# Appendix J: Introduction to Sound and Acoustic Assessment

## J.1 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.2 Physics of Underwater Sound

Sounds are created by the vibration of an object within its medium (Figure J-1). This movement generates kinetic energy (KE), 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. The vibration is transferred to adjacent particles, which are pushed into areas of high pressure (i.e., compression) and low pressure (i.e., rarefaction). Acoustic pressure is a non-directional (i.e., scalar) quantity, whereas particle motion is an inherently directional quantity (i.e., a vector) taking place in the axis of sound transmission. The total energy of the sound wave includes the potential energy (PE) associated with the sound pressure as well as the KE from particle motion.

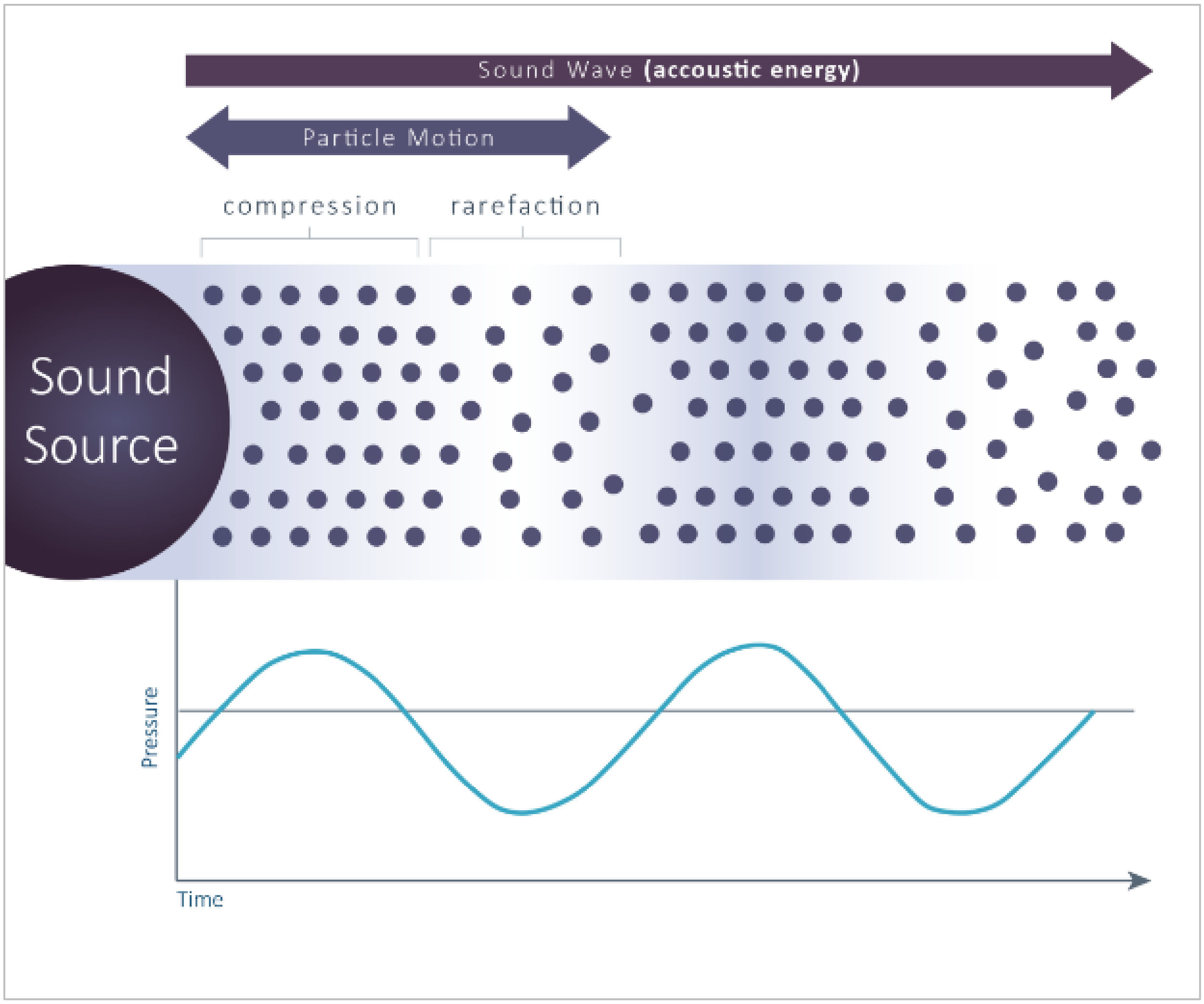


**Figure J-1. Basic mechanics of a sound wave**

### J.2.1 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 International System of Units (SI) units (in parentheses) are as follows.

***Acoustic pressure (pascal, Pa)***: The values used to describe the acoustic (or sound) pressure are peak pressure, peak-to-peak pressure, and root-mean-square (rms) pressure 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). 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 peak level ($L_{pk}$), peak-to-peak level ($L_{pk\text{-}pk}$), and sound pressure level ($L_{rms}$ or SPL) are computed by multiplying the logarithm of the ratio of the peak or rms pressures to a reference pressure (1 microPascal [µPa] in water) by a factor of 20 and are reported in decibels, see **Sound levels** below.

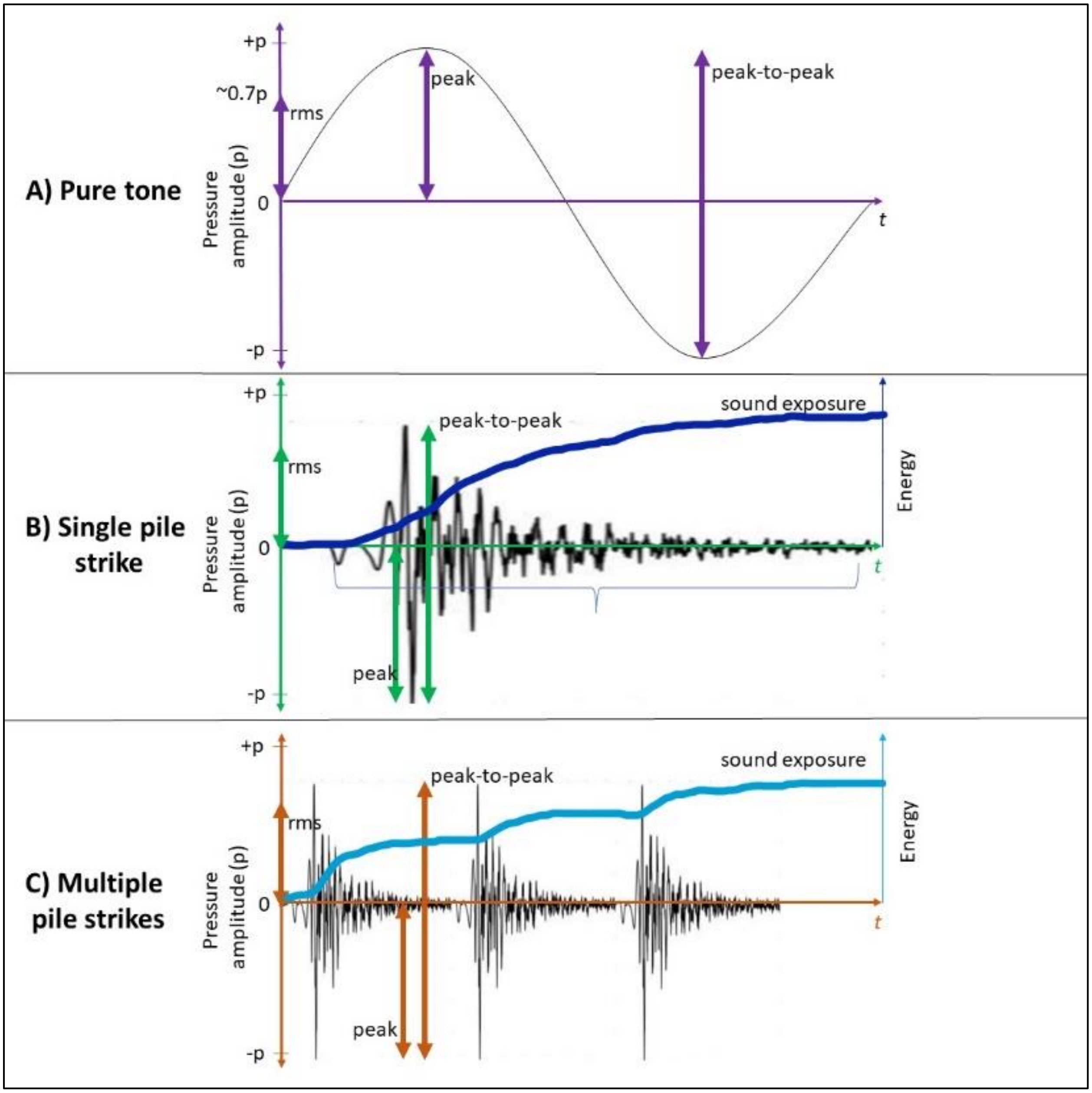


**Figure J-2. Sound pressure wave representations of four metrics: root-mean-square ($L_{rms}$), peak ($L_{pk}$), peak-to-peak ($L_{pk-pk}$), and sound exposure level (SEL)**

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 isn't necessarily the same magnitude. In this example, the negative pulse is more extreme so is the reported peak value, and the peak-to-peak is 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.

***Particle velocity (meter per second, 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 root-mean-square 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, or $Pa^2$-s)***: 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, or $W/m^2$)***: 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 decibels (dB), which is the logarithmic ratio of the measurement in question to a fixed reference value. Underwater acoustic sound pressure levels are referenced to a pressure of 1 µPa (equal to $10^{-6}$ pascals [Pa] or $10^{-11}$ bar). Note: airborne sound pressure levels have a different reference pressure: 20 µPa.

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

- Root-mean-square 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 ($L_{pk-pk}$, units of dB re 1 µPa)
- Sound exposure level (SEL, units of dB re 1 $µPa^2s$)

**Note:** A few commonly used time periods are used for SEL, including a 24-hour period (used in the United States 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 air gun 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 (m) from the source, but this can lead to confusion as an actual measurement at 1 m 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, though 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.2.2 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 m, and because of sound's preference for lower speeds, sound waves above and below this "deep sound channel" often bend towards 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.2.3 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 (National Marine Fisheries Service [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):

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

Whereas the characteristics of non-impulsive sound sources are less clear but may be:

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

Impulsive sounds associated with offshore wind development include explosions, sparkers, boomers, and impact pile-driving; it is generally accepted that impulsive sources have a greater likelihood of causing hearing damage than non-impulsive sources (note: explosions are further considered for non-auditory injury; see Thresholds for Non-Auditory Injury in Programmatic Environmental Impact Statement [PEIS] Section 3.5.6.1.3). At close distances to impulsive sounds, physiological effects on an animal are likely, including temporary threshold shift and permanent threshold shift, although these effects are also possible after exposure to non-impulsive sounds if the duration of exposure is long enough. 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, though 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. And even 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. By definition, 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. Martin et al. (2020) showed that 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.3 Sound Sources Related to Offshore Wind Development

### J.3.1 Geophysical and Geotechnical Surveys

Geophysical and geotechnical 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 high-resolution geophysical (HRG) sources that may be used in geophysical surveys includes side-scan sonars (SSS), multibeam echosounders (MBES), magnetometers and gradiometers, parametric sub-bottom profilers, compressed high-intensity radiated pulses (CHIRP) sub-bottom profilers, boomers, and 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 (ROVs) or autonomous underwater vehicles (AUVs).

Many HRG sources are active acoustic sources, meaning they produce sound deliberately in order to obtain information about the environment. With the exception of some MBES and SSS, they produce sounds below 180 kilohertz (kHz) and thus may be audible to marine species. Source levels vary widely depending on source type and operational power level used, from ~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 smaller portion of the water column, thus reducing the likelihood that an animal encounters the sound (Ruppel et al. 2022). While sparkers are omnidirectional, most other HRG sources have narrower beamwidths (e.g., MBES: up to 6°, parametric SBPs: 30°, boomers: 30–90°) (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 will be introduced as a byproduct of these actions. It is likely that the sound of the vessel will exceed that generated by the geotechnical method itself.

The potential impacts of geophysical and geotechnical surveys during construction activities on marine mammals and sea turtles are analyzed in Chapter 3, *Affected Environment and Environmental Consequences,* of the PEIS.

### J.3.2 Unexploded Ordnance Detonations

Unexploded Ordnances (UXOs) 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 is extremely 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 to 2,000 m from the source, in water depths ranging from 6 to 22 m. The measured SEL from the explosive removal of a 263 kilogram (kg) charge was 216 dB re 1 µ$Pa^2$s at a distance of 100 m and 196 dB re 1 µ$Pa^2$s at 2,000 m. 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 hertz (Hz). The potential impacts of UXO detonations on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

As an alternative to traditional detonation, a newer method called deflagration allows for the controlled burning of underwater ammunition. Typically, an ROV 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 $L_{pk}$ 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.3.3 Construction and Installation

#### J.3.3.1 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 to 50 strikes/minute (sm). Typically, force is applied over a period of less than 20 sm, but the pile can generate sound for upwards of 0.5 s. Impact 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 (kJs), 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.

Thus far, there are only a few measurements from construction of offshore wind turbines in United States waters. Two monopiles (7.8-m diameter) were installed off the coast of Virginia (27-m 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. The unmitigated SPL source level was 213 dB re 1 µPa-m; the mitigated SPL source level was 204 dB re 1 µPa-m.

Jacket foundations are also common, if not for the main turbine structures, for other structures associated with the wind farm such as the offshore substations (OSSs). Jacket foundations are installed using pin piles, which are generally significantly smaller than monopiles, on the order of 2 to 5 m in diameter, 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 the Block Island Wind Farm (BIWF), Amaral et al. (2018a) measured sound levels at various distances during pile-driving of jacket foundations (50 -inch pile diameter, 30-m water depth). It should be noted that the piles were installed at an angle (from vertical), which influenced the directionality of the noise produced, so caution is encouraged with interpretation. Nonetheless, the authors reported SPL received levels between 150 and 160 dB re 1 µPa at approximately 750 m from the piles. The maximum single strike SEL measured at 750 m from the jacket foundations at BIWF ranged from 160–168 dB re 1 $\mu Pa^2 s$, nearly 10 dB lower than at Coastal Virginia Offshore Wind (CVOW) (OCS-A 0497). Using measurements combined with acoustic modeling, the peak-peak source levels for pile-driving at BIWF were estimated to be between 233 and 245 dB re 1 µPa-m (Amaral et al. 2018b).

The potential impacts of impact pile-driving on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

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 to 40 Hz (Matuschek and Betke 2009) and produces most of its acoustic energy below 2 kHz. Buehler et al. (2015) measured sound levels at 10-m distance from a 72-inch steel pile, and found them to be 185 dB re 1 µPa, but this is significantly smaller than the sizes expected for offshore wind. While no measurements of vibratory piling for large monopiles have been conducted, modeling predictions from South Coast Wind (OCS-A 0521), for example, estimate that SPL received levels could exceed the behavioral harassment threshold for marine mammals (120 dB re 1 µPa) at distances > 40 kilometers (km) for a 16-m-diameter monopile (LGL Ecological Research Associates 2022). Vibratory pile-driving is a non-impulsive sound source and the hammer produces sound continuously, so different criteria are used for assessing behavioral and physiological effects on marine mammals.

The potential impacts of vibratory pile-driving on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

A technique that is quickly gaining use for installation in hard rock substrates is down-the-hole (DTH) 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 DTH pile-driving include both impulsive and non-impulsive components. The impulsive component of DTH 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 DTH pile-driving noise, its characteristics strongly resemble those of impact pile-driving, but with a higher hammer striking rate (approximately 10 to 15 Hz). The dominant frequencies from DTH pile-driving are below 2 kHz, similar to 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 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 RODEO measurements from CVOW (OCS-A 0497), double Big Bubble Curtains (dBBC) 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 to 5 dB below 200 Hz, and 8 to 20 dB above 200 Hz, depending on the characteristics of the bubble curtain (Amaral et al. 2020).

### J.3.4 Drilling

Drilling associated with offshore wind activities may involve geotechnical surveys, HDD at the export cable landfalls, and, if necessary, removing large boulders at the site of foundation installation. Sounds from drilling are generally considered to be non-impulsive and are nearly continuous in nature, though they may be highly variable depending on the type of substrate that is encountered (Richardson et al. 1995). There could be tonal sound generated by the drill bit, mechanical noise transferred through the ship's hull, and noise from the vessels and dynamic positioning systems. HDD uses equipment that is generally located on shore, and the sound that propagates into the water is expected to be negligible. Geotechnical drilling SPLs (in the 30–2000 Hz band) have been measured up to 145 dB re 1 µPa-m from a jack-up platform (Erbe and McPherson 2017), and up to 162 dB re 1 µPa-m from an anchored drilling vessel (Huang et al. 2023). If drilling is required for foundation installation, a large drill bit at the bottom of the pile would slowly rotate to break up the material inside the pile, and the liquefied material would be pumped out. While measurements of these operations specifically for offshore wind installation have not been conducted, the closest proxy is from oil and gas-related operations, where a 6-m-diameter drill bit was used for the excavation of mudline cellars (Austin et al. 2018). Austin et al. (2018) measured received levels at 1,000 m from the operations and back-calculated the SPL source levels to be between 191 and 193 dB re 1 µPa-m.

#### J.3.4.1 Vessels

During construction, vessels and aircraft may be used to transport crew and equipment. See Section J.3.5, *Operations and Maintenance,* for further detail about sounds related to those activities. Large vessels will also be used during the construction phase to conduct pile-driving, and may use Dynamic Positioning (DP) systems. DP 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 (GPS), active acoustic positioning systems, and wind sensors to determine relative movement and environmental forces at work. Generally speaking, most acoustic energy is <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, DP 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 DP are difficult to obtain because the sound transmitted is often highly directional and context specific. The direction of sound propagation may change as different DP needs requiring different configurations are applied.

Many studies have found that the measured sound levels of DP alone are, counterintuitively, higher than those of DP 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 DP 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 and 30 Hz. The received SPL measured at 100 m from the vessel was 188 dB re 1 µPa. Warner (2011) found that most DP-related sounds from the self-propelled drill ship, R/V *Fugro Synergy* were in the 110 to 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 DP, 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 DP. 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 DP thrusters are highly directional systems.

The active acoustic positioning systems used in DP 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. The Kongsberg High Precision Acoustic Positioning (HiPAP) system produces pings in the 10 to 32 kHz frequency range. The hull-mounted transducers have source levels of 188 to 206 dB re 1 µPa-m depending on adjustable power settings (Kongsberg Maritime AS 2013). The fixed transponders have maximum source levels of 186 to 206 dB re 1 µPa-m depending on model and beam width settings from 15 to 90° (Jiminez-Arranz et al. 2020). These systems have high source levels, but beyond 2 km, they are generally quieter than other sound components from DP vessels for various reasons including: their pulses are produced in narrowly directed beams, each individual pulse is very short, and their high frequency content leads to faster attenuation. The potential impacts of vessel noise on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

### J.3.4.2 Site Preparation

Prior to offshore wind project foundation and export cable installation, boulder clearance and pre-lay grapnel runs may be conducted to clear the area of obstructions. This may involve the use of a displacement plow, a subsea grab or, in shallower waters, a backhoe dredger. Sandwave clearance may also be conducted in advance of export cable installation to remove mobile sediments using a suction hopper dredger, controlled flow excavation, or plow. At landfall locations, export cables may be installed using HDD, which may require mechanical dredging of the HDD exit pit.

Sounds from site preparation activities are considered non-impulsive and are nearly continuous in nature. Dredging produces distinct sounds during each specific phase of operation: excavation, transport, and placement of dredged material (Central Dredging Association 2011; Jiminez-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. 2011a). 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. 2014). SPL source levels during backhoe dredge operations range from 163 to 179 dB re 1 µPa-m (Nedwell et al. 2008; Reine et al. 2012). As a whole, dredging activities generally produce low-frequency sounds, with most energy below 1,000 Hz and frequency peaks typically occurring between 150 and 300 Hz (McQueen et al. 2018). Additional detail and measurements of dredging sounds can be found in Jiminez-Arranz et al. (2020), McQueen et al. (2018), and Robinson et al. (2011a).

The potential impacts of site preparation activities on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

#### J.3.4.3 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, control flow excavation, trenching, and plowing. Burial depth of the cables is typically 1–2 m. Cable installation vessels may utilize dynamic positioning to lay the cables, which can introduce considerable levels of noise into the marine environment (see Section J.3.4.1, *Vessels*).

Nedwell and Edwards (2004) measured sounds from a 130-m-long trenching vessel and found that sound levels were similar to those produced during pipeline-laying in the same area, with the exception of a 20 kHz tonal sound, which they attributed to the vessel’s DP thrusters. Nedwell et al. (2003) recorded underwater sound 160 m away from trenching activity (water depth 7–11 m) and back-calculated the SPL source level of trenching to be 178 dB re 1 µPa-m (assuming propagation loss of 22logR). They described the sound as generally spanning a wide range of frequencies, variable over time, and accompanied by some tonal machinery noise and transient noises associated with rock breakage.

Johansson and Andersson (2012) recorded underwater noise levels during both pipelaying and trenching. The mean SPL measured (at 1,500 m from the pipeline) during pipelay operations was 130.5 dB re 1 µPa, nearly 20 dB higher than average background noise at the same location. There were eight support vessels in the vicinity during pipelaying operations. During trenching, with only one vessel in the vicinity, received levels were 126 dB re 1 µPa, and the authors back-calculated the SPL source level to be 183.5 dB re 1 µPa, similar to that of commercial vessels in the region.

### J.3.5 Operations and Maintenance

#### J.3.5.1 Aircraft

Staffed aircraft consist of propeller and jet engines, fixed-wing craft, as well as helicopters. Unmanned systems also exist. For jet engine aircraft, the engine is the primary source of sound. For propeller driven aircraft and helicopters, the propellers 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 penetrates 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

~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 and 80 Hz) from a maritime patrol aircraft with an altitude of 76 m, 109 dB re 1 µPa (dominant frequency content below 22 Hz) from a utility helicopter with an altitude of 152 m, and 107 dB re 1 µPa (tonal, 82 Hz) from a turbo propeller with an altitude of 457 m. 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. The potential impacts of aircraft noise on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

### J.3.5.2 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 kHz. This low-frequency noise can travel extremely far distances and has been shown to be detectable at 125 km from the source (Aulanier et al. 2017). Smaller vessels typically produce higher-frequency sound concentrated in the 1 to 5 kHz 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 to 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 that are in place along the Atlantic Outer Continental Shelf (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- to 250-m water depths) showed that reducing speeds to 11 knots reduced vessel source levels by 5.9 to 11.5 dB, depending on the vessel type (MacGillivray et al. 2019). Furthermore, Findlay et al. (2023) documented how small reductions in cargo vessel speed in the Port of Vancouver can substantially reduce noise impacts on marine mammals. Vessel noise is also expected to be lower during geophysical and geotechnical surveys, as they typically travel around 5 knots when towing instruments. The potential impacts of vessel noise on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

### J.3.5.3 Turbine Operations

Once wind farms are operational, low-level sounds are generated by each wind turbine generator (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 wind turbine operations are likely to increase somewhat with increasing generator size and power ratings, as well as with wind speeds. Recordings from BIWF 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 megawatts (MW) in size, showed that operational noise generally attenuates rapidly with distance from the turbines, falling to near ambient sound levels within ~1 km from the source; 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 10-fold 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 m from a hypothetical 15 MW turbine in operation in 10 m/s (19 kilotons [kt] or 22 miles per hour [mph]) wind would be 125 dB re 1 μPa. However, all 46 data points in Tougaard et al. (2020), with the exception of the two from BIWF, were from WTGs operated with gear boxes of various designs rather than the newer use of direct-drive motor technology, which is expected to generate less underwater noise (Stöber and Thomsen 2021; Betke and Bellmann 2023). An additional compilation by Stöber and Thomsen (2021) made 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. A recent study by Holme et al. (2023) indicated that the Tougaard et al. (2020) equations may overestimate underwater sound levels generated by operating WTGs, particularly at short distances from the foundation, suggesting that SPLs may drop below the behavioral threshold at shorter distances than predicted. Holme et al. (2023) examined underwater noise measurements recorded within and outside operating offshore wind farms consisting of 6.3 MW (with direct-drive motors) and 8.3 MW (with planetary gear box) turbines, respectively. The results imply that there is no significant relationship between the broadband underwater noise levels and turbine activity for any of the examined wind farms in the monitored distances (up to 70 m) (Holme et al. 2023). An additional study by Betke and Bellmann (2023) examined turbines up to 8 MW and did not find an upward trend in underwater noise with rated power (a proxy for turbine size), whereas both Tougaard et al. (2020) and Stöber and Thomsen (2021) included piles up to 6 MW and found a statistically significant relationship. Bellmann et al. (2023) suggest that the modeling approaches by Tougaard et al. (2020) and Stöber and Thomsen

(2021) for operational noise are primarily based on a few types of smaller turbine types (often with gear boxes), so that predictions of the noise conditions of existing offshore windfarms of the latest generation (e.g., Holme et al. 2023) lead to overestimations of the measured operational noise of turbines of up to 8 dB.

Underwater noise has been characterized in two locations in Scotland using a five-turbine array of 9.5-MW semi-submersible foundations with gear boxes in Kincardine, and 6-MW floating spar buoys with direct drive motors located in "Hywind Scotland" (Risch et al. 2023). Source levels for turbine operational noise (25 Hz–20 kHz) increased with wind speed at both recording locations. At a wind speed of 15 m/s, operational noise levels were found to be about 3 dB higher at Kincardine (148.8 dB re 1 µPa) as compared to Hywind Scotland (145.4 dB re 1 µPa), which might be a function of the different power ratings, gear box vs. direct drive technology, or the difference in mooring structure of the two turbines (i.e., semi-submersible vs. spar-buoy). Assuming 15 m/s wind speed, predicted noise fields for unweighted SPLs were above median ambient noise levels in the North Sea for maximum distances of 3.5–4.0 km from the centroid of the Kincardine five-turbine array, and 3.0–3.7 km for the five-turbine array at Hywind Scotland (Risch et al. 2023).

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 is 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. The potential impacts of operational turbine noise on marine mammals and sea turtles are analyzed in PEIS Chapter 3.

### J.3.6 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.3.2, *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, some insights can be gleaned 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 to 72 revolutions per minute (RPM), and the cutting time varied widely between cuts (on the order of minutes to hours). At distances of 106 to 117 m from the cutting, received SPLs were 120 to 130 dB re 1 µPa, with most acoustic energy falling between 20 and 2000 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.3.4.1, *Vessels*) and other machinery may also be introduced throughout the decommissioning process.

### J.3.7 Non-pile-driving Foundations and Noise Abatement

BOEM encourages the consideration of low-noise foundation types first, and if use of low-noise foundation types is not possible, BOEM encourages the application of one or more noise-abatement systems during impact pile-driving and other low noise best practices. There are three ways to reduce noise during foundation installation of offshore wind farms. The various methods for reducing underwater noise are described briefly here based on the European experience as summarized in Bellmann et al. 2020.

1. One way to reduce noise impacts is to *avoid pile-driving all together* by selecting a different foundation type. There are several foundation types that are under consideration in the New York (NY) Bight, including monopiles, jacket piles, suction mono-bucket, suction bucket jacket, tri-suction pile caisson, and gravity-based structures. See Section J.3.3, *Construction and Installation*, on the various foundation types. The reader is referred to ICF 2021 for a description of the various site conditions required for each foundation type (ICF 2021, Table 10) and the effects by foundation type (ICF 2021, Table 11). While there are no known acoustic measurements of installation, both suction buckets and gravity-based foundations are expected to produce less noise than the installation of monopiles:

    - Suction buckets are installed by pumping water into the suction bucket as it penetrates the seafloor, and then pumping the water out to force it further into the seafloor. This pumping action produces noise but is not likely to exceed noise limits set to protect marine life.

    - Gravity foundations are composed of heavy material that weighs them down to the seafloor. The installation of these may require site preparation work, such as dredging, to ensure the seafloor beneath the foundation is flat so it will not move. For an understanding of dredging noise and its potential effects, the reader is referred to PEIS Section 2.1.2.1.1 on site preparation.

    - In all installation approaches there is also noise associated with the vessels required for conducting these activities, which may include dynamic positioning for certain activities. Several vessels and different types may be needed, including a barge for towing the gravity base, or a dedicated installation vessel for the impact pile-driving hammer.

2. If an alternative foundation type cannot be used, technology can be applied such that pile-driving noise can be *reduced as it is produced*. These technologies include:

    - Vibratory pile-driving. A vibratory hammer provides a method for partially driving piles at lower sound levels than impact pile-driving. Injury is less likely from vibratory hammering as the impulsive nature of impact hammer strikes produces a greater likelihood of injury. Vibratory hammers will be insufficient to completely drive foundation piles and some impact hammering will be required.

    - The IQIP BLUE hammer. IQIP EQ-Piling uses a longer impact force from a contained water mass to transfer energy to the pile and estimates a 20-dB reduction in sound levels relative to equivalent impact hammer strikes (IQIP 2024a).

    - The IQIP Pulse Unit. The IQIP Pulse Unit uses an impact hammer with a volume of water between the hammer and pile to reduce the amplitude of the pile-driving strike. Noise reduction up to 6–10 dB (SEL) is estimated from this device (IQIP 2024b).

- The Menck Noise Reduction Unit. The Menck Noise Reduction Unit augments the force applied by the hammer to the pile head with noise level reductions of 9–12 dB (Acteon 2024).

3. Finally, a common way to reduce noise impacts from pile-driving is by reducing the amount of noise that gets *transmitted through the water*. Technologies that can be used to dampen the sound in the water column include:

   - The Hydro-Sound Damper uses sound absorbing elements attached to a net deployed circumferentially around the pile to reduce the sound levels by 10 to 12 dB (SEL) (Bellmann et al. 2020).

   - The AdBm Noise Mitigation System similarly utilizes volumes of air contained in plastic Helmholtz resonators deployed around the pile with published reductions of 8 dB (SEL) (Wochner 2019).

   - The HydroNas is a deployable fabric sleeve that inflates to surround the pile with a layer of air. The manufacturers advertise a reduction of 25 dB (SEL) (HydroNas 2023).

   - The IQIP Noise Mitigation Screen uses an impedance mismatch (like the aforementioned systems) to reduce the propagated noise levels between 13 and 17 dB (Bellmann et al. 2020).

   - The Grout Annulus Bubble Curtain is a bubble curtain that is generated between a pile sleeve, like the IQIP Noise Mitigation Screen, and the pile with noise reductions of 2–7 dB (Bellmann et al. 2020).

   - Big Bubble Curtains are generated around pile-driving locations from hoses that emit pressurized air in configurations of up to three concentric hoses to introduce an impedance mismatch to reduce the propagated sound levels by up to 20 dB (Bellmann et al. 2020). The Big Bubble Curtains can be used in most if not all projects and have been used in all U.S. offshore wind projects to date.

Many of these near-field resonator systems are tunable to reduce certain frequencies of sound, with lower frequencies being more difficult to target. The options outlined here may not be comprehensive; other systems may exist or be under development that are similar in principle to the approaches outlined here. In addition to the Bellmann et al. (2020) and ICF (2021) reports, a recent workshop was conducted that identified the advantages and disadvantages of the various noise-mitigation systems available today (Green et al. 2023). As an example, none of the systems to date reduce noise associated with pile-driving in the substrate. This will be an area for future innovation. Many of these options are not mutually exclusive; however, thus far, only one near-field system (i.e., Hydro-Sound Damper, AdBm Noise Mitigation System, HydroNas, IQIP Noise Mitigation Screen, and Grout Annulus Bubble Curtain) has been used at a time. Capacity, logistics, imagination, and motivation are the only limiting factor to the combined use of, for example, the IQIP Noise Mitigation Screen and Hydro-Sound Damper. These near-field systems can also be used in combination with bubble curtains for further noise reduction. The

IQIP Blue hammer, IQIP Pulse Unit, and Menck Noise Reduction Unit cannot be used together and therefore only one would be usable for a project.

## J.4 Acoustic Assessment

Chapter 3 of the PEIS provides a high-level qualitative assessment of impacts of sound on marine life based on the information available related to the NY Bight alternatives and the mitigations contained within these alternatives. This section supplements the Chapter 3 findings by providing more detail on potential acoustic impacts and uses a relativistic risk assessment framework to discuss tradeoffs to marine mammals associated with the alternatives and select avoidance, minimization, mitigation, and monitoring (AMMM) measures under consideration.

Over the last decade, Bureau of Ocean Energy Management (BOEM) has funded the development of a risk assessment framework that can be used to assess the relative risk to marine mammals of acoustic disturbances associated with different development scenarios. This relativistic risk assessment framework is the foundation for the analyses in this section. The framework was most recently used for oil and gas activity in the Gulf of Mexico (Southall et al. 2021a) and for potential offshore wind development in New England waters (Southall et al. 2021b). The framework identifies risk to marine mammals based on the exposure, or the spatio-temporal-spectral overlap of noise-generating activities with the marine mammals, and considers numerous contextual variables that define the vulnerability of a species to acoustic disturbances. The framework has been effective in comparing the *relative risk* of different development scenarios and the *relative risk* of each scenario between species.

Due to the programmatic nature of this PEIS and the long lead times in the regulatory process, many details needed to fully complete the risk assessment framework for the NY Bight projects are still unknown. Therefore, this assessment draws on thematical findings from a completed hypothetical case study (Southall et al. 2021b) that analyzes the development of two wind farms off New England and serves as the best available proxy for the NY Bight analysis at this time.

Using this case study, the analysis to follow focuses on tradeoffs associated with NY Bight alternatives and associated mitigation measures being considered in the PEIS to lessen the extent of acoustic disturbance on marine mammals associated with pile-driving and, to a lesser extent, vessel noise. This analysis is done through assessing the potential changes in exposure risk of marine mammals to noise with different AMMM measures. The vulnerability of a species is also an important factor in assessing the overall risk of offshore wind development on marine life, but this factor cannot be directly controlled for in this analysis and therefore is not analyzed further.

The use of this framework does not replace sound field modeling and other standard numeric modeling exercises at the project level, which are needed for specific purposes such as informing take estimates and mitigation zones.

### J.4.1 NY Bight Alternatives

The PEIS analyzes three alternatives:

- **Alternative A (No Action Alternative):** No development would occur on any of the six NY Bight lease areas. There would be no acoustic impacts associated with the development of the six NY Bight lease areas under Alternative A. This alternative is not discussed further in this assessment. However, note that Section 3.5.6.3 of the PEIS still discusses noise impacts on marine mammals associated with the No Action Alternative that exist regardless of the presence of any NY Bight project development.
- **Alternative B – No Identification of AMMM Measures at the Programmatic Stage:** Alternative B considers the potential impacts of future offshore wind development for the NY Bight area without the AMMM measures identified in Appendix G, *Mitigation and Monitoring*, that could avoid, minimize, mitigate, and monitor those impacts.
- **Alternative C (Proposed Action) – Identification of AMMM Measures at the Programmatic Stage:** Alternative C consists of two sub-alternatives:
    - **Sub-alternative C1 (Preferred Alternative): Previously Applied AMMM Measures.** Sub-alternative C1 analyzes the AMMM measures that BOEM has required as conditions of approval for previous activities proposed by lessees in Construction and Operations Plans submitted for the Atlantic OCS or through related consultations. The analysis for Sub-alternative C1 is presented as the change in impacts from those discussed under Alternative B.
    - **Sub-alternative C2: Previously Applied and Not Previously Applied AMMM Measures.** Sub-alternative C2 analyzes the AMMM measures under Sub-alternative C1 plus the AMMM measures that have not been previously applied. Therefore, under this alternative, the analysis is presented as the change in impacts from those discussed under Sub-alternative C1. In the case where there are no AMMM measures applied under Sub-alternative C1, the analysis for Sub-alternative C2 is described as the change in impacts from those discussed under Alternative B.

Alternatives B and C analyze impacts at both a single project level and across all six proposed projects. The acoustic impacts associated with the development of the six NY Bight lease areas under Alternative B and C will be discussed, to the extent possible, in sections later in this document.

### J.4.2 Overview of Relativistic Risk Assessment Framework

A team of experts recently developed the newest iteration of their acoustic risk assessment framework for marine mammals (Wood et al. 2012); the most recent framework considers aggregate acoustic exposures from the construction and operation of multiple wind farms (Southall et al. 2021b, 2023). The framework was intentionally designed to be tunable to allow users to assess specific scenarios based on the temporal, spatial, and spectral overlap of noise-generating activities and marine species. Their case study for offshore wind development in New England (Southall et al. 2021b, 2023) provides a useful analog to the potential development in the NY Bight and is used here to consider the relative risks posed by the alternatives and associated mitigations considered in the PEIS.

This framework is based on an exposure index (representing the probability of exposure of a species to an activity) and the vulnerability index (representing the inherent vulnerability of a given species to anthropogenic disturbance) (Figure J-3). The resultant risk value is calculated for each species and each month of a specified scenario, providing high-level insights about the spatio-temporal-spectral interactions and risk trade-offs associated with different development scenarios.

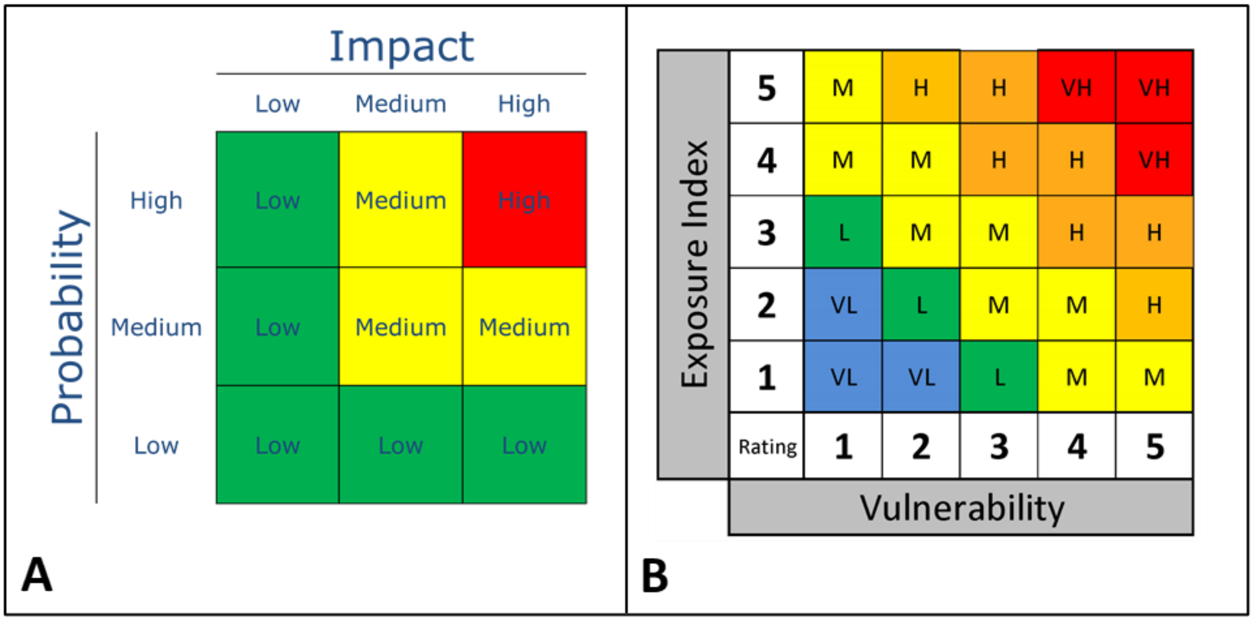


**Figure J-3. Generic risk assessment matrix (left) and risk assessment matrix from Southall et al. (2021b, 2023) (right)**

A. Example risk assessment matrix.
B. Risk assessment matrix from Southall et al. (2021b, 2023). The exposure index reflects the spatial, spectral, and temporal overlap of the noise event and the species at hand, and the vulnerability axis reflects species-specific contextual factors.

### J.4.2.1 Exposure Index

The exposure index aims to quantify the "severity" of a given noise event by considering the spatio-temporal extent of a noise-generating activity and its overlap with the spatio-temporal presence of a species. The spatial component of the exposure index is based on the area within which a behavioral response is likely to occur (but can be tuned to reflect any type of response, ranging from auditory detection to auditory injury). The temporal component considers the proportion of a population present at a given time in the spatial area that is exposed, in comparison to the overall population present over a larger geographic zone or region at the same time. The spectral content of the noise source is considered to focus on the portion of the noise that actually overlaps with the hearing range of each marine mammal hearing group (Southall et al. 2007). The exposure index is calculated separately for each wind farm, month, and species combination. An aggregate exposure index also can be calculated for an individual species for a defined project development scenario by summing the monthly exposure index values across a year. This value is normalized by the number of animals in the geographical zone (or local population as may be referred to here) to obtain a percentage, such that the aggregate exposure index percentage represents the portion of the population that would be exposed.

#### J.4.2.2 Vulnerability Index

The vulnerability index aims to quantify the baseline vulnerability of a given population. Therefore, it is species-specific, and includes the following factors: (1) the spatio-temporal presence of the species in the activity area, (2) the species' ecological use of the activity area and environmental risk factors of the specific area considered, (3) the hearing capabilities of the species, and (4) the general trends in the size and health of the population. As these factors may change over time, these are evaluated at a monthly resolution to capture the temporal variation in vulnerability associated with these factors.

#### J.4.2.3 Final Risk Score

The final integrated risk score for a species is assessed by intersecting the exposure index and vulnerability index on a five-by-five matrix (which is skewed toward the exposure index), depicting the relative risk with a color bar reflecting highest, higher, moderate, lower, and lowest risk. Because the parameters of both the exposure index and vulnerability index are specified for each development scenario of interest, a separate risk matrix will be obtained for each specific geographic area, species, and activities considered and should only be used to assess *relative* risk within the scenarios analyzed. This analysis should not be considered a measure of absolute risk.

#### J.4.2.4 What the Framework Is and Is Not

Due to the broad temporal and spatial resolution of this framework in its current form, it cannot be used to evaluate specific interactions between individual animals and individual noise-generating events. The framework provides a broader view of the effect of larger-scale or longer-term projects on a given population and gives insight about *relative* risk of the multiple scenarios under consideration and the *relative* risk posed to each species. In its current form, the framework makes no attempt to differentiate between the types of effects (i.e., injury, behavior, or masking) because acoustic disturbance is considered more generally as an exposure term; however, the exposure term could later be tuned to consider specific types of effects. This framework also does not include noise propagation modeling, individual animal movement, or energetic model assumptions; these factors will be considered at the project level.

### J.4.3 Overview of Hypothetical New England Wind Farm Case Study

The acoustic risk assessment framework was most recently used to explore the trade-offs associated with hypothetical wind farm development in southern New England waters (Southall et al. 2021b), herein referred to as the "case study." This case study provides a useful analog for offshore wind farm development in the NY Bight due to similarities in geographic location and trends in species occupancy in the area. The case study is being introduced and described here to provide insight about the possible spatio-temporal-spectral factors that should be considered with respect to the alternatives being considered for offshore wind in the NY Bight.

The hypothetical wind farms considered in the case study include two wind farms in southern New England, located ~35 km apart (Figure J-4). This distance was chosen so that the wind farms would be near to each other, but any acoustic impact radii associated with the two wind farms would be expected to be non-overlapping. Although the parameters of these wind farms are realistic, they were not intended to represent a specific project.

- Wind farm 1 (WF1): 25 by 25 $km^2$ area (150,000 acres), 180 monopiles
- Wind farm 2 (WF2): 10 by 20 $km^2$ area, (50,000 acres), 60 monopiles

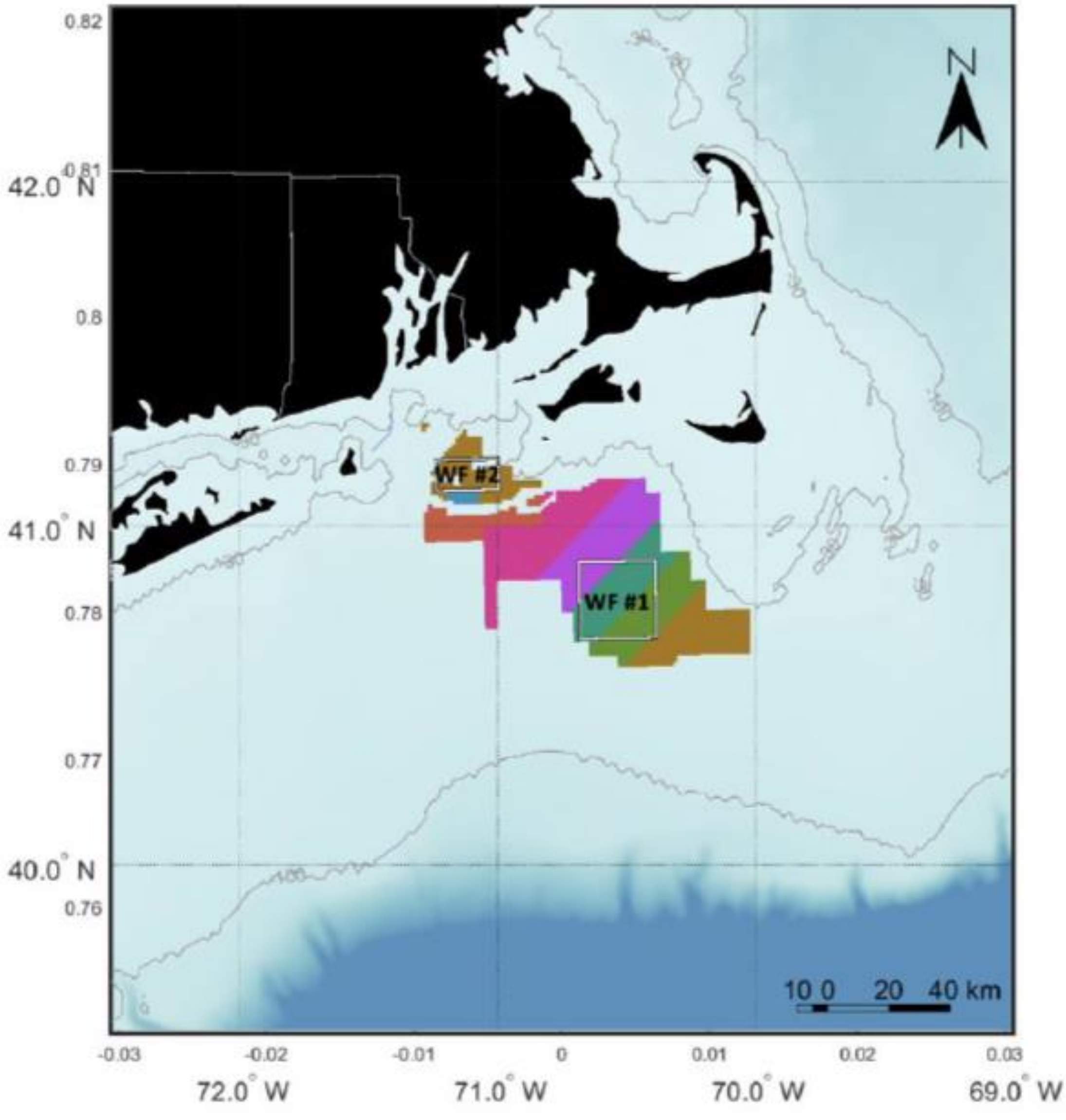


**Figure J-4. Hypothetical New England wind farm locations off Massachusetts**

Offshore leased areas shown in colored polygons, with two white rectangles outlining the locations of the two wind farms assessed.
Source: Southall et al. (2021b).

The team assessed the relative risk to these focal species for the following reasons:

- **North Atlantic Right Whale (NARW)**: Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) listed and in the low-frequency hearing group.
- **Humpback whale (humpback)**: not ESA listed but a relatively common whale in the low-frequency hearing group.
- **Common dolphin (dolphin)**: an odontocete in the mid-frequency hearing group; very common in the geographic analysis area.
- **Harbor porpoise (porpoise)**: a less common odontocete but particularly sensitive to noise; represents the high-frequency hearing group.
- **Gray seal (seal)**: represents the phocid pinniped group; increasingly common in the geographic analysis area, although less so in the open ocean of the continental shelf.

For simplicity, these species are referred throughout by the short-hand term listed next to the species name in parentheses in the previous list.

The spatio-temporal presence of these species in the geographical locations of the hypothetical wind farms was obtained from the Roberts et al. (2020)[1] marine mammal density data set. A monthly risk matrix was calculated for each of the five species for a 3-year time span. See Southall et al. (2021b) for complete details of the New England case study and risk assessment process, including components not further discussed here (e.g., masking).

### J.4.3.1 Exposure Index Calculations

*Year 1*

The objective of the Year 1 assessment was to explore the trade-offs associated with construction timing, the duration of pile-driving each day, and the use of mitigation (noise abatement). The following details provide the parameters and assumptions used in calculating the exposure index for all five species in Year 1.

### J.4.3.2 Scenarios

- 120 foundations were installed on WF1; pile-driving was the main contributor of noise.
- Option of either unmitigated or mitigated pile-driving (using noise abatement).

[1] Although gray seal is the species specified here, the Roberts et al. (2020) data is not specific to that species of seal. This specific species was considered for obtaining information relevant to other components of the vulnerability score.

### J.4.3.3 Spatial Component

- The authors used measurements made during the installation of a 7.8-m monopile with (mitigated) and without (unmitigated) a double bubble curtain during the construction of the Coastal Virginia Offshore Wind Farm (OCS-A 0497) (Ørsted 2020) to calculate the radial distance around each pile at which the received levels to behavioral impact would be exceeded.
    - Harbor porpoise
        - Behavioral disturbance would occur at a received level of 120 dB re 1 μPa; this sound level was exceeded at distances up to:
            - 20 km for the unmitigated scenario.
            - 15 km for the mitigated scenario.
    - Other four marine mammals considered
        - Behavioral disturbance would occur at received levels of 160 dB re 1 μPa; this sound level was exceeded at distances up to:
            - 10 km under the unmitigated scenario.
            - 5 km for the mitigated scenario.

### J.4.3.4 Temporal Component

- Three potential construction start dates explored: March 1, May 1, or July 1.
- Option of either one pile driven per day or two piles driven per day:
    - Total duration of pile-driving: 4 months for one pile/day.
    - Total duration of pile-driving: 2 months for two piles/day.

### J.4.3.5 Spectral Component

The spectral index is calculated by multiplying the species abundance number by a coefficient that indicates the spectral overlap of the noise and the functional hearing (Southall et al. 2007) of the marine mammal species under consideration. This calculation deemphasizes the exposure (essentially decreasing the number of animals exposed) if the spectral energy in a signal is outside the frequencies that the species hears best. To do this weighting a spectrum of the source signal was needed. For pile-driving, a spectrum from HDR (2020) was used from the pile-driving installation of a 7.8-m monopile measured within 3 km of the monopile.

#### J.4.3.6 Year 2

The objective in the Year 2 assessment was to explore the relative interactions and cumulative effects associated with installation of more than one wind farm, as well as the trade-offs associated with the timing of installation.

#### J.4.3.7 Scenarios

- 60 foundations were installed on WF1, and 60 installed on WF2; pile-driving was the main contributor of noise.
- Only considered unmitigated pile-driving and installation of one pile/day.

#### J.4.3.8 Spatial Component

- Same as Year 1 unmitigated scenarios (20 km for porpoises and 10 km for all other species considered).

#### J.4.3.9 Spectral Component

- Same as Year 1.

#### J.4.3.10 Temporal Component

- The analysis explored three installation timing scenarios that affected the temporal component of the exposure index. The scenarios all assumed installation of only one pile/day but varied in the degree of overlap between the two nearby windfarms:
  - *Sequential installation*: WF1 construction July/August, WF2 construction September/October (total of 4 months to install 120 foundations).
  - *Partial overlap*: WF1 construction July and August; WF2 construction August and September (total of 3 months to install 120 foundations).
  - *Total overlap*: WF1 and WF2 construction August and September (total of 2 months to install 120 foundations).

#### J.4.3.11 Year 3

The objective in the Year 3 assessment was to explore the relative risk associated with the operational phase of offshore wind development. The following assumptions were made for Year 3.

#### J.4.3.12 Scenario

- Both WF1 and WF2 were fully operational.

- Operational noise from each turbine and vessel noise (defined by vessel type, number of trips, speed, and trip duration) were the main contributors of noise.

#### J.4.3.13 Spatial Component

- *Operational noise:* The radial distance to the behavioral thresholds for an operating turbine was considered to be 100 m for all species (Tougaard et al. 2020). It is worth noting that the spatial extent of exposure for turbine operations was also a function of the number of operating turbines and thus was twice as large for WF1 than WF2.
- *Vessel noise:* The exposure associated with vessel noise was calculated as a function of vessel speed in the wind farm area (31 km/hour), average length of a vessel trip (4 hours), and the radius of behavioral response, which was assumed to be 0.5 km from a vessel (Holt et al. 2021). These estimates were based on a crew transfer vessel, which is expected to be the most prevalent in the area during operations and maintenance times.

#### J.4.3.14 Temporal Component

- *Operational noise* was considered to be uniform throughout the year.
- *Vessels* were assumed to make 30.8 trips each month to WF1 and 10.3 trips each month to WF2, with a uniform distribution across the year.

#### J.4.3.15 Spectral Component

- *Operational turbine:* The authors used a spectrum measured by Ingemansson Technology AB (2003) during wind speeds of 14 m/s, measured within 83 m of the turbine.
- *Vessel noise:* The authors used a spectrum measured by Hermannsen (2014) at 100 m from a vessel transiting at 30 km/hour.

For complete details of the New England case study and risk assessment process, including components not further discussed here (e.g., masking and vulnerability index), see the full report by Southall et al. (2021b). Note: the utility of the risk assessment framework for offshore wind has been summarized in Southall et al. 2023.

### J.4.4 Overview of Findings from the New England Case Study

Overall, the New England case study identified several key results and mitigative principles.

#### J.4.4.1 Results

- The lowest exposure risk associated with pile-driving coincided with times of lowest animal abundance.

- Mitigated pile-driving reduced the overall exposure indices in comparison to unmitigated pile-driving.
- Of the scenarios explored, there was no common strategy for minimizing exposure risk to each species with the installation scenarios explored (i.e., *sequential installation, partial overlap, total overlap*).
- The exposure risk associated with the construction of multiple wind farms is not additive and depends heavily on the spatio-temporal overlap of the animals and the activity. Higher relative exposure risk is expected when activity overlaps most in time and space with the location of the animals.
- The relative noise exposure risk of offshore wind development on marine mammals is higher for low frequency cetacean (LFC) than mid frequency cetacean and high frequency cetacean due to the low frequency nature of the noises most-commonly generated during offshore wind development (i.e., pile-driving and vessel noise).

#### J.4.4.2 Mitigative Principles

- A reduction in noise at the source could reduce the spatial extent of potential exposure to all species.
- Focusing activity (pile-driving or vessel activity) to times when animals are not present or are in very low abundance in the area could decrease the risk to marine mammals. As no time exists when no animals are present, the specific trade-offs to certain species would have to be weighed against conservation needs and priorities.
- Increased monitoring could lead to increased opportunities to further mitigate effects on marine mammals.
- For some species, some temporal overlap in construction windows could reduce aggregate impacts, while for other species, it may increase it. During project planning, careful consideration should be given to the spatio-temporal distribution of species of interest with the overlap of the spatio-temporal aspects of development. With an adaptable development timeline, risks to marine mammal species of interest could be reduced.

The details of these results follow. The discussion focuses on results from the one pile/day unmitigated scenario as these parameters were used consistently across Years 1 and 2 in the New England case study. Examples from other scenarios will be used to highlight key points and will be specifically called out. Each species had a different vulnerability index, which is a critical component of the overall risk assessment but is not discussed further here as the primary purpose is to consider the ways that different development scenarios affect the exposure index.

### J.4.4.3 Year 1

The difference in the results across the three start time scenarios for a given species was primarily driven by the animal abundance, with the lowest risk occurring when pile-driving coincided with the times of lowest animal abundance. Animal abundance can change drastically over a year for some species. For the NARW and harbor porpoise, the lowest aggregate exposure resulted from a July start, while for humpbacks and seals, it was a May start, and for common dolphins, a March start (Table J-1).

**Table J-1. Aggregate exposure index percentages over the course of the year for each construction start time scenario by species for the one pile/day, unmitigated scenarios**

| Species | March Start | May Start | July Start |
|---|---|---|---|
| NARW | 3.1915 | 2.8316 | 2.3398 |
| Humpback | 1.1440 | 0.8271 | 0.8649 |
| Dolphin | 0.1747 | 0.2540 | 0.4438 |
| Porpoise | 1.3046 | 1.0413 | 0.8522 |
| Seal | 0.7096 | 0.1470 | 0.1671 |

In comparing the one pile/day versus the two piles/day unmitigated scenarios, when pile-driving started in July, the two piles/day scenario posed a lower exposure risk to all species except porpoise (Table J-2). In contrast, when pile-driving started in either March or May, the exposure index was higher for every species (except dolphins) in the two piles/day scenario (Table J-2). *This suggests that pile-driving noise exposure, and consequently the overall risk to the five marine mammal species considered here, can be substantially lowered by concentrating pile-driving efforts when the fewest animals are present in the area.*

**Table J-2. Aggregate exposure index percentages for each construction start time scenario by species for the two piles/day, unmitigated scenarios**

| Species | March Start | May Start | July Start |
|---|---|---|---|
| NARW | 4.1906 | 3.6195 | 2.0325 |
| Humpback | 1.3793 | 0.9281 | 0.7206 |
| Dolphin | 0.1357 | 0.2141 | 0.2965 |
| Porpoise | 1.4826 | 1.1235 | 0.9537 |
| Seal | 0.9322 | 0.2398 | 0.1074 |

However, given that not all species are affected equally due to their different distributions throughout the year, the specific trade-offs to certain species would have to be weighed against conservation needs and priorities, and care is needed when considering the timing of these events. It is important to emphasize that for some species, the risk would increase for two piles/day versus one pile/day if the timing does not coincide with periods of lowest abundance. For example, a March start date with the two piles/day scenario led to higher exposure indices than one pile/day for certain species (NARW, porpoise, seal). That is because these species have higher densities in the geographical area during March than in July. Thus, when animals are more abundant, the exposure index is higher in a two piles/day scenario.

Intuitively, the exposure index was always lower in the mitigated scenarios versus the unmitigated scenarios because the spatial component of the exposure index was smaller. For a reduction in the behavioral impact range from 10 km down to 5 km, the decrease in the resulting exposure index was four-fold, since the area exposed is reduced as a function of $r^2$. This consistently led to a change in the integrated risk assessment score by at least one step (e.g., lower to lowest) when comparing the mitigated and unmitigated case of the same scenario, although in many cases the risk decreased by multiple steps (e.g., from highest to moderate). *This finding suggests that anything that can be done to reduce the spatial extent of noise exposure will reduce overall risk from noise across species.*

This overall synthesis demonstrates the utility of this framework for identifying the risks and tradeoffs to multiple species associated with different potential development scenarios. It also demonstrates that, with an adaptable development timeline, risks to marine mammals can be reduced.

#### J.4.4.4 Year 2

The Year 2 analysis considered only the unmitigated one pile/day conditions for the construction of 60 piles at each of two wind farms in either a sequential, partial overlap, or total overlap construction scenario. Based on the Year 1 findings, only the late summer/fall seasons (July–October) were considered for pile-driving as this was the period with the lowest overall risk to the species analyzed.

When comparing the three installation timing scenarios, the lowest aggregate exposure for three of the five species (NARW, dolphin, seal) occurred with the partial overlap scenario, while the sequential construction led to the lowest aggregate exposure for humpback whales and total overlap led to the lowest aggregate exposure for porpoise (Table J-3). *These results suggest that for the scenarios explored in the New England case study, a condensed construction timeline may help to reduce the exposure for marine mammals, but consideration needs to be given with respect to species of interest, their density, and distribution at each of the construction sites for the times when construction is anticipated, as no common reduction was seen across all species by condensing construction. Similar trade-offs would likely exist if additional species were also considered, and in the case of the NY Bight.*

**Table J-3. Aggregate exposure index percentages for each construction timeline approach by species**

| Species | Sequential Construction | Partial Overlap | Total Overlap |
|---|---|---|---|
| NARW | 1.8415 | 1.6665 | 1.6775 |
| Humpback | 2.1419 | 2.2610 | 2.3287 |
| Dolphin | 0.2592 | 0.2341 | 0.3358 |
| Porpoise | 0.7455 | 0.5649 | 0.5090 |
| Seal | 0.3579 | 0.3327 | 0.3715 |

To understand the difference in aggregate exposure of two wind farms near each other being constructed instead of one wind farm, this analysis compared the Year 1, unmitigated, one pile/day, July start scenario with Year 2 sequential installation results. In both scenarios, a total of 120 piles were driven over 4 months. There was no common trend across all species; for some species (i.e., humpbacks and seals), the construction of one wind farm led to lower aggregate exposure, whereas for other species (i.e., NARW, dolphins, and porpoise), the construction of two wind farms led to lower aggregate exposure (Table J-4). The differences across species were driven by small-scale differences in animal densities at WF1 versus WF2, underscoring *the need for careful consideration of the spatio-temporal distribution of species of interest with the overlap of the spatio-temporal aspects of development during planning.*

**Table J-4. Aggregate exposure index percentages for Year 1 and Year 2 by species**

| Species | Year 1 | Year 2 |
|---|---|---|
| NARW | 2.3398 | 1.8415 |
| Humpback | 0.8649 | 2.1419 |
| Dolphin | 0.4438 | 0.2592 |
| Porpoise | 0.8522 | 0.7455 |
| Seal | 0.1671 | 0.3579 |

Notes: **Year 1**: unmitigated, one pile/day, July start scenario of Year 1 construction of WF1; **Year 2**: unmitigated, one pile/day, Year 2 sequential construction of WF1 and WF2.

These results demonstrate that there are species-specific differences in the magnitude and direction of change in aggregate exposure associated with the development of one versus multiple wind farms, linked to the specific location of the wind farms and construction timing, which interact differently with the unique spatio-temporal distribution of the species. In terms of the NY Bight, this is surely to be the case. For example, one of the NY Bight lease areas is located closer to shore than the other five. As a result, there are clear differences in the density magnitude of certain species there than at the other lease areas, although there are similar seasonal presence trends at all of the NY Bight lease areas. In particular, dolphins are present in lower numbers and seals are present in higher numbers at the more coastal lease area than in comparison to the other lease areas. Because many of the species considered are migratory animals there are also differences that can be expected due to the latitudinal range of a species. Therefore, it seems reasonable to expect different exposure risk across the lease areas. The cumulative exposure associated with the build-out of two or more wind farms simultaneously will depend on the construction timing and wind farm locations. For the NY Bight, if multiple wind farms will be constructed simultaneously (e.g., sequentially, or some degree of overlap), this relative risk framework can be used to identify a construction scenario that reduces aggregate exposure for priority species.

### J.4.4.5 Year 3

Both vessel noise (primarily from wind farm maintenance) and turbine operational noise were considered in Year 3. Because the exposure index results were higher for vessel operations than operating turbines, the exposure index results reported were only a function of vessel operations. The authors of the analysis emphasized caution in using the results of the Year 3 analysis as there were no large-scale wind farms in operation in the United States from which to build the necessary assumptions for this part of the case study. Therefore, the case study was informed by the best available, albeit cursory, knowledge of likely vessel use during the operational phase of a wind farm; the assumption is that vessels would primarily be used to transfer crew for maintenance of the turbines.

The case study assumed that vessel use would be uniform across the year, leading to a higher aggregate exposure for several species (NARW, humpback, and gray seals) for the Year 3 scenario compared to the Year 1, July start scenario. The case study demonstrated this result despite generally *lower* exposure risk associated with vessel noise in any given month. Because the aggregate exposure index is calculated by summing across all months with the assumption that there was vessel activity in every month, the aggregate exposure index percentage associated with vessel noise was *higher* than for pile-driving, assumed to occur for only 2 to 4 months of a given year. It is worth noting that exposure risk in this analysis does not specifically mean risk of auditory injury, but rather the potential risk to some noise effect. A uniform distribution was assumed for vessel activity across the year, leading to high aggregate exposure. Similar to restricting pile-driving activity to certain times of the year, *there may be decreased relative risk to marine mammals if maintenance of wind farms could coincide with periods of low marine mammal abundance.* For example, for humpback whales and the NARW, concentrating maintenance activity to the summer and early fall could lead to the lowest relative risk for these species. *Because the seasonality of marine mammals is similar in the NY Bight and New England waters, this potential mitigation could also hold true for the NY Bight.*

Although this analysis focused on vessel noise, the results also are relevant to vessel strike risk. Minimizing the exposure to vessel activity in general could mitigate both vessel noise and vessel strike risk.

#### J.4.4.6 Final Remarks on New England Case Study

A final observation of this analysis is that there are still limitations in our understanding of where and when animals are present on the OCS, in particular the lack of data on species vulnerability. This gap was particularly the case for seals and harbor porpoise in the area where the scenarios were being considered. *This deficiency may be overcome with increased long-term, continuous, and comprehensive monitoring efforts. Long-term Passive Acoustic Monitoring (PAM) to collect additional information about the presence and distribution of marine mammals is an AMMM measure considered for the NY Bight.*

While considering the results for the New England case study, it is important to keep a few things in mind. These results are provided here to understand how noise exposure might be reduced with different approaches and the trade-offs for each approach. This understanding is the emphasis of this analysis, not the absolute numbers presented from the case study. By staying within the limiting parameters (similar seasonality and overall abundance between the NY Bight and southern New England, for example), valid conclusions can still be extrapolated from even relative results for specific and well-chosen questions.

The results and mitigative principles from the New England case study informed the identification of noise-related AMMM measures and guided the discussion of the acoustic impacts of the alternatives.

### J.4.5 Comparison of Southern New England and NY Bight

The United States East Coast can be divided into different ecoregions based on species distributions, ecological processes, geology, oceanography, biology, environmental threats, among other factors

(Greene et al. 2010). The NY Bight/southern New England area forms one ecoregion. Relative to the rest of the Atlantic OCS, the NY Bight and southern New England are fairly similar and likely to serve similar ecosystem services. Therefore, the presence, abundance, and ecological use of the NY Bight lease areas by marine mammals is not expected to differ greatly from the area of the hypothetical wind farms in the New England case study, and the case study can be used to make inferences about potential wind farm development in NY Bight.

To confirm that this assumption was reasonable, BOEM used the marine mammal data that informed the case study (Roberts et al. 2020) to compare the densities of marine mammals in the New England case study area to the lease areas under consideration in the PEIS. Since the completion of the case study, however, the marine mammal density data has been updated (Roberts et al. 2016, 2023), so BOEM also compared marine mammal densities between the two areas using the more recent models (Figure J-5). In most cases, the marine mammal densities at the New England locations were similar to or greater than the densities for the NY Bight, which means the results of the case study are somewhat conservative and can potentially serve as an upper bound for potential risk in similar scenarios. However, for common dolphins, the density in the NY Bight was generally higher than New England, so the potential risk identified in the case study is likely an underestimate for this species.

- Harbor porpoise and seal density in the New England case study was generally similar both in magnitude and seasonality to the NY Bight lease areas, though for WF2 the largest peak in seal density was in winter as opposed to in the spring for WF1 and the NY Bight lease areas. The overall trend remained the same: seals were present in high numbers in both locations in the winter and spring and not present, or present in low numbers, in the summer and early fall.

- For the NARW, the seasonality patterns were similar; there were few animals present in summer and fall, but more animals were present in winter and spring. However, the number of animals in the New England wind farms were much higher, suggesting the results from the New England case study should serve as an upper bound for the NARW in the NY Bight.

- For humpback whales, there was a 1-month difference in the timing of the peak humpback density in the fall. This peak occurred in September for New England and October for the NY Bight.

- For common dolphins, the general distribution across the year was similar, but the number of animals in the NY Bight lease areas was higher than in the New England wind farm locations. One outlier in the NY Bight leases was OCS-A 0544, the most coastal of the NY Bight leases. This area had lower overall densities across the year than the other NY Bight lease areas and represents a more coastal location than the other lease areas. This trend is similar to the magnitude difference in the New England wind farms, where WF2 (the more coastal site) has lower overall numbers of animals in comparison to WF1. Therefore, the two New England wind farm locations capture the variation seen in common dolphin density between coastal and offshore locations in the NY Bight lease areas.

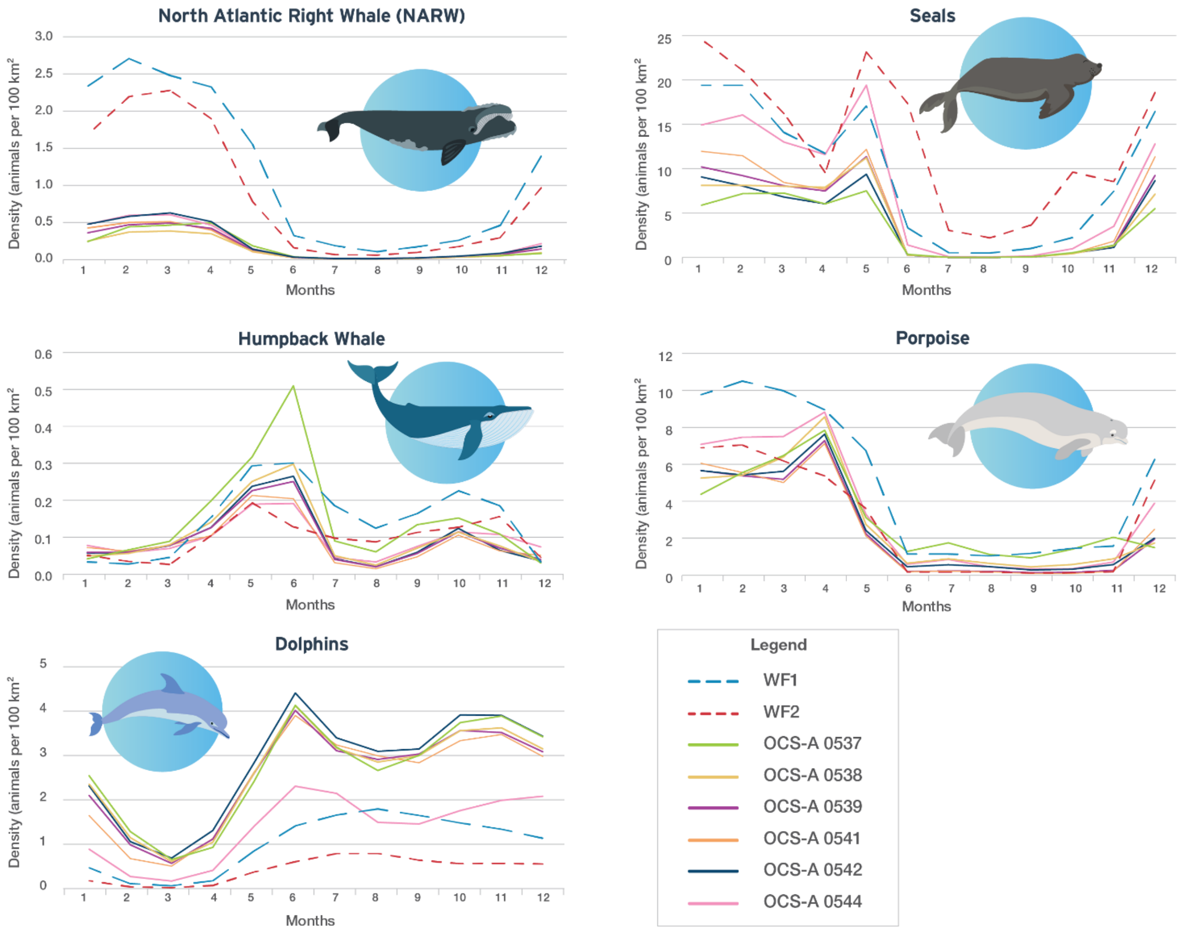


**Figure J-5. Comparison of average animal density in the New England hypothetical wind farm areas (WF1 and WF2) with the average animal density in the NY Bight lease areas (OCS-A 0537, 0538, 0539, 0541, 0542, and 0544)**

Note: The y-axis scales are different among the plots.
Source: Roberts et al. (2022).

In summary, the density distribution differences identified for each species between the New England wind farms and NY Bight lease areas point to only a few shortcomings in the overall applicability of the New England case study findings to the NY Bight. First, that the densities associated with the common dolphin, particularly those associated with WF1, may be less than for the NY Bight, which could underestimate the risk to common dolphins. However, common dolphins had the lowest assessed risk of any of the species considered in the New England case study, in part, due to their low vulnerability. Second, some species' densities in the NY Bight lease areas exceed those of the hypothetical wind farms at certain times of the year, such as for humpback whales in spring and early summer at OCS-A 0537. However, this difference is acceptable because this programmatic-level assessment considers the general trend in density distribution across the year rather than on a single month resolution.

### J.4.6 Discussion of Acoustic Impacts Under Alternative B

Under Alternative B, AMMM measures are not identified at the programmatic stage and the largest spatio-temporal extent of noise associated with the development of offshore wind in the NY Bight has the potential to be realized. Pile-driving would be expected to be the greatest contributor to potential noise-associated effects on marine mammals.

Under Alternative B, pile-driving would not be excluded in certain time periods, including periods when species of greatest concern such as the NARW could be present, and periods when other species are in high abundance in the area and on the lease site. At the programmatic level, there would not be measures in place to monitor for marine mammals or modify activities should an animal be exposed to impactful levels of sound. Baleen whales and seals would be especially susceptible, as their hearing range overlaps with the low frequency sounds produced during offshore construction activities.

It is difficult to predict the spatio-temporal impact of the project build-outs under Alternative B without an understanding of many of the construction specifics of the NY Bight projects, e.g., construction effort within a day (e.g., number of piles driven in a day), order of construction among the leases, whether construction on one project will overlap in time with one another, and whether construction on a single project will occur all in one year. A few example scenarios using what is known either from the representative project design envelope (RPDE), or what can be built from the New England case study, are provided to help illuminate the subject. These are only illustrations of what could be, and should not be considered as the only possibilities. Until more details are known, these scenarios should only be considered as hypothetical.

#### J.4.6.1 Build-out of One Project

*Marine Mammals Exposed*

Year 1 unmitigated results of the New England case study, as previously described, may provide the best available hypothetical example of the relative risk and aggregate exposure associated with the build-out of one project for the NY Bight. However, some limitations should be considered. The case study considered construction of 120 foundations in 1 year, and more construction activity would increase the chance of exposure.

*Exposure Time*

Based on the RPDE, a maximum of 280 foundations is anticipated for a single wind farm in the NY Bight. If pile-driving takes 4 hours per pile and one pile is driven per day, then 16.66% of a 24-hour period would have pile-driving noise occurring. If the rate increases to two piles/day, the time of pile-driving noise increases to 33.33%. It would take a minimum of 9.33 months to install 280 foundations in a one pile/day scenario, or 4.67 months with two piles/day. (As a reminder, in the case study it took 4 months or 2 months, respectively, to drive 120 piles). In either scenario, or with more piles driven per day for the same total number of foundations, construction noise would occur for 12.78% of the year. The difference is in the amount of “quiet time” per day at or near the pile-driving location, which could be an important factor for animals in the vicinity (i.e., recovery of fatigued auditory systems, offering a break from masking, etc.). If construction occurred continuously in a single year, under a one pile/day scenario, construction during periods when more animals are in the area would be unavoidable for many species, as no seasonal restrictions would be in place at the programmatic level under Alternative B.

#### *Exposure Area*

The spatial extent of behaviorally impactful noise levels under Alternative B during a single pile-driving event is anticipated to be of a similar order of magnitude as the unmitigated scenarios in the New England case study, unless mitigation were to be conducted at the project level. The unmitigated pile-driving scenario considered in Southall et al. (2021b) predicted potential effects on marine mammal behavior within 10 km of the foundation being installed. This radius would represent a potential exposure area of 314 $km^2$ (180% the smallest NY Bight lease area, i.e., 174 $km^2$; or ~62% of the largest NY Bight lease area, i.e., 510 $km^2$). Overlapping sound fields would not occur as a result of pile-driving in the build-out of one wind farm unless multiple pile-driving events were conducted at the same time.

### J.4.6.2 Build-out of Six Projects

Because so many of the construction details are unknown at the time of this programmatic acoustic assessment, there are countless ways in which six projects could be built out, and it is difficult to predict what the effect of simultaneous build-out of six wind farms would look like. As shown in the New England case study, the aggregate marine mammal exposure associated with the build-out of one wind farm versus build-out of two *was not additive* and was dependent on the site-specific density patterns of a species at the time of construction. However, BOEM does assume that the spatio-temporal exposure would be greater for six wind farms than one and would vary by species. Though the relativistic risk assessment framework would not be used at the programmatic level under Alternative B, it could be used at the project level to predict the relative exposure risk to the marine mammal species of interest by considering the species density and distribution at the construction sites at the time of year planned for construction.

The simultaneous build-out of six wind farms has the potential, albeit unlikely, for overlapping sound fields if concurrent pile-driving is pursued at two close proximity sites. It is not likely that the isopleths associated with injury or behavioral effects (NMFS 2022) associated with construction on lease areas OCS-A 0544 and OCS-A 0537 would overlap with any other NY Bight lease area due to the distance of these wind farms from the other NY Bight lease sites, which exceeds 28 km at their closest points (Figure J-6). For the other lease areas, overlapping sound fields would be unrealistic due to safety concerns between the two operations, equipment logistics, and equipment bottlenecks. However, if pile-driving were to occur simultaneously, the spacing between concurrent pile-driving would have to be within 5 km for the sound fields to add in a meaningful way that could potentially change the impact ranges.

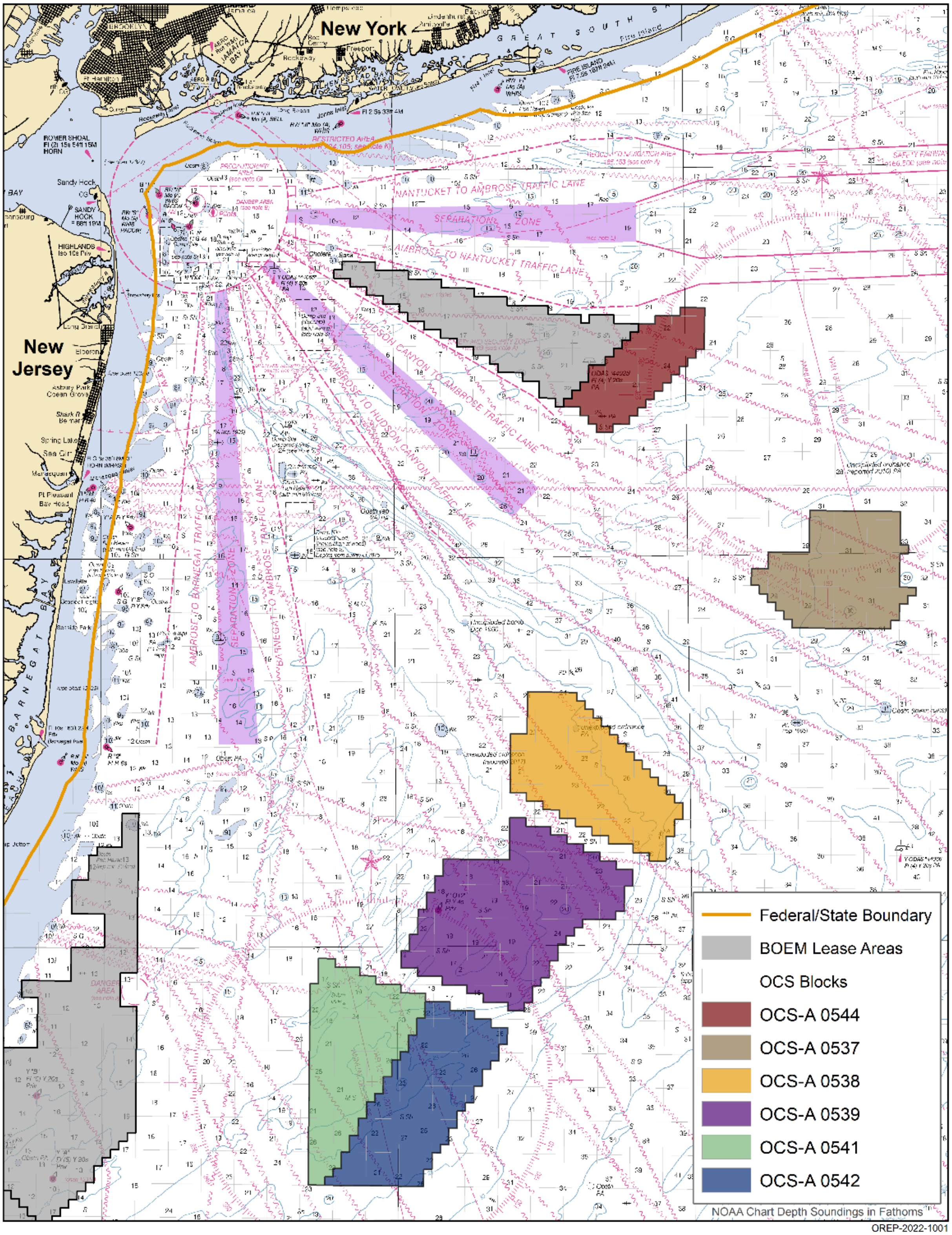


**Figure J-6. NY Bight lease areas**

### J.4.7 Identification of AMMM Measures and Recommended Practices to Reduce Noise Impacts for the NY Bight

The results and mitigative principles from the New England case study were used to inform the identification of AMMM measures and Recommended Practices (RPs) that can potentially reduce noise impacts on marine mammals in the NY Bight. These AMMM measures and RPs fall into several themes. Note that there are other noise-related AMMM measures and RPs that are not discussed further as they neither directly (e.g., reporting requirements) nor indirectly reduce acoustic impacts on marine mammals. The complete list of noise-related AMMM measures and RPs is provided in Table J-5 for reference.

#### J.4.7.1 Noise-related AMMM Measure and RP Themes

Modifications in offshore wind development activity schedules that limit temporal exposure to noise include:

- Prohibiting or minimizing construction during periods when species of the highest conservation concern (the NARW) are expected to be present in greater numbers in the region (covered under MMST-4).
- Using daytime-only pile-driving (covered under MMST-4).
- Considering increased construction effort in periods with lowest animal density to complete more of the work and shorten total construction timelines:
    - Considering night-time and low-visibility conditions and enhance monitoring (MMST-6, MMST-1).

Measures and RPs that limit the spatial extent of noise include:

- Using equipment, technology, and best practices that produce the least amount of noise practicable to avoid and minimize noise impacts on the environment (MUL-5).
- Prioritizing low noise foundations when practicable (MUL-6).
- Received Sound Level Limit (RSLL): Limiting noise levels above the injury threshold for LFC to below a fixed distance from pile-driving (MUL-22).
- Following current International Maritime Organization (IMO) Guidelines for the reduction of underwater radiated noise from vessels to the extent practicable (MUL-7).
- Using soft start for pile-driving (MUL-20).

Use of real-time and near-real time monitoring to inform adaptive mitigation measures include:

- Monitoring clearance/shutdown zones using visual observation and real-time PAM during pile-driving (covered under MMST-2, MMST-4).
- Visually monitoring clearance/shutdown zones during HRG surveys (MMST-12).
- Using real-time PAM detection of marine mammals and alert system for operators near other concentrated development activities (e.g., transit or cable-laying corridor) or between lease areas to increase overall alertness of operators and readiness to implement shut-downs as needed (MM-2).
- Conducting Sound Field Verification (SFV) at every pile at 750 m (abbreviated “SFV”). “Thorough SFV” monitoring (defined as recording along a minimum of two radials with at least one radial containing recorders at three or more distances) must be conducted for the first three foundations of a project, and the first installation represented by each modeling scenario used. If levels measured in any SFV (Thorough or Abbreviated) imply the exceedance of agency-identified ranges to regulatory thresholds, the lessee must take mitigative actions in consultation with the federal permitting agencies. The lessee must submit an SFV plan for review, which, among other things, should include approximations of the expected variation of key parameters (e.g., difficulty to drive, predicted number of necessary strikes, foundation type, pile size, installation method, hammer energy rating, water depth, seabed composition, and season) across the project and an estimate of how many thorough monitoring locations will be required to cover this variability (MUL-29).
- Using sound field measurements to verify or adjust monitored impact zones and protected species observer (PSO) coverage (MMST-3, MMST-5).

Collection of baseline information to better anticipate potential impacts and further mitigate effects on marine mammals in the future includes:

- Conducting long-term PAM or contribute to a research fund to support PAM on the lease area for 1 year before construction through at least 3 years but no more than 10 years of operations (MM-3).
- Archiving SFV data (MUL-29).

A final point to make about the identification of AMMM measures and RPs is that the NARW is the species of greatest concern. Therefore, many AMMM measures and RPs are designed specifically in consideration of the NARW and, in certain circumstances, may increase risk to other species (e.g., seasonal construction window). In other instances, AMMM measures and RPs provide similar benefits to other species. Table J-5 lists the noise-related AMMM measures and RPs for the NY Bight; for the full details of each measure, see Appendix G, *Mitigation and Monitoring*, of the PEIS.

**Table J-5. Noise AMMM measures and RPs for the NY Bight**

| Measure ID | Measure | Discussed in this Analysis | AMMM or RP | Previously Applied? |
|---|---|---|---|---|
| MM-1 | Reporting of all NARW detections | -- | AMMM | Yes |
| MM-2 | Real-time PAM monitoring and alert system for baleen whales | Yes | RP | -- |
| MM-3 | Long-term PAM monitoring | Yes | AMMM | Yes |
| MMST-1 | Reduced Visibility Monitoring Plan/Nighttime Pile Driving Monitoring Plan | Yes | AMMM | Yes |
| MMST-2 | Marine Mammal and Sea Turtle Monitoring Plan for Pile-Driving | Yes | AMMM | Yes |
| MMST-3 | Pile-driving clearance and shutdown zone adjustments | Yes | AMMM | Yes |
| MMST-4 | Establishment of foundation pile-driving measures | Yes | AMMM | Yes |
| MMST-5 | PSO coverage of expanded pile-driving clearance/shutdown zones | Yes | AMMM | Yes |
| MMST-6 | Pile-driving visibility requirements | Yes | AMMM | Yes |
| MMST-7 | PSO coverage and training requirements for pile-driving | -- | AMMM | Yes |
| MMST-10 | Reporting of ESA-Listed Species within Shutdown Zone During Active Pile Driving | -- | AMMM | Yes |
| MMST-12 | Marine mammal and sea turtle geophysical survey clearance and shutdown zones and mitigations | Yes | AMMM | Yes |
| MUL-5 | Low noise best practices | Yes | RP | -- |
| MUL-6 | Low noise foundations | Yes | RP | -- |
| MUL-7 | Vessel noise reduction guidelines | Yes | RP | -- |
| MUL-20 | Soft start for impact pile-driving | Yes | AMMM | Yes |
| MUL-22 | Received Sound Level Limit (RSLL) | Yes | AMMM | No |
| MUL-29 | Sound Field Verification (SFV) Process, Plan and Reporting | Yes | AMMM | Yes |
| MUL-32 | Weekly, monthly, and final PSO reporting requirements (including foundation pile-driving) | -- | AMMM | Yes |
| MUL-34 | Detected or impacted protected species reporting | -- | AMMM | Yes |

### J.4.8 Discussion of Acoustic Impacts Under Alternative C

Under Alternative C there are two sub-alternatives:

- Sub-alternative C1 (Preferred Alternative), Previously Applied AMMM Measures.
- Sub-alternative C2, Previously Applied and Not Previously Applied AMMM Measures.

In addition to the AMMM measures identified under each sub-alternative, BOEM is recommending lessees consider analyzing the RPs in Table G-2 in Appendix G. For completeness, the acoustic impacts associated with the implementation of the RPs are also discussed here.

Under both sub-alternatives, pile-driving would be expected to contribute the greatest to potential effects on marine mammals associated with noise. However, there are several ways it would differ from Alternative B due to the AMMM measures. With the AMMM measures in Sub-alternative C1 or Sub-alternative C2, the spatial extent of noise associated with pile-driving in the NY Bight would be reduced with respect to Alternative B. In addition, the temporal overlap of construction activities with times when the NARW are present would be avoided to the extent possible. Procedures would be in place such that if animals came into the area in which noise effects may occur, the area would be monitored both visually and acoustically such that any marine mammal in the area should be detected. Procedures would be in place such that if an animal was detected pile-driving would stop, if safe to do so, until the animal(s) left the area. These issues and any differences between Sub-alternative C1 and C2 are further discussed in the sections that follow.

### J.4.8.1 Impacts of Noise AMMM Measures

*Exposure Time*

Under both Sub-alternative C1 and Sub-alternative C2, there are four ways in which exposure time is reduced. These are related to the timing of pile-driving activity: (1) a seasonal restriction on pile-driving between January 1 and April 30 (covered under MMST-4), (2) a time-of-day restriction to daylight hours (covered under MMST-4), (3) a requirement for an alternative monitoring plan if construction were to occur outside daylight hours (MMST-1), and (4) low visibility condition requirements for pile-driving (MMST-6). With the implementation of a seasonal construction restriction, pile-driving would not be allowed to occur during periods when the NARW have historically been present in relatively higher numbers in the NY Bight/southern New England ecoregion (i.e., January 1–April 30) and further would not be allowed to occur in December unless a developer requests and is approved to do so. Exposure to pile-driving for the NARW would be minimized due to this seasonal restriction. This seasonal restriction would likely benefit other species with a similar phenology, or seasonal occurrence, as the NARW, such as harbor porpoise and seals. However, it may be less beneficial to species that may be present in higher numbers when construction is allowed, such as humpback whales, dolphins (Figure J-5), and other species not examined as part of this work. The benefit of a time-of-day restriction is that observers can visually monitor the area around pile-driving activity for marine mammals reliably. With additional low visibility and night-time monitoring requirements, enhanced monitoring (such as the use of technology to aid or supplement visual monitoring) would increase the likelihood of detecting marine life in the area. If pile-driving occurs only in daylight hours, this effectively means there is a period of time, i.e., during the night, when no pile-driving noise is produced. This measure may provide periods of time when animals that are present could recover from auditory fatigue or use the area in ways that they were unable to when construction noise was present. One advantage of pile-driving at any time of the day is that construction could be condensed to periods when animals are not present or in low abundance, effectively reducing the time that construction would occur when animals are present or in higher abundance. The risk assessment framework provides a tool for exploring such scenarios, as the value of either approach will depend on the specific context under consideration (i.e., species of interest, construction location, etc.). Additional modifications could also be made to fine-tune the construction window and further reduce potential exposure to the NARW and other species of interest by using the relative risk assessment framework.

### *Exposure Area*

There are four identified AMMM measures and RPs related to the spatial extent of noise exposure: (1) use of low noise foundations and/or the best available quieting technology (MUL-6); (2) received sound level limit to keep noise levels that exceed the injury threshold for LFC to within a fixed distance from a foundation (MUL-22); (3) adherence to the IMO Guidelines for vessel quieting, where practicable (MUL-7); and (4) soft start for pile-driving (MUL-20).

With MUL-6, the spatial extent of noise associated with pile-driving could be reduced with the use of foundation types other than impact-pile-driven monopiles, such as gravity-base, suction buckets, and other designs that do not require pile-driving. There are different noises associated with the installation of other foundation types; however, they are generally not as loud or as impulsive as impact pile-driving. If the use of non-pile-driving foundations was not possible, the best available quieting technology should be applied. The New England case study simulated the effect of noise mitigation technology on impact pile-driving by reducing the behavioral effect ranges from 20 km and 10 km to 15 km and 5 km for harbor porpoise and other marine mammals, respectively. This reduction is a reasonable expectation of the order of magnitude that noise mitigation could help to reduce the spatial exposure extent of noise under Alternative C. Adherence to the IMO Guidelines on vessel quieting may lead to decreases in vessel noise, which would decrease the risk of masking associated with vessel noise to marine mammals in the area. A final AMMM measure that may have benefits to marine life is the requirement for a soft start during pile-driving (MUL-20). The purpose of this AMMM measure is to capitalize on a potential avoidance response of some marine life by requiring that pile-driving begin at reduced power and strike rate (i.e., fewer strikes per time period) to elicit an avoidance response of any animals in the area before the sound reaches potentially impactful levels. There is no clear evidence for the effectiveness of this mitigation.

In addition to the previously mentioned measures, Sub-alternative C2 would require a received sound level limit (MUL-22). MUL-22 would further limit the spatial extent of sound exposure around impact pile-driving. This AMMM measure was designed to ensure that injurious sound levels to LFC may only occur within a short and fixed distance from the pile-driving source such that the area can be sufficiently monitored for marine mammals. Although this AMMM measure would likely result in decreased noise exposure to all species, it prioritizes LFC. Therefore, it may have greater benefits to those species in comparison to others if, for example, the target was achieved by focusing only on a reduction of the lowest frequencies of pile-driving sound. Reaching the RSLL could be achieved in several ways, including the application of various noise mitigations or the installation of low noise foundations.

### *Other Potential Reductions in Impacts on Marine Mammals*

Several of the other AMMM measures in place in Sub-alternatives C1 and C2 provide opportunities to detect marine mammals or sea turtles during construction and other development activity. With increased opportunities to detect marine mammals, there would be more opportunities to mitigate potential impacts should they arise.

For example, clearance and exclusion zones would be monitored visually and acoustically with real-time PAM during pile-driving (covered under MMST-2, MMST-4). If a marine mammal is detected in those zones, procedures would be triggered to cease pile-driving, to the extent practicable, thereby avoiding a potential exposure that could cause injury or behavioral disturbance to an animal. Clearance and exclusion zones also would be visually monitored during HRG surveys for marine mammals and sea turtles, allowing for a potential exposure to be avoided by shutting down the activity should a marine mammal be present (MMST-12).

Several other monitoring AMMM measures and RPs could directly or indirectly lead to reduced impacts on marine mammals by updating our baseline understanding of marine mammals and potential noise impacts. For example, through long-term PAM monitoring (MM-3), information about marine mammal presence, density, and phenology can be obtained, which can be used to update AMMM measures like the seasonal restrictions. However, under MM-3, data is likely to be collected on a yearly basis, and it is unclear how quickly, or even if, that information could be incorporated into the same project from which the data was collected. The data collected during sound field verification (MUL-29) may be used to adjust a project's shutdown, clearance, and monitoring zones if the sound field differs from what was authorized (MMST-3). In addition, sound field data may also be archived to inform the development of AMMM measures for subsequent projects.

Sound field verification AMMM measures (MUL-29) would not directly change the impact of noise on marine mammals, but the information collected during sound field verification would inform regulators whether the sound produced is within the allowable limits. If not, two AMMM measures (MMST-3 and MMST-5) are in place to ensure adequate monitoring of the area for marine mammals should they be present during construction. MMST-3 would allow for the adjustment of the monitored impact zones based on the sound field measurements, and MMST-5 would modify the number of visual observers based on the adjusted monitoring impact zones. These measures would ensure that any assumptions made in setting up the initial monitoring zones are met, and, if not, modifications are made to ensure adequate monitoring for marine mammals.

If MM-2 (RP) was implemented, real-time PAM would be conducted near any other concentrated development activities, such as laying cables or near a designated transit corridor. Any detections would be communicated to operators on the water. Although this measure would lead to increased opportunities to detect marine mammals in the area and increase operator vigilance of their presence, there is no mitigation directly tied to this AMMM measure. Therefore, any benefits would be indirect, such as if a vessel operator was able to use the detection to identify a marine mammal that it might otherwise have not visually observed. In this case, other AMMM measures are in place that would require the operator to avoid the marine mammal.

The preceding discussion applies to the build-out of one or six projects. The sections that follow provide additional information specifically about these build-outs. However, without an understanding of many of the construction specifics of the NY Bight projects, it is difficult to predict the spatio-temporal impact of the build-out of one or six projects. Consequently, the discussions that follow are only illustrations of potential impacts and should not be considered as the only possibilities. Until more details are known, these should only be considered as hypothetical.

### J.4.8.2 Build-out of One Project

#### *Exposure Area*

Under RP MUL-5, operators are encouraged to use equipment, technology, and best practices that produce the least amount of noise practicable to avoid and minimize noise impacts on the environment. With the implementation of noise mitigation technology, a project would reduce the area exposed to noise. For example, under the mitigated pile-driving scenarios in the New England case study, the behavioral impact radius was 5 km, or a 79-$km^2$ area, around a pile during a single impact pile-driving event. This dimension would equate to an area 45.4% of the size of the smallest NY Bight lease area (i.e., 174 $km^2$) or 15.5% of the size of the largest NY Bight lease area (i.e., 510 $km^2$).

With MUL-22, a physical distance limit to injurious sound levels to LFC would be in place. A received level limit at 1 km around a pile would equate to an area 3.14 $km^2$ (i.e., 1.8% the smallest NY Bight lease area or 0.62% of the largest NY Bight lease area) ensonified by noise exceeding the LFC acoustic injury threshold.

### J.4.8.3 Build-out of Six Projects

#### *Exposure Area*

Under Alternative C, if pile-driving occurred on a single lease site at a time, the space exposed during pile-driving would not differ from the build-out of one project. If pile-driving occurred simultaneously on each of the six leases with no overlapping spatial exposure and RP MUL-5 is implemented with the use of noise mitigating technology, a reduced area of exposure—as in the New England case study—could be achieved. As an example from the case study, a 5-km radius of exposure around each pile-driving event for potentially behavioral impactful sound levels would equate to an area equivalent to 471 $km^2$ (or 24% of the total leased NY Bight area). Under Sub-alternative C2. MUL-22 and a 1-km radius for injury levels for LFC would equate to an 18-$km^2$ (or 0.95% of the total leased NY Bight area) area exposed to potentially behavioral impactful sound levels.

### J.4.8.4 Conclusion

The AMMM measures and RPs identified in this analysis serve key functions in reducing noise impacts. The AMMM measures focused on reducing the spatio-temporal overlap of noise with marine life may have the greatest potential to reduce impacts. However, these AMMM measures and RPs are built on a foundation of knowledge that would not be possible without continued environmental monitoring to understand where and when animals are present and to characterize the sound fields associated with noise-generating activities. Therefore, the monitoring AMMM measures and RPs are also critical in ensuring that the spatio-temporal AMMM measures are most effective and are based on the best available and current information.

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