlenose dolphin take for bayside (vs. Atlantic-facing) cofferdams is likely overestimated, as this stock has been shown to prefer coastal to estuarine environments (Toth et al. 2011).

Table 6-20. Requested Level A and Level B Takes Resulting from the Detonation of up to 10 UXOs and the Percentage of Each Population or Stock Taken for the Effective Period of the LOA (5-year total).

Species	Population Size	10 dB of Attenuation		
		Level A Harassment Takes	Level B Harassment Takes	Max Percent Population
North Atlantic right whale [a]	368	0	1	0.00
Blue whale [a]	unknown	0	0	0.00
Fin whale [a]	6,802	0	3	0.04
Sei whale [a]	6,292	0	1	0.02
Minke whale	21,968	0 [b]	27	0.12
Humpback whale	1,396	0	4	0.29
Sperm whale [a]	4,349	0	3 [c]	0.07
Atlantic white-sided dolphin	93,233	0	2	0.01
Atlantic spotted dolphin	39,921	0	45 [c]	0.11
Common bottlenose dolphins:				
Offshore	62,851	0 [b]	25	0.04
Coastal	6,639	0 [b]	138	2.08
Pilot whales:				
Short-finned pilot whale	28,924	0	10 [c]	0.03
Long-finned pilot whale	39,215	0	10 [c]	0.03
Risso's dolphin	35,215	0	30 [c]	0.09
Common dolphin	172,974	0	5	<0.01
Harbor porpoise	95,543	10	47	0.06
Seals:				
Gray seal	27,300	3	51	0.20
Harbor seal	61,336	7	143	0.24

Note: Calculated exposures that were ≥0.5 were rounded up to the nearest whole number.

[a] Listed as Endangered under the ESA.

[b] A small number of Level A exposures were estimated based on density calculations; however, no Level A take in these instances is requested due to mitigation measures outlined in **Section 11**.

[c] The requested take for these species was adjusted based on mean group size:

- Sperm whale: Barkaszi and Kelly, 2019.
- Atlantic spotted dolphin: Kenney and Vigness-Raposa, 2010.
- Pilot whales: Kenney and Vigness-Raposa, 2010.
- Risso's dolphin: Barkaszi and Kelly, 2019.

Table 6-21. Requested Level A and Level B Takes Per Year for High-resolution Geophysical Surveys Conducted during Ocean Wind Construction.

Species	Population Size	Years 1, 4, and 5 (88 days of HRG surveys per year)			Years 2 and 3 (180 days of HRG surveys per year)		
		Annual Level A Harassment Takes	Annual Level B Harassment Takes	Annual Max Percent Population	Annual Level A Harassment Takes	Annual Level B Harassment Takes	Annual Max Percent Population
North Atlantic right whale [a]	368	0	1 [d]	0.27	0	2 [d]	0.54
Blue whale [a]	unknown	0	0	0.00	0	0	0.00
Fin whale [a]	6,802	0	2	0.03	0	3	0.04
Sei whale [a]	6,292	0	0	0.00	0	1 [b]	0.02
Minke whale	21,968	0	3	<0.01	0	5 [b]	0.02
Humpback whale	1,396	0	2	0.14	0	3 [b]	0.21
Sperm whale [a]	4,349	0	3 [b]	0.07	0	3 [b]	0.07
Atlantic white-sided dolphin	93,233	0	5	<0.01	0	11	0.01
Atlantic spotted dolphin	39,921	0	45 [b]	0.11	0	45 [b]	0.11
Common bottlenose dolphins:							
Offshore	62,851	0 [c]	174	0.28	0 [c]	349	0.62
Coastal	6,639	0 [c]	465	7.00	0 [c]	934	19.70
Pilot whales:							
Short-finned pilot whale	28,924	0	10 [b]	0.03	0	10 [b]	0.03
Long-finned pilot whale	39,215	0	10 [b]	0.03	0	10 [b]	0.03
Risso's dolphin	35,215	0	30 [b]	0.09	0	30 [b]	0.09
Common dolphin	172,974	0	29	0.01	0	60	0.03
Harbor porpoise	95,543	0 [c]	22	0.02	0 [c]	45	0.05
Seals:							
Gray seal	27,300	0	34	0.12	0 [c]	68	0.25
Harbor seal	61,336	0 [c]	93	0.15	0 [c]	189	0.31

[a] Listed as Endangered under the ESA.

[b] The requested take for these species was adjusted based on mean group size:

- Sei whale: Kenney and Vigness-Raposa, 2010.
- Minke whale: Kenney and Vigness-Raposa, 2010.
- Humpback whale: CeTAP, 1982.
- Sperm whale: Barkaszi and Kelly, 2019
- Atlantic spotted dolphin: Kenney and Vigness-Raposa, 2010.
- Pilot whales: Kenney and Vigness-Raposa, 2010.
- Risso's dolphin: Barkaszi and Kelly, 2019.

[c] A small number of Level A exposures were estimated based on density calculations; however, no Level A take is requested due to mitigation measures outlined in **Section 11**.

[d] For all species other than NARW, estimated take values greater than 0.5 were rounded up to 1. Take values for NARW were set manually for conservatism: 0.45 was rounded to 1, and .93 was rounded to 2.

Table 6-22. Requested Level A and Level B Takes for All Activities Conducted During Ocean Wind Construction.

Species	Population Size	Year 1			Year 2			Year 3			Year 4			Year 5		
		Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %	Level A	Level B	Max %
North Atlantic right whale [a]	368	0	3	0.82	0	7	1.90	0	2	0.54	0	1	0.27	0	1	0.27
Blue whale [a]	unknown	0	0	N/A	0	4	N/A	0	0	N/A	0	0	N/A	0	0	N/A
Fin whale [a]	6,802	0	7	0.10	4	13	0.25	0	3	0.04	0	2	0.03	0	2	0.03
Sei whale [a]	6,292	0	2	0.03	1	3	0.06	0	1	0.02	0	0	0.00	0	0	0.00
Minke whale	21,968	0	33	0.15	22	74	0.44	0	5	0.02	0	3	0.01	0	3	0.01
Humpback whale	1,396	0	9	0.64	6	21	1.93	0	3	0.21	0	2	0.14	0	2	0.14
Sperm whale [a]	4,349	0	6	0.14	0	6	0.14	0	3	0.07	0	3	0.07	0	3	0.07
Atlantic white-sided dolphin	93,233	0	12	0.01	0	100	0.11	0	11	0.01	0	5	0.01	0	5	0.01
Atlantic spotted dolphin	39,921	0	135	0.34	0	135	0.34	0	45	0.11	0	45	0.11	0	45	0.11
Common bottlenose dolphins:																
Offshore	62,851	0	671	1.07	0	1,454	2.31	0	349	0.56	0	174	0.28	0	174	0.28
Coastal [b]	6,639	11	1,634	24.78	0	934	14.07	0	934	14.07	0	465	7.00	0	465	7.00
Pilot Whales:																
Short-finned pilot whale	28,924	0	30	0.10	0	30	0.10	0	10	0.03	0	10	0.03	0	10	0.03
Long-finned pilot whale	39,215	0	30	0.08	0	30	0.08	0	10	0.03	0	10	0.03	0	10	0.03
Risso's dolphin	35,215	0	90	0.26	0	90	0.26	0	30	0.09	0	30	0.09	0	30	0.09
Common dolphin	172,974	0	47	0.03	0	1,584	0.92	0	60	0.03	0	29	0.02	0	29	0.02
Harbor porpoise	95,543	10	97	0.11	69	350	0.44	0	45	0.56	0	22	0.02	0	22	0.02
Seals:																
Gray seal	27,300	31	200	0.85	4	305	1.13	0	68	0.25	0	34	0.12	0	34	0.12
Harbor seal	61,336	35	556	0.96	13	844	1.40	0	189	0.31	0	93	0.15	0	93	0.15

[a] Listed as Endangered under the ESA.

[b] Coastal bottlenose dolphin take for bayside (vs. Atlantic-facing) cofferdams is likely overestimated, as this stock has been shown to prefer coastal to estuarine environments (Toth et al. 2011).

Table 6-23. Summary of Level A and Level B Takes for All Activities Conducted During Ocean Wind Construction.

Species	Population Size	5 Year Total		
		Level A	Level B	Max Percent
North Atlantic right whale [a]	368	0	14	3.80
Blue whale [a]	unknown	0	4	N/A
Fin whale [a]	6,802	4	27	0.46
Sei whale [a]	6,292	1	6	0.11
Minke whale	21,968	22	118	0.64
Humpback whale	1,396	6	37	3.08
Sperm whale [a]	4,349	0	24	0.55
Atlantic white-sided dolphin	93,233	0	133	0.14
Atlantic spotted dolphin	39,921	0	405	1.01
Common bottlenose dolphins:				
Offshore	62,851	0	2,822	4.49
Coastal [b]	6,639	11	4,432	66.92
Pilot Whales:				
Short-finned pilot whale	28,924	0	90	0.31
Long-finned pilot whale	39,215	0	90	0.23
Risso's dolphin	35,215	0	270	0.77
Common dolphin	172,974	0	1,749	1.01
Harbor porpoise	95,543	79	536	0.64
Seals:				
Gray seal	27,300	35	641	2.48
Harbor seal	61,336	48	1,775	2.97

[a] Listed as Endangered under the ESA.

[b] Coastal bottlenose dolphin take for bayside (vs. Atlantic-facing) cofferdams is likely overestimated, as this stock has been shown to prefer coastal to estuarine environments (Toth et al. 2011).

References

Toth, J.L., Hohn, A.A., Able, K.W. and Gorgone, A.M., 2011. Patterns of seasonal occurrence, distribution, and site fidelity of coastal bottlenose dolphins (*Tursiops truncatus*) in southern New Jersey, USA. Marine Mammal Science, 27(1), pp.94-110.