Petition for Incidental Take Regulations for the Construction and Operation of the Revolution Wind Offshore Wind Farm

Submitted To:

National Marine Fisheries Service
Office of Protected Resources
Silver Spring, MD

Submitted By

Revolution Wind, LLC

Revolution Wind | Powered by Ørsted & Eversource

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CONTAINS CONFIDENTIAL BUSINESS INFORMATION

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1 Description of Specified Activity

Revolution Wind, LLC (Revolution Wind) (formerly DWW Rev I, LLC), a 50/50 joint venture between Orsted North America Inc. and Eversource Investment, LLC, proposes to construct and operate the Revolution Wind Farm Project (hereinafter referred to as the Project). The purpose of the Project is to provide clean, reliable offshore wind energy that will increase the amount and availability of renewable energy to New England consumers while creating the opportunity to displace electricity generated by fossil fuel-powered plants and offering substantial economic and environmental benefits to the New England region. Massachusetts, Rhode Island, Connecticut, and New York have adopted substantial renewable portfolio standards and clean energy targets to address issues associated with climate change, highlighting the current and future demand for this Project. In response to this expressed need and demand, Rhode Island and Connecticut have awarded Revolution Wind five Power Purchase Agreements (PPAs) to date, totaling 704 MW of generation capacity. The Project will fulfill Revolution Wind's obligations to both Connecticut and Rhode Island in accordance with the PPAs and provide substantial environmental and economic benefits.

The Project is defined within the Revolution Wind Construction and Operations Plan (Revolution-Wind 2021) using a Project Design Envelope (PDE) approach. The PDE defines "a reasonable range of project designs" associated with various components of a project (e.g., foundation and WTG options) (BOEM 2018). The PDE for the Project is based on a maximum operating capacity ranging between 704 and 880 megawatts (MW) and includes the following primary assumptions: up to 100 wind turbine generators (WTGs) connected by a network of Inter-Array Cables measuring up to 155 miles (mi) (250 kilometers [km]) in total length; up to two Offshore Substations (OSS), connected by an up to 9 mi (15 km) long OSS-Link Cable; up to two export cables (i.e., the RWEC) measuring up to 50 mi (80 km) in length; up to two underground transmission circuits (referred to as the Onshore Transmission Cable) located onshore and measuring up to 1 mi (1.6 km); and a new Onshore Substation and Interconnection Facility (ICF) and associated interconnection circuits.

The wind farm portion of the Project will be located in federal waters on the Outer Continental Shelf (OCS) in the designated Bureau of Ocean Energy Management (BOEM) Renewable Energy Lease Area OCS-A 0486 (Lease Area) (Figure 1). Based on stakeholder feedback, Revolution Wind is committed to a Project layout with WTGs situated in an approximate 1.15 mi (1 nm, 1.8 km) by 1.15 mi (1 nm, 1.8 km) grid, aligned with layouts proposed for other projects in the Rhode Island/Massachusetts Wind Energy Area (RI-MA WEA) and Massachusetts Wind Energy Area (MA WEA). The RWEC will make landfall at Quonset Point in North Kingstown, Rhode Island and will interconnect to the existing electric transmission system via the Davisville Substation, which is owned and operated by The Narragansett Electric Company (TNEC), located in North Kingstown, Rhode Island. Figure 2 depicts the conceptual arrangement of offshore and onshore Project components.

For the purposes of analyzing potential take of marine mammals as a result of construction and operations activities, the project has been split into five (5) primary elements including: WTG monopile foundations, OSS monopile foundations, cable landfall construction, high resolution geophysical (HRG) surveys, and potential munitions explosives of concern (MEC)/unexploded ordnance (UXO) detonations.

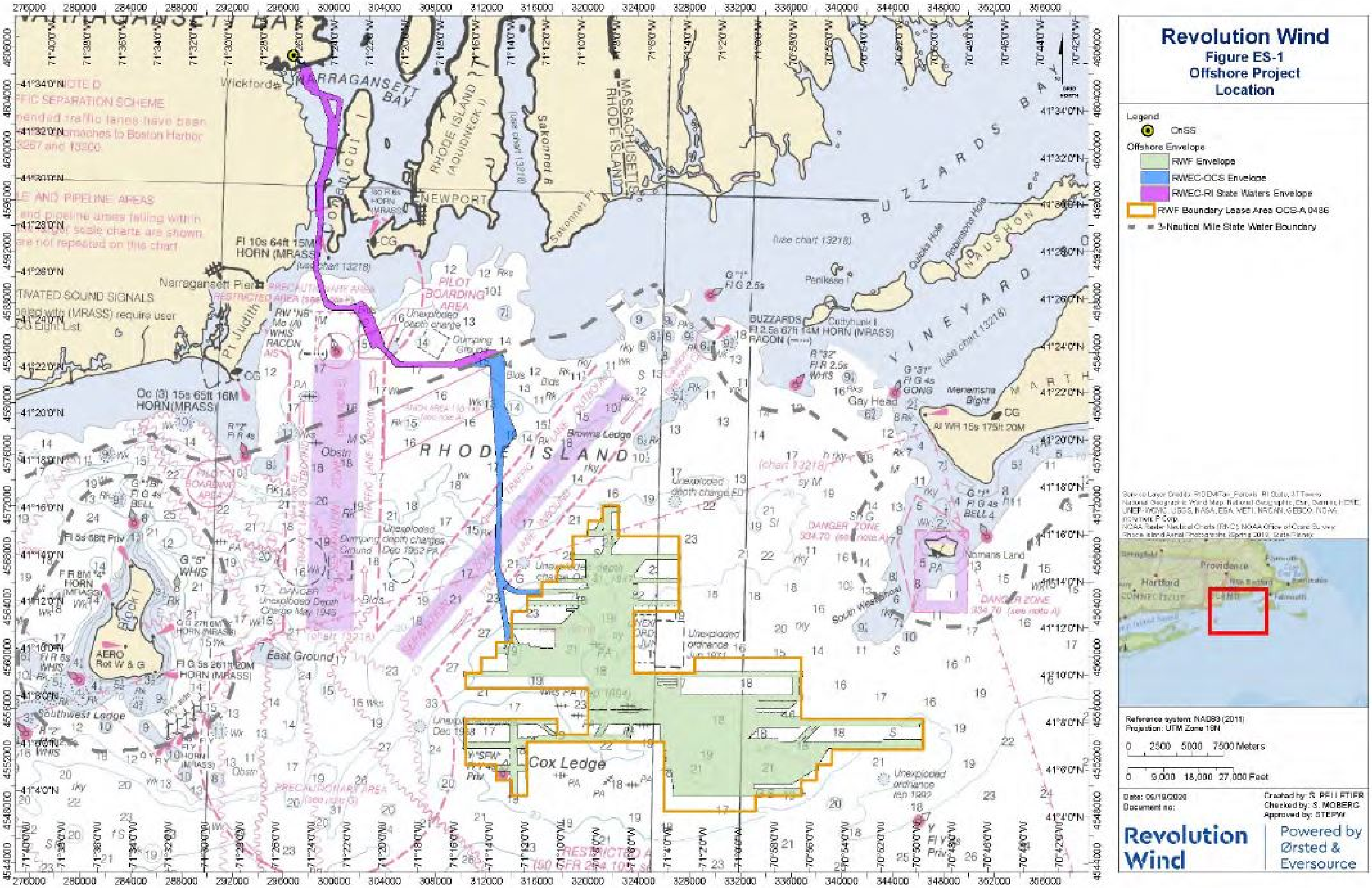

Figure 1. Location of the RWF within Lease Area OCS-A 0486 and the RWEC (Revolution-Wind 2021).

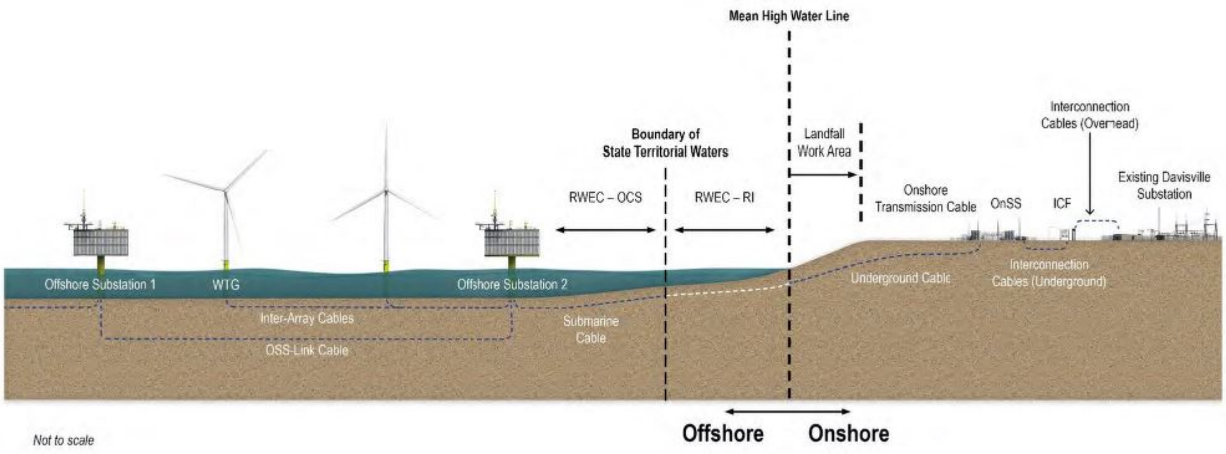

Figure 2. Onshore and offshore project components (reproduced from COP Figure 1.1-2) (Revolution-Wind 2021).

1.1 Offshore Project Components and Construction Activities

The Project's key offshore components are described in detail in Section 3.3.3 and 3.3.4 of Volume I of the COP (Revolution-Wind 2021). These include components within the RWF (WTG and OSS Foundations) and the RWEC. Revolution Wind has evaluated all Project activities for potential acoustic harassment as required under 50 CFR §216.104 governing the submission of requests for incidental taking of small numbers of marine mammals. Construction of the RWF and RWEC will include WTG monopile foundation installation, OSS monopile foundation installation, cable landfall construction, HRG surveys, potential in-situ MEC/UXO disposal, and construction vessel activity including during inter-array cable and RWEC installation.

1.1.1 *WTG Monopile Foundation Installation*

Figure 3 provides a conceptual example of the WTG support structures (i.e., towers and foundations) which will be designed to withstand 500-year hurricane wind and wave conditions, and the external platform level will be designed above the 1,000-year wave scenario. A WTG monopile foundation typically consists of a single steel tubular section, with several sections of rolled steel plate welded together. A transition piece (TP) may be fitted over the top of the monopile and secured via a bolted connection. Secondary structures on each WTG monopile foundation will include a boat landing or alternative means of safe access (e.g., Get Up Safe – a motion compensated hoist system allowing vessel to foundation personnel transfers without a boat landing), ladders, a crane, and other ancillary components. The TP may either be installed separately following the monopile installation or the monopile and TP may be fabricated and installed as an integrated single component. If the monopile and TP are fabricated and installed as an integrated component, the secondary structures will be installed on the TP subsequently and in separate smaller operations. The TP will be painted yellow and marked according to USCG requirements.

Up to 100 WTG monopile foundations with a maximum diameter of 12 m (39 ft) will be installed in the Lease Area. Monopiles will be installed using an impact pile driver with a maximum hammer energy of 4,000 kJ to a maximum penetration depth of 40 m (131 ft). Installation of each monopile will include a 20-minute soft start or ramp-up where lower hammer energy is used at the beginning of each pile segment during pile driving activity to provide additional protection to mobile species (e.g., whales, dolphins, porpoises) in the vicinity by allowing them to vacate the area prior to the commencement of pile driving activities. Under normal conditions, after completion of the 20-minute soft start period, installation of a single monopile foundation is estimated to require 1-4 hours (12 hours maximum). It is anticipated that a maximum of three (3) monopile foundations can be driven into the seabed per day assuming 24-hour pile driving operation[1].

To be able to install WTG and OSS monopile foundations, impact pile driving 24-hours per day is deemed necessary by taking into account the amount of time required to install the foundations in comparison to the time available for installation when factoring in various limitations. Under ideal conditions and consistent with the assumption that up to three foundations could be installed in a single day (24-hour period including nighttime), installation of a single pile at a minimum would involve a 1-hour pre-clearance period, 4 hours of piling, and 4 hours to move to the next piling location where the process would begin again. This results in an estimated 9 hours of installation time per pile, or 918 total hours for 100 WTG foundations and 2 OSS foundations assuming ideal conditions for all installations.

If pile driving were only allowed from sunrise to sunset, and no pile driving was conducted from January 1 through April 30, then approximately 2,940 hours would initially be available for pile driving (this assumes an average of 12 hours of daylight per day for 245 days). Based on prior experience it is reasonable to assume that approximately 30% of the time would be unavailable due to weather conditions, bringing the available time down to 2,058 hours and leaving a buffer of approximately 1,100 hours between the minimum time required to install the foundations and the time available. However, many other factors are anticipated to further reduce the time available for installations. For example, delays are likely due to the presence of protected species, equipment downtime and/or supply chain issues in receiving materials, commercial fishing, and other marine activity in the area. Other project operations that must occur during good weather conditions such as vessel-to-vessel transfers of crew, equipment, and materials are all likely to prohibit piling during otherwise available daylight hours. COVID-19 has introduced new challenges, increases the potential for in-season project delays, and highlights the schedule risks associated with heath concerns. Although not quantifiable at this time, the combined effect of these unforeseeable factors will further reduce the available time for piling to a point where there is an insufficient buffer between the time required for installations and the time available for installations within a single operational season should piling only be allowed during daylight hours.

To complete installation within a single season and should pile driving be limited to daylight hours, operations would need to be conducted in the currently excluded January-April timeframe to create a sufficient buffer between required installation time and available installation time. Since the January to April timeframe is when NARW are present in the region in higher numbers, the potential impacts to this species would increase. Alternatively, if the installations were to occur within the same May–December period during daylight only but extend across multiple seasons, there would be an overall increase in vessel traffic, which could also increase potential impacts to NARW and other marine mammals. For these reasons, the ability to conduct nighttime impact pile driving of monopile foundations during time

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[1] In support of the request for nighttime piling, Ørsted is assessing the opportunity to conduct a marine mammal monitoring field demonstration project in the spring of 2022. Additional details on the project and further engagement will follow.

periods when the fewest number of NARW are likely to be present in the region is expected to result in the lowest overall impact of the project on marine mammals, including NARW.

Should nighttime pile driving occur, the best currently available technology will be used to mitigate the potential impacts and result in the least practicable adverse impacts. These monitoring methods will include the use of night vision equipment and infrared/thermal imaging. Night vision equipment and infrared/thermal imaging have been shown to allow for the detection of marine mammals at night at a similar probability of detecting marine mammals during daylight visual monitoring (Verfuss et al. 2018; Guazzo et al. 2019).

One or more noise abatement systems (NAS), such as a bubble curtain, evacuated sleeve system, encapsulated bubble system (HydroSound Dampers), or Helmholtz resonators (AdBm) will be used during WTG and OSS foundations installations to reduce sounds propagated into the marine environment. Several recent studies summarizing the effectiveness of NAS have shown that broadband sound levels are likely to be reduced by anywhere from 7 to 17 dB, depending on the environment, pile size, and the size, configuration and number of systems used (Buehler et al. 2015; Bellmann et al. 2020a). The type and number of NAS to be used during construction have not yet been determined but at a minimum will consist of a double big bubble curtain or a single bubble curtain paired with an additional sound attenuation device. Based on prior measurements this combination of NAS is reasonably expected to achieve at least 10 dB broadband attenuation of impact pile driving sounds (described further in Section 6.3.2).

A typical monopile installation sequence begins with the monopiles transported directly to the Lease Area for installation or to the construction staging port by an installation vessel or a feeding barge. At the foundation location, the main installation vessel upends the monopile in a vertical position in the pile gripper mounted on the side of the vessel. The 4,000-kJ hydraulic hammer is then lifted on top of the pile to commence pile driving with a soft start. Piles are driven until the target embedment depth is met (40 m), then the pile hammer is removed and the monopile is released from the pile gripper. Once the monopile is installed to the target depth, the TP or separate secondary structures will be lifted over the pile by the installation vessel. If used, the TP will be bolted to the monopile. Once installation of the monopile and TP is complete, the vessel moves to the next installation location.

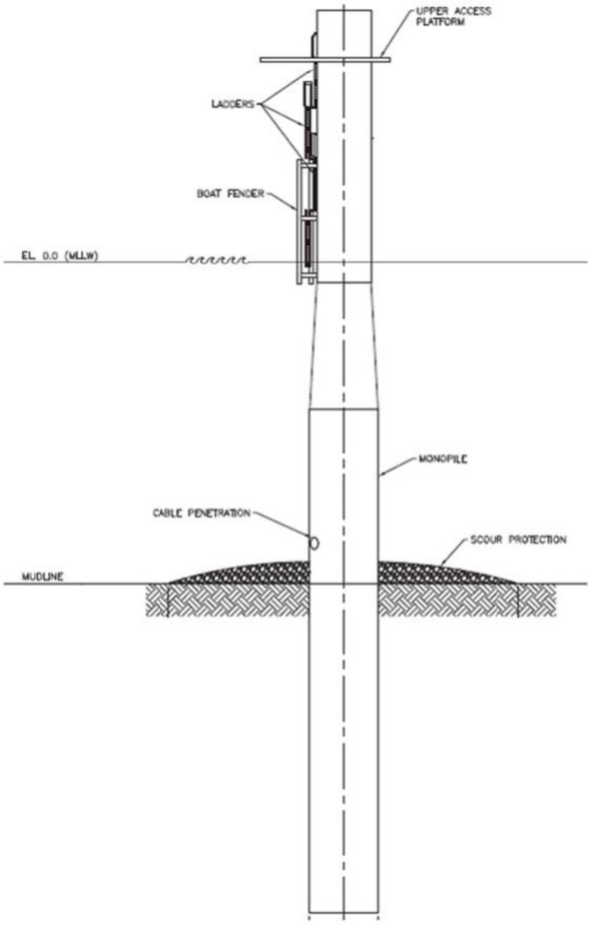

Figure 3. Schematic drawing of a WTG monopile foundation (reproduced from COP Figure 3.3.4-1) (Revolution-Wind 2021).

1.1.2 *OSS Monopile Foundation Installation*

Two OSS monopile foundations will be constructed to support the two OSSs. Pile driving noise from the OSS foundation installation has been evaluated based on the use of a 4,000-kJ hammer for monopile foundations as this is representative of the worst-case condition as it relates to maximum noise levels (Appendix A).

The OSS monopile foundations will be similar to the WTG monopile foundations. However, OSS monopile foundations will be larger in diameter (15 m) and will include a Module Support Frame between monopile and the Topside (Figure 4). Two monopiles with a maximum diameter of 15 m will be installed using an impact pile driver with a maximum hammer energy of 4,000 kJ. The target penetration depth will be 50 m. Installation of a single monopile foundation is estimated to normally require 1-4 hours (12 hours maximum for a single monopile) of pile driving including the 20-minute soft start period.

The installation sequence for OSS foundation installation using monopiles will follow the same sequence as the monopile installation outlined above for the WTG monopile foundation installation.

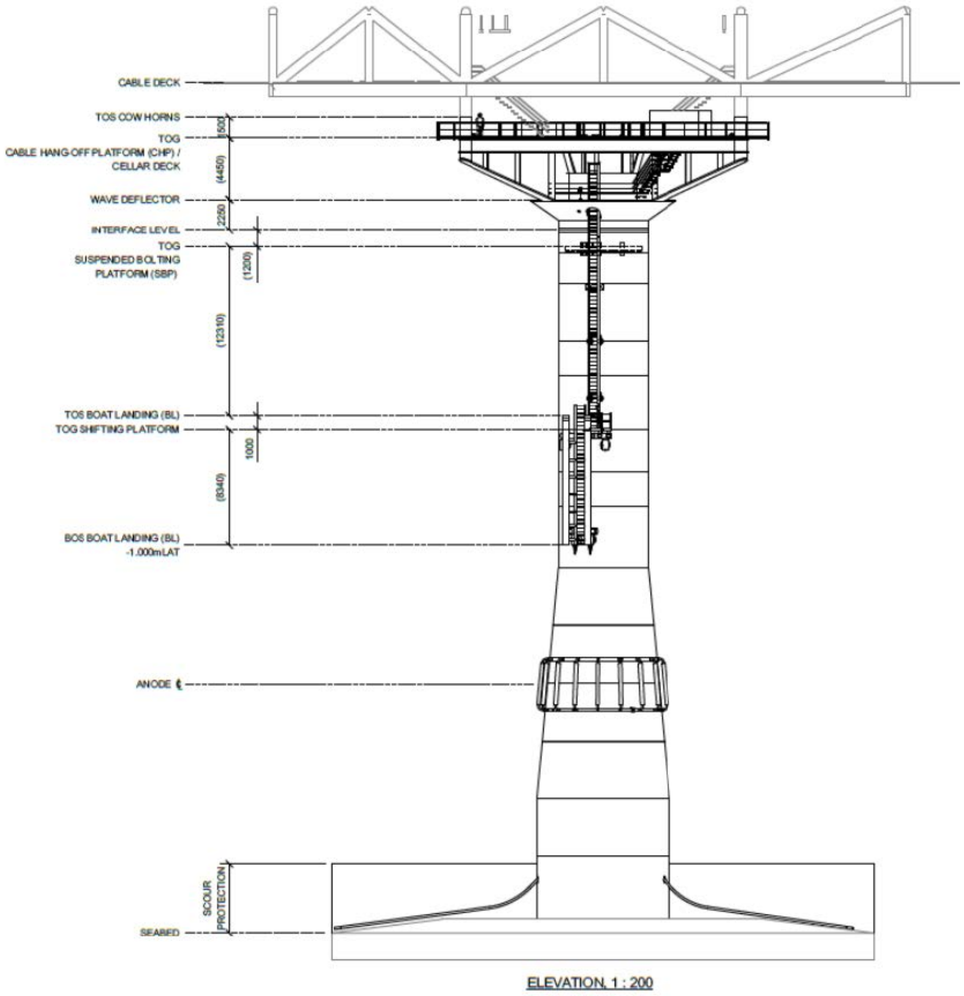

Figure 4. Example monopile OSS foundation concept, including module support frame (reproduced from COP Figure 3.3.4-2) (Revolution-Wind 2021).

1.1.3 *Cable Landfall Construction*

Installation of the RWEC landfall will be accomplished using a horizontal directional drilling (HDD) methodology. The drilling equipment will be located onshore and used to create a borehole, one for each cable, from shore to an exit point on the seafloor approximately 250 m (800 ft) offshore. At the seaward exit site for each borehole, construction activities may include the temporary installation of a casing pipe, supported by sheet pile “goal posts”, to collect drilling mud from the borehole exit point. Alternatively, a temporary cofferdam may be installed to create a dry environment from which drilling mud could be collected. Only one of these two installation methods would be used, not both.

Installation of casing pipe would be completed using pneumatic pipe ramming equipment while installation of sheet pile for goal posts or a cofferdam would be completed using a vibratory pile driving hammer. Installation of casing pipe using a pneumatic pipe ramming tool and installation of a sheet pile using a vibratory pile driving hammer would not occur simultaneously as some of the same equipment on the barge is necessary to conduct both types of installations. All installation activities would occur during daylight periods.

The casing pipe would be installed at a slight upward angle relative to the seabed so that the casing pipe creates a straight alignment between the point of penetration at the seabed and the construction barge. Casing pipe installation would occur from the construction barge and be accomplished using a pneumatic pipe ramming tool (Gundoram Taurus or similar) with a hammer energy of up to 18 kJ. If necessary, additional sections of casing pipe may be welded together on the barge to extend the length of the casing pipe from the barge to the penetration depth in the seabed. Each casing pipe would require up to 2 days of pneumatic hammering to install which may be spread out over up to 8 days for each pipe, depending on the number of pauses required to weld additional sections onto the casing pipe. Thus, installation of casing pipes for both cables may require pneumatic hammering for a total of 4 days. Removal of the casing pipe would also involve the use of a pneumatic pipe ramming tool, but the pipe would be pulled out of the seabed while hammering was occurring instead of pushed into it. The same total of 4 days of pneumatic hammering may be required for removal.

Up to six goal posts may be installed to support the casing pipe between the barge and the penetration point on the seabed. Each goal post would be composed of 2 vertical sheet piles installed using a vibratory hammer such as an American Piledriving Equipment (APE) model 300 (or similar). A horizontal cross beam connecting the two sheet piles would then be installed to provide support to the casing pipe. Up to 10 additional sheet piles may be installed per borehole to help anchor the barge and support the construction activities. This results in a total of up to 22 sheet piles per borehole and two boreholes bringing the overall total to 44 sheet piles. Sheet piles used for the goal posts and supports would be up to 30 m (100 ft) long, 0.6 m (2 ft) wide, and 1 inch thick. Installation of the goal posts would require up to 6 days per borehole, or up to 12 days total for both boreholes. Removal of the goal posts would also involve the use of a vibratory hammer and likely require approximately the same amount of time as installation (12 days total for both boreholes). Thus, use of a vibratory pile driver to install and remove sheet piles may occur on up to 24 days at the landfall location. Installation of the RWEC landfall will be subject to Rhode Island state time of year restrictions. All landfall activities will be conducted within this allocated timeframe.

As an alternative to the casing pipe and goal post method described above, a cofferdam may be installed to allow for a dry environment during construction and manage sediment, contaminated soil, and bentonite (drilling mud used during HDD operations). If required, the cofferdam may be installed as either a sheet piled structure into the sea floor or a gravity cell structure placed on the sea floor using ballast weight and will be constructed from an offshore work barge anchored at the site. The cofferdam could measure up to 50 m x 10 m x 3 m (164 ft x 33 ft x 10 ft). If a gravity cell structure was used as a cofferdam, the structure would be fabricated onshore, transported to the site on a barge, and then lifted off the barge and placed on the seafloor using a crane. This process would not involve pile driving or other underwater sound producing activities so is not carried forward in this application.

If a cofferdam is installed using sheet piles, a vibratory hammer such as an APE model 200T (or similar) would be used to drive sheet piles of up to 30 m (100 ft) long, 0.6 m (2 ft) wide, and 1 inch thick. The sidewalls and endwall will be driven to a depth of up to 30 ft (9.1 m); sections of the shoreside endwall will be driven to a depth of up to 6 ft (1.8 m) to facilitate the borehole entering underneath the endwall. Installation of a sheet pile cofferdam may take up to 14 days. After the sheet piles are installed, the inside of the cofferdam will be excavated to approximately 10 ft (3 m). After HDD operations are complete and the cable installed, the cofferdam would be removed over the course of up to 14 days. Separate cofferdams would be installed and removed for each of the two cables, so vibratory pile driving may occur on up to 56 days at the landfall location.

For take assessment purposes, the cofferdam scenario is assessed in Section 6.4 of this application as the most conservative installation method. This is because more Level B take would be requested from the use of cofferdams than from casing pipes with goal post supports as summarized here and explained in greater detail in Section 6.4. Vibratory pile driving is expected to have a Level B threshold distance of approximately 10 km while impact hammering (with a pneumatic pipe ramming tool) of casing pipe would have a Level B distance of approximately 0.92 km. The cofferdam scenario would require up to 56 days of vibratory pile driving for installation and removal, while the casing pipe scenario would require up to 24 days of vibratory pile driving plus 8 days of impact pile driving (with a pneumatic pipe ramming tool). The larger number of total days of pile driving in the cofferdam scenario, and the fact that all of those days would involve the larger Level B zone from vibratory pile driving means the anticipated Level B take from the cofferdam scenario would be higher, and is therefore carried forward as the more conservative assumption.

In terms of potential Level A take, the acoustic ranges to $\mathrm{SEL_{cum}}$ thresholds from vibratory pile driving are expected to be less than 10 m for low-frequency (LF), mid-frequency (MF), and phocid pinniped (PP) hearing groups and 190 m for the high-frequency hearing group. Vibratory pile driving would not generate sounds above $\mathrm{SPL_{pk}}$ thresholds. The acoustic ranges to $\mathrm{SEL_{cum}}$ thresholds from impact pile driving (pneumatic hammering) of the casing pipe are estimated to be the following: LF = 3.87 km, MF = 0.23 km, HF = 3.95 km, and PP = 1.29 km. $\mathrm{SPL_{pk}}$ thresholds are not expected to be generated by pneumatic hammering. The estimated distances to Level A $\mathrm{SEL_{cum}}$ thresholds are larger than the Level B SPL thresholds. This is due to the high strike rate of the pneumatic hammer resulting in a high number of strikes per day. However, LF cetaceans are unlikely to occur close to this nearshore site and individuals of any species are not expected to remain within the estimated $\mathrm{SEL_{cum}}$ threshold distances for the entire 3-hour duration of piling in a day. With the implementation of planned monitoring and mitigation (see Section 11 and Appendix A), no Level A takes are anticipated.

1.1.4 *High Resolution Geophysical (HRG) Surveys*

HRG surveys will be conducted intermittently during the construction period to identify any seabed debris. These surveys may utilize equipment such as multi-beam echosounders, sidescan sonars, shallow penetration sub-bottom profilers (SBPs) (e.g., “Chirp”, parametric, and non-parametric SBPs), medium penetration sub-bottom profilers (e.g., sparkers and boomers), ultra-short baseline positioning equipment, and marine magnetometers.

An estimated 17,347 km may be surveyed within the lease area and along the export cable route in water depths ranging from 2 m (6.5 ft) to 50 m (164 ft). A maximum of four (4) total vessels will be used for surveying. On average, 70-line km will be surveyed per vessel each day at approximately 4 km/hour (2.16 knots). HRG survey operations will occur on a 24-hour basis, although some vessels may only operate during daylight hours (~12-hour survey vessels). While the final survey plans will not be completed until construction contracting commences, HRG surveys are anticipated to operate at any time of year for a maximum of 247.8 active sound source days.

During the operations phase (a period of 4 years following construction anticipated to be covered by the requested incidental take regulations) an estimated 1,713 km may be surveyed in the lease area and along the export cable route each year. Using the same estimate of 70 km of survey completed each day per vessel, approximately 24.5 days of survey activity would occur each year.

1.1.5 *Munitions, Explosives of Concern (MEC)/Unexploded Ordnance (MEC/UXO) Disposal*

Within the RWF and along the export cable route there is potential for construction activities to encounter Munitions and Explosives of Concern (MEC) and/or unexploded ordnances (MEC/UXO) on the seabed. These include explosive munitions such as bombs, shells, mines, torpedoes, etc. that did not explode when they were originally deployed or were intentionally discarded in offshore munitions dump sites to avoid land-based detonations. The risk of incidental detonation associated with conducting seabed-altering activities such as cable laying and foundation installation in proximity to MEC/UXOs jeopardizes the health and safety of project participants. Revolution Wind follows an industry standard As Low as Reasonably Practical (ALARP) process that minimizes the number of potential detonations (COP Appendix G, (Revolution-Wind 2021).

For MEC/UXOs that are positively identified in proximity to planned activities on the seabed, several alternative strategies will be considered prior to in-situ MEC/UXO disposal. These may include relocating the activity away from the MEC/UXO (avoidance), moving the MEC/UXO away from the activity (lift and shift), cutting the MEC/UXO open to apportion large ammunition or deactivate fused munitions, using shaped charges to reduce the net explosive yield of a MEC/UXO (low-order detonation), or using shaped charges to ignite the explosive materials and allow them to burn at a slow rate rather than detonate instantaneously (deflagration). Only after these alternatives are considered would a decision to utilize in-situ MEC/UXO disposal. To detonate a MEC/UXO, a small charge would be placed on the MEC/UXO and detonated causing the MEC/UXO to then detonate.

While many of the munitions dump sites are mapped and can be avoided, some MEC/UXOs may have migrated from those sites or are unrecorded elsewhere in the region. To better assess the potential MEC/UXO encounter risk, geophysical surveys have been and continue to be conducted to identify potential MEC/UXOs that have not been previously mapped. The current estimate of the number of UXOs that may need to be detonated is based on preliminary findings of historical information on MEC/UXOs in the region and HRG survey data. However, potential MEC/UXOs identified by HRG surveys have not yet been investigated to determine if they truly are MEC/UXOs. Some that are determined to be MEC/UXOs may be able to be avoided without the need for detonation, but other MEC/UXOs may be encountered that have not yet been identified by the HRG surveys. As these surveys and analysis of data from them are still underway, the exact number and type of MEC/UXOs in the Project area are not yet know. Based on prior experience in other regions, the total number of potential MEC/UXOs that have thus far been identified was reduced to the existing estimates using conservative assumptions of how many may actually be MEC/UXOs, and how many of those may not be possible to avoid, and thus will have to be detonated. It is currently assumed that up to 7 MEC/UXOs in the RWF and up to 6 MEC/UXOs along the export cable route may have to be detonated in place. If necessary, these detonations would occur on 13 different days.

1.1.6 *Construction Vessel Activity*

Offshore construction will occur over an approximate 18-month period, during which time Project construction vessels will increase the volume of traffic in the Project Area. The largest vessels are expected during the WTG installation phase, with floating/jack-up crane barges, DP-equipped cable laying vessels, and associated tugs and barges transporting construction equipment and materials. Up to 60 vessels may be utilized for construction across various components of the Project including installation of the foundations, WTGs, OSSs, IAC, and OSS-Link Cable (COP Table 3.3-26) (Revolution-Wind 2021). The types of vessels anticipated to be used during construction activities, as well as the anticipated number of vessels and vessel trips[2], are summarized in Table 1. The actual number of vessels involved in the Project at one time is highly dependent on the final schedule, the final impacts of ROW preparation (i.e. boulder clearance and in situ MEC/UXO disposal), the final design of the Project's components, and the logistics needed to ensure compliance with the Jones Act, a Federal law that regulates maritime commerce in the U.S.

During construction, the Project will involve temporary construction laydown areas and construction ports. The Project is considering multiple port locations and any combination of the ports under consideration may be utilized. The ports that may be used during construction, but which have independent utility and are not dedicated to the Project, are as follows*:*

- Construction Hub: Port of Montauk (New York), Port Jefferson (New York), Port of Brooklyn (New York), Port of Davisville and Quonset Point (Rhode Island), and/or Port of Galilee (Rhode Island).
- Foundation Marshalling and Advanced Foundation Component Fabrication: Port of Providence (Rhode Island), Paulsboro Marine Terminal (New Jersey), and/or Sparrows Point (Maryland)
- WTG Tower, Nacelle, and Blade Storage, Pre-commissioning, and Marshalling: Port of Providence (Rhode Island), Port of New London (Connecticut), Port of Norfolk (Virginia), and/or New Bedford Marine Commerce Terminal (Massachusetts).
- Electrical Components: Port of Providence (Rhode Island).

Vessels not transporting material from the ports listed above may travel with components and equipment directly to the Lease Area from locations such as the Gulf of Mexico, Atlantic Coast, Europe, or other worldwide ports. Before arriving at the Lease Area, a port call for inspections, crew transfers and bunkering may occur.

Construction vessel traffic will result in a relatively localized impact which will occur sporadically throughout the approximate 18-month time period of offshore construction around the RWF, temporarily increasing the volume and movement of vessels in the RWF. Large work vessels for foundation and WTG installation will generally transit to the work location and remain in the area until installation is complete. These large vessels will move slowly over a short distance between work locations. Transport vessels will travel between several ports and the RWF over the course of the construction period following mandatory vessel speed restrictions (see Appendix C). These vessels will range in size from smaller crew transport boats, to tug and barge vessels. However, construction crews will hotel onboard installation vessels at sea, thus limiting the number of crew vessel transits expected during RWF installation and decommissioning. Vessels will comply with NMFS' regulations, speed restrictions, and state regulations as applicable for NARW. While Project related vessel traffic will slightly increase local and transiting traffic within the region, the number of Project vessels that will operate during construction is expected to be a nominal addition to the normal traffic in the region (COP Appendix R) (Revolution-Wind 2021).

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[2] The anticipated number of vessels and vessel trips are considered within the Vessel Strike Avoidance Plan (Section 11.1.4). The number of vessels and trips would increase with vessel speed constraints.

Table 1: Type and Number of Vessels and Number of Vessel Trips Anticipated during Construction Activities over the Effective Period of the Requested ITRs.

Vessel Type	Maximum Number of Simultaneous Vessels	Maximum Number of Return Trips
Foundation Installation		
Heavy Lift Installation Vessel	1	1
Heavy Lift Installation Vessel (secondary steel)	1	1
Towing Tug (for fuel barge)	1	10
Anchor Handling Tug	2	50
Vessel for Bubble Curtain	1	20
Heavy Transport Vessel	4	25
Crew Transport Vessel	1	30
PSO Noise Monitoring Vessel	4	80
Platform Supply Vessel (secondary steel)	2	65
Platform Supply Vessel (completions)	1	20
Fall Pipe Vessel	1	6
Turbine Installation		
Jack-up Installation Vessel	1	20
Fuel Bunkering Vessel	1	8
Towing Tug (for fuel barge)	1	8
Array Cable Installation		
Pre-Lay Grapnel Run	1	4
Boulder Clearance Vessel	1	10
Sandwave Clearance Vessel	1	2
Cable Laying Vessel	1	6
Cable Burial Vessel	1	6
Crew Transport Vessel	1	231
Walk to Work Vessel (SOV)	1	6
Survey Vessel	1	8
DP2 Construction Vessel	1	5

Vessel Type	Maximum Number of Simultaneous Vessels	Maximum Number of Return Trips
OSS Topside Installation		
Heavy Transport Vessel	1	1
Offshore Export Cable Installation		
Pre-Lay Grapnel Run	1	2
Boulder Clearance Vessel	1	3
Sandwave Clearance Vessel	1	1
Cable Lay and Burial Vessel	1	5
Cable Burial Vessel - Remedial	1	1
Cable Lay Barge	1	3
Tug - Small Capacity	2	3
Tug - Large Capacity	1	8
Crew Transport Vessel	1	214
Guard Vessel/Scout Vessel	5	8
Survey Vessel	1	3
DP2 Construction Vessel	1	2
Supply Barge	1	4
All Construction Activities		
Safety Vessel	2	100
Crew Transport Vessel	3	395
Lift Boat – Jack-Up Accommodation Vessel	1	1
Supply Vessel	1	30
Service Operation Vessel	1	1
Helicopter	1	76

1.1.7 *Fisheries Monitoring*

Fisheries and benthic monitoring surveys have been designed for the Project in accordance with recommendations set forth in "Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf" (BOEM 2019), which state that a fishery survey plan should aim to:

- Identify and confirm which dominant benthic, demersal, and pelagic species are using the project site, and when these species may be present where development is proposed;

- Establish a pre-construction baseline which may be used to assess whether detectable changes associated with proposed operations occurred in post-construction abundance and distribution of fisheries;
- Collect additional information aimed at reducing uncertainty associated with baseline estimates and/or to inform the interpretation of research results; and
- Develop an approach to quantify any substantial changes in the distribution and abundance of fisheries associated with proposed operations.

The Rhode Island Coastal Resources Management Council (RI CRMC) also set out monitoring guidelines as part of the Rhode Island Ocean Special Area Management Plan (Ocean SAMP; RICRMC 2010) which stipulate that RI CRMC shall work in conjunction with the Joint Agency Working Group to "determine requirements for monitoring prior to, during, and post construction. The Project's plan was developed through an iterative process, and the survey protocols and methodologies were refined and updated based on feedback received from stakeholder groups. Revolution Wind met with numerous regulatory agencies and stakeholders during the development of this plan including NOAA/NMFS, BOEM, RI CRMC, Rhode Island Department of Environmental Management Division of Marine Fisheries, Massachusetts Division of Marine Fisheries, Massachusetts Office of Coastal Zone Management, and representatives from the Responsible Offshore Science Alliance and the Responsible Offshore Development Alliance. Table 2 summarizes the survey types to be implemented per the Project's Fisheries and Benthic Monitoring Plan.

Table 2. Summary of Fisheries Monitoring Plan Survey Types and Marine Mammal Harassment Potentials[1]

Activity/Type	Description	Potential Take Requested	Risk Assessment and Mitigation Measures
Trawl Survey	Northeast Area Monitoring and Assessment Program (NEAMAP) style trawl survey to sample fish and invertebrate community.	None	Minimal risk. Marine mammal monitoring prior to, during, and after haul-back; gear won't be deployed if marine mammals observed in the area, as discussed in Section 1.1.7.1.
Acoustic telemetry	Highly Migratory Species (bluefin tuna, shortfin mako sharks, and blue sharks) will be tagged during the trawl survey. This study will use a combination of fixed station receivers and active mobile telemetry to assess the movements of these species. Revolution Wind will deploy up to 100 additional acoustic tags opportunistically for cod caught as part of trawl survey.	None	Minimal risk associated with telemetry is anticipated due to this activity. Vessel mitigation measures within this section will be employed while collecting samples.

Activity/Type	Description	Potential Take Requested	Risk Assessment and Mitigation Measures
Ventless Trap Survey (Outer Continental Shelf)	The ventless trap survey will be conducted twice per month between May and November[2] to investigate the relative abundance of lobster, Jonah crab, and rock crab. Ten trap trawls (6 ventless and 4 vented) will be fished on a five-day soak time.	None	Mitigation Measures discussed in Section 1.1.7.1 result in minimal risk. Mitigation measures associated with vessel movement as described within this section will be employed during deployment and retrieval.
Benthic Habitat Monitoring	Hard bottom habitat monitoring using a remotely operated vehicle (ROV) and video surveying approach to characterize changes from pre-construction conditions. Soft bottom habitat monitoring using Sediment Profile and Plan View Imaging (SPI/PV) to document physical (and biological changes.	None	Minimal risk is anticipated due to this activity. Vessel mitigation measures described in this section will be employed while retrieving and deploying the ROV and SPI/PV.

[1] Revolution Wind will support expanding ventless trap surveys in RI State Waters, as currently performed by the RI Department of Environmental management Division of Marine Fisheries (DMF). DMF began the lobster ventless trap survey in state waters in 2006 as part of a regional effort to provide fisheries-independent abundance indices for juvenile lobsters (McManus et al. 2021). DMF's ongoing survey will be expanded to cover portions of the RWEC-RI to investigate the relative abundance of lobster, crabs, and fish. This survey is excluded from this table as it will be performed under DMF's existing authority and approvals.

[2] The Project has been advised by staff at the Greater Atlantic Regional Fisheries Office (GARFO) Protected Resources Division that the survey cannot operate from December through May unless the Project is able to partner with a local lobster vessel and complete the survey using traps that are already allocated to the fishery, in order to minimize the risk of protected species interactions. Revolution Wind will attempt to partner with a local lobster fisherman and execute the survey using their trap tags. If this cannot be accomplished, the survey will instead sample from June through November to avoid sampling in May.

Survey activities for the offshore Lease Area are bound by several key mitigation measures, in addition to additional mitigations for specific gear types. All vessels will comply with the vessel speed plan outlined in the PSMMP.

In addition to speed restrictions, vessel operators and crews shall receive protected species identification training and maintain a vigilant watch for marine mammals and other protected species and respond with the appropriate action (e.g., change course, slow down, steer away from the animal) to avoid striking marine mammals. Vessels will maintain separation distances of 500 m for North Atlantic right whales, 100 m for other whales, and 50 m for dolphins, porpoises, seals, and sea turtles.

All attempts shall be made to remain parallel to the animal's course when a travelling marine mammal is sighted in proximity to the vessel in transit. If an animal or group of animals is sighted in the vessel's path, attempts shall be made to divert away from the animals or reduce speed and shift gears into neutral until the animal(s) have moved beyond the associated separation distance (with the exception of voluntary bow riding dolphin species).

Effective monitoring is a key step in implementing mitigation measures and is achieved through regular marine mammal watches. Marine mammal watches and monitoring occur during daylight hours prior to deployment of gear (e.g., trawls, ventless traps) and will continue until gear is brought back on board. If marine mammals are sighted in the area within 15 minutes prior to deployment of gear and are considered to be at risk of interaction with the research gear, then the sampling station is either moved or canceled or the activity is suspended until there are no sightings for 15 minutes within 1nm of sampling location.

1.1.7.1 Gear Specific Mitigation

In addition to the general measures that apply to all vessels outlined above, gear-specific measures will also be implemented to avoid the potential for interactions with MMPA species.

Research Trawl Survey

The following mitigation measures will be used to minimize the potential for marine mammal capture during the research trawling:

- All gear restrictions, closures, and other regulations set forth by take reduction plans (e.g., Harbor Porpoise Take Reduction Plan, Atlantic Large Take Whale Reduction Plan, etc.) will be adhered to as with typical scientific fishing operations to reduce the potential for interaction or injury;
- Marine mammal monitoring will be conducted by the captain and/or a member of the scientific crew before, during, and after haul back;
- Trawl operations will commence as soon as possible once the vessel arrives on station; the target tow time will be limited to 20 minutes;
- Revolution Wind will initiate marine mammal watches (visual observation) 15 minutes prior to sampling within 1 nautical mile (nm) of the site;
- If a marine mammal is sighted within 1 nm of the planned location in the 15 minutes before gear deployment, Revolution Wind will delay setting the trawl until marine mammals have not been resighted for 15 minutes, or Revolution Wind may move the vessel away from the marine mammal to a different section of the sampling area. If, after moving on, marine mammals are still visible from the vessel, Revolution Wind may decide to move again or to skip the station;
- Gear will not be deployed if marine mammals are observed within the area and if a marine mammal is deemed to be at risk of interaction, all gear will be immediately removed;
- Revolution Wind will maintain visual monitoring effort during the entire period of time that trawl gear is in the water (i.e., throughout gear deployment, fishing, and retrieval). If marine mammals are sighted before the gear is fully removed from the water, Revolution Wind will take the most appropriate action to avoid marine mammal interaction;
- Revolution Wind will open the codend of the net close to the deck/sorting area to avoid damage to animals that may be caught in gear; and
- Gear will be emptied as close to the deck/sorting area and as quickly as possible after retrieval;
- Trawl nets will be fully cleaned and repaired (if damaged) before setting again.

Revolution Wind does not anticipate and is not requesting take of marine mammals incidental to research trawl surveys but, in the case of a marine mammal interaction, the Marine Mammal Stranding Network will be contacted immediately.

Ventless Trap Survey (Outer Continental Shelf)

The ventless trap surveys will adhere to the following mitigating measures to minimize the potential for a take of protected species associated with the vertical lines:

- No buoy line will be floating at the surface.

- All sampling gear will be hauled at least once every 30 days, and all gear will be removed from the water at the end of each sampling season (November).
- All groundlines will be constructed of sinking line.
- Fishermen contracted to perform the field work will be encouraged to use knot-free buoy lines.
- To reduce the potential risk to right whales buoy/end lines with a breaking strength of <1700lbs will be used. All buoy line will use weak links that are chosen from the list of NMFS approved gear. This may be accomplished by using whole buoy line that has a breaking strength of 1700lbs; or buoy line with weak inserts that result in line having an overall breaking strength of 1700lbs.
- All buoys will be labeled as research gear, and the scientific permit number will be written on the buoy. All markings on the buoys and buoy lines will be compliant with the regulations, and all buoy markings will comply with instructions received by staff at NOAA Greater Atlantic Regional Fisheries Office Protected Resources Division.
- Any lines or trawls that go missing will be reported to the NOAA Greater Atlantic Regional Fisheries Office Protected Resources Division as soon as possible.

1.2 Activities Resulting in Potential Take of Marine Mammals

Based on the planned construction activities summarized above, pile driving during WTG monopile foundation installation, OSS monopile foundation installation, cable landfall construction, HRG surveys and potential in-situ MEC/UXO disposal may cause incidental take of marine mammals.

Impact pile driving during the Project could result in incidental take of marine mammals through the introduction of sound into the water column. When piles are driven with impact hammers, they deform, sending a bulge travelling down the pile that radiates sound into the surrounding air, water, and seabed. Thus, noise generated by impact pile driving consists of regular, pulsed sounds of short duration. This sound may be received as a direct transmission from the source to biological receivers such as marine mammals, sea turtles, and fish; through the water, as the result of reflected paths from the surface, or re-radiated into the water from the seabed. Sound transmission depends on many environmental parameters, such as the sound speeds in water and substrates, and sound production parameters of the pile and how it is driven, including the pile material, size (length, diameter, and thickness), and the type and energy of the hammer.

Studies of underwater sound from impact pile driving have found that most of the acoustic energy is below one to two kHz, with broadband sound energy near the source (40 Hz to >40 kHz) and only low-frequency energy (<400 Hz) at longer ranges (Illinworth & Rodkin 2007; Erbe 2009; Bailey et al. 2010). There is typically a decrease in sound pressure and an increase in pulse duration the greater the distance from the noise source (Bailey et al. 2010). Maximum noise levels from impact pile driving usually occur during the last stage of driving each pile where the highest hammer energy levels are used (Betke 2008).

During cable landfall construction, a pneumatic pipe rammer and/or impact hammer may be used to install and remove casing pipe while a vibratory hammer may be used to install and remove sheet piles for the goal posts or a cofferdam. Vibratory hammering is accomplished by applying rapidly alternating (~250 Hz) forces to the pile that create non-impulsive sounds while the pneumatic pipe rammer and/or impact hammer produce pulsed sounds like an impact pile driver. The overall sound levels associated with vibratory hammering are typically less than impact hammering, but the lower disturbance threshold (120 dB) for non-impulsive sounds means that vibratory pile driving activity will result in a larger area ensonified above that threshold and therefore a larger number of potential takes. Exposure to sounds from either source is not expected to induce injury because they produce relatively low peak pressure levels and will be used for short durations of time.

Some of the sounds produced by HRG survey equipment have the potential to be audible to marine mammals (MacGillivray et al. 2014) including those with operating frequencies below 180 kHz. As noted in the previous section (Section 1.2), HRG equipment with operation frequencies below 180 kHz may cause take. HRG survey sources with operating frequencies >180 kHz are outside the hearing range of marine mammals and will not cause take. The operating frequencies of representative HRG sound sources are shown in Table 3. Despite generating sounds in frequencies below 180 kHz, certain characteristics of the signals produced by some HRG survey equipment mean that they are unlikely to cause takes of marine mammals (see Section 1.3). However, the frequency range and signal characteristics of sparkers, boomers, and non-parametric SBPs may cause behavioral take and are therefore assessed further in Section 6.

Table 3. Representative HRG survey equipment and operating frequencies.

Equipment Type	Representative Model	Operating Frequency
Sub-bottom Profiler	EdgeTech 216	2 – 16 kHz
	EdgeTech 424	4 – 24 kHz
	EdgeTech 512	0.7 – 12 kHz
	GeoPulse 5430A	2 – 17 kHz
	Teledyne Benthos Chirp III – TTV 170	2 – 7 kHz
Sparker	Applied Acoustics Dura-spark UHD (400 tips, 500 J)	0.3 – 1.2 kHz
Boomer	Applied Acoustics triple plate S-Boom (700-1,000 J)	0.1 – 5 kHz

Underwater detonations create broadband impulsive sounds with a high peak pressures and rapid rise times (Richardson et al. 1995). MEC/UXOs with more net explosive weight will produce higher peak pressures. For example, MEC/UXOs with 2.3 kg (5 lb) may produce peak pressures of ~255 dB at 10 m, while MEC/UXOs of 454 kg (1,000 lb) may produce peak pressures of over 270 dB at 10 m. At close ranges, these sounds have the potential to cause non-auditory injury to marine mammals and at longer ranges, auditory injury and behavioral disturbance are possible. The unique nature of sounds from underwater detonations, including the high peak pressure levels and the fact that they are typically just a single impulsive event, means threshold criteria for MEC/UXO detonations are different than for other anthropogenic sounds. Further descriptions of those criteria are provided in Section 6.2.

To estimate the potential take of marine mammals from these activities and sound sources, acoustic propagation modeling was conducted to determine distances to relevant acoustic impact thresholds. For WTG and OSS foundation installations, animal movement modeling was also performed to better understand the potential for incidental take of marine mammals. The modeling results are summarized in Section 6 along with the estimates of take. Appendix A contains a detailed description of the propagation and animal movement modeling, including modeling procedures and assumptions.

1.3 Activities Not Resulting in Potential Incidental Take of Marine Mammals

Routine vessel activities such as transits between ports and the RWF and RWEC corridor or between worksites within those areas are not anticipated to cause take of marine mammals. As part of various construction related activities, including cable laying and construction material delivery, dynamic positioning (DP) thrusters may be utilized to hold vessels in position or move slowly. Sound produced through use of DP thrusters is similar to that produced by transiting vessels and DP thrusters are typically operated either in a similarly predictable manner or used for short durations around stationary activities. Sound produced by DP thrusters would be preceded by, and associated with, sound from ongoing vessel noise and would be similar in nature; thus, any marine mammals in the vicinity of the activity would be aware of the vessel's presence, further reducing the potential for startle or flight responses on the part of marine mammals. Monitoring of past projects that entailed use of DP thrusters has shown a lack of observed marine mammal responses as a result of exposure to sound from DP thrusters (NMFS 2018b). As DP thrusters are not expected to result in take of marine mammals, these activities are not analyzed further in this document.

HRG survey sources with operating frequencies above 180 kHz, including most multi-beam echosounders and side scan sonars, are not anticipated to cause take since these frequencies are not audible to marine mammals. As noted in the previous section (Section 1.2), HRG equipment with operating frequencies below 180 kHz may cause take. However, some HRG survey equipment with operating frequencies below 180 kHz are also not anticipated to cause take. Parametric SBPs produce very narrowly focused beams of sound (0.5–3°) at relatively high frequencies that attenuate rapidly in water and are therefore not expected to cause takes of marine mammals (NMFS 2021p). Similarly, USBL systems used for high-accuracy positioning of survey equipment have previously been shown to produce extremely short distances to threshold levels under typical operating conditions so are also not expected to result in take (NMFS 2021p).

2 Dates, Duration, and Specified Geographic Region

2.1 Dates of Construction Activities

The overall duration of offshore construction activities in the RWF and RWEC will occur over approximately 12 to 18 months from third quarter 2023 to fourth quarter 2024. During this time, activities will occur 24-hours a day to minimize the overall duration of activities and the associated period of potential impact on marine mammals. Pile driving during nighttime hours could potentially occur. The total number of construction days will be dependent on a number of factors, including environmental conditions, planning, construction, and installation logistics. The general construction schedule is provided in Table 4. The installation schedule includes all of the major project components including those that may result in harassment takes and those that are not expected to result in any take.

In the RWF, the WTG monopile installation campaign is expected to be completed in a single 5-month period in Q2–Q3 2024 (Figure 5); however, pile driving to install a single WTG monopile is anticipated to only last for 1-4 hours at a time. There will also be time between piling events to mobilize to the next location and prepare for the next installation. The OSS foundation installation may occur anytime within a 4-month period in Q2–Q3 2024, but the actual impact pile driving would likely occur within a 1–2-week period. Although monopile installations are intended to occur in Q2–Q3, it is possible that installations will take place in Q4, including during the month of December. Installation of other project components within the RWF include the array cable and HRG surveys, as well as potential in-situ MEC/UXO disposal. Array cable installation is expected to occur within a 5-month window in Q1–Q3 2024 but is not likely to be continuous during that time. HRG surveys could take place within the RWF at any time during the overall construction period from third quarter 2021 to fourth quarter 2024. In-situ MEC/UXO disposal may occur sometime during Q3–Q4 2023.

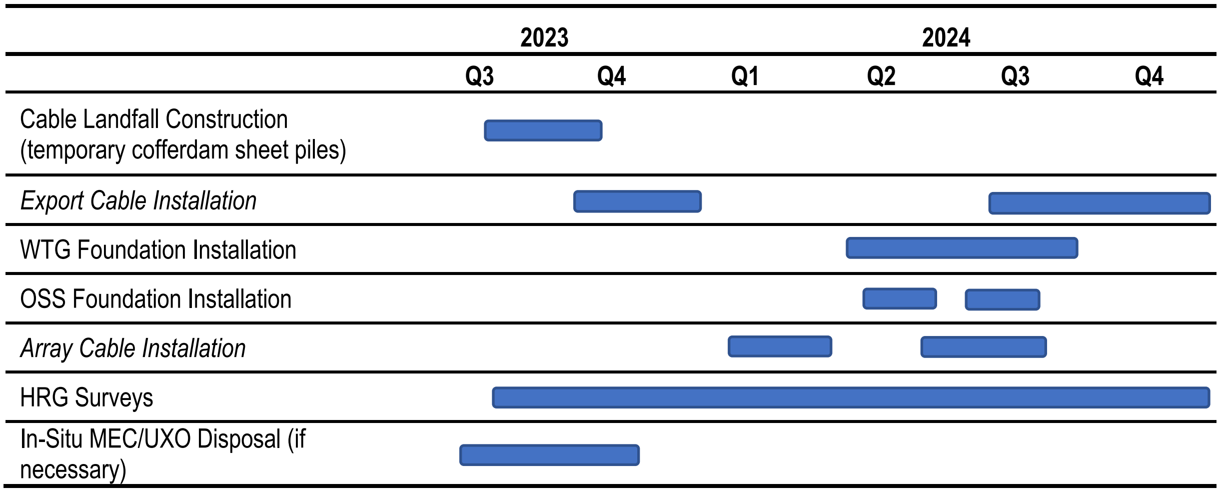
Construction activity within the RWEC area includes cable landfall installation, offshore export cable installation, potential in-situ MEC/UXO disposal, and HRG surveys. Installation of the cable landfall may involve the use of a casing pipe supported by sheet pile goal posts or a sheet pile cofferdam. Installation and removal of these structures would involve the use of a vibratory pile driver and/or a pneumatic pipe ramming tool in Q3–Q4 2023; although vibratory pile driving and/or pipe ramming activities for installation and removal are only anticipated to occur on up to 56 days. Offshore export cable installation is expected to occur over a total of 8-months in two separate periods, from fourth quarter 2023 to first quarter 2024 and Q3–Q4 2024. HRG surveys could take place within the RWEC at any time during the overall construction period from third quarter 2021 to fourth 2024.

After construction is completed and through the end of the effective period for the requested regulations in Q3 2028, HRG surveys could take place within the RWF and RWEC at any time of year. However, it is anticipated that the annual amount of survey activity will be less than that required during the construction phase.

Table 4. Anticipated installation schedule for the major RWF and RWEC project components. Project components in *italics* are not anticipated to cause take.

Project Area	Project Component	Expected Duration and Timing
RWF Construction	WTG Foundation Installation	~ 5 months Q2 – Q3 2024
	OSS Foundation Installation	~ 2-3 days Q2 – Q3 2024
	Array Cable Installation	~ 5 months Q1 – Q3 2024
	HRG Surveys	Any time of year Q3 2023 to Q4 2024
	In-Situ MEC/UXO Disposal	~ Up to 7 days Q3 – Q4 2023
RWEC Construction	Cable Landfall Installation (temporary cofferdam installation and removal)	~ Up to 56 days Q3 – Q4 2023
	Offshore Export Cable Installation	~ 8 months Q4 2023 to Q4 2024
	HRG Surveys	Any time of year Q3 2023 to Q4 2024
	In-Situ MEC/UXO Disposal	~ Up to 6 days Q3 – Q4 2023
Operations	HRG Surveys	Any time of year Q4 2024 to Q3 2028

Figure 5. Anticipated installation periods for the major RWF and RWEC project components. Project components in *italics* are not anticipated to cause take.



2.2 Specified Geographical Region of Activity

The RWF is located in federal waters within the designated BOEM Renewable Energy Lease Area OCS A-0486. The RWEC will traverse both federal waters and state territorial waters of Rhode Island, extending up to approximately 50 mi (80 km) from the RWF to the Landfall Work Area at Quonset Point in North Kingstown, Rhode Island. Refer to Figure 1 for a depiction of the RWF and RWEC location.

Temporary construction staging areas for Onshore Facilities will also be located in North Kingstown, primarily on parcels owned by QDC (refer to COP Section 3.3.1.2 for additional information regarding temporary onshore staging areas) (Revolution-Wind 2021). Additionally, while a final decision has not yet been made, existing port facilities in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Virginia, and Maryland are being evaluated to support the Project. Section 3.3.10 of the COP provides further detail regarding specific ports being considered and their potential usage.

3 Species and Number of Marine Mammals

3.1 Species Present

There are 40 marine mammal species and/or stocks in the Western North Atlantic OCS Region that are protected under the MMPA and whose ranges include the Northeastern U.S. region where the Project will be located (BOEM 2013, 2014b). This includes two different stocks of the common bottlenose dolphin (offshore and migratory coastal) as well as four different species of beaked whale that are often pooled together when estimating abundance. The marine mammal assemblage comprises cetaceans (whales, dolphins, and porpoises), pinnipeds (seals), and sirenians (manatee). There are 35 cetacean species, including 29 members of the suborder Odontoceti (toothed whales, dolphins, and porpoises) and 6 of the suborder Mysticeti (baleen whales) within the region. There are four phocid species (true seals) that are known to occur in the region, including harbor seals (*Phoca vitulina*), gray seals (*Halichoerus grypus*), harp seals (*Pagophilus groenlandica*), and hooded seals (*Cystophora cristata*) (Hayes et al.

2020). Finally, one species of sirenian, the Florida manatee (*Trichechus manatus latirostris*), is an occasional visitor to the region during the summer months (USFWS 2019).

Six of the species known to occur in the Western North Atlantic are listed under the Endangered Species Act (ESA); these include the fin whale (Endangered), sei whale (Endangered), blue whale (Endangered), North Atlantic right whale (Endangered), sperm whale (Endangered), and Florida manatee (Threatened). Five of these six species, the blue whale, fin whale, sei whale, North Atlantic right whale, and sperm whale are expected to occur in the Project Area and are considered potentially affected species. The Florida manatee is uncommon in the Project Area and is unlikely to be affected. The blue whale is uncommon in the RWF; however, blue whale vocalizations and sighting data in the region demonstrate the possibility for the species to be present in the Project Area. The following sections provide further information regarding species occurrence in the Project Area.

The protection status, habitat, seasonality in the Project Area, stock identification, and abundance estimates of each marine mammal species with geographic ranges that include the Northeastern U.S. region are provided in Table 5. Abundance information was included in this table from Roberts et al. (2018; 2020) when available; however, abundance estimates were not available for all species. Table 5 evaluates the potential occurrence of marine mammals in the Project Area based on five categories defined as follows:

- **Common** – Occurring consistently in moderate to large numbers;
- **Regular** – Occurring in low to moderate numbers on a regular basis or seasonally;
- **Uncommon** – Occurring in low numbers or on an irregular basis;
- **Rare** – Records for some years but limited; and
- **Not expected** – Range includes the Project Area, but due to habitat preferences and distribution information, species are not expected to occur in the Project Area although records may exist for adjacent waters.

The expected occurrence of each species in the Project Area is based on information provided in EAs conducted by BOEM offshore Rhode Island and Massachusetts (BOEM 2013, 2014b); regional surveys such as the Northeast Large Pelagic Survey, the Atlantic Marine Assessment Program for Protected Species (AMAPPS), or the Cetacean and Turtle Assessment Program (CETAP) (CeTAP 1982; Kraus et al. 2016; Palka et al. 2017); stock information from NMFS and USFWS available for the region; density and other available information from published literature. Available information was applicable to both the RWF and RWEC corridor.

Of the 40 marine mammal species and/or stocks within geographic ranges that include the western North Atlantic OCS, 24 are not expected to be present or are considered to be “rare” or “not expected” in the Project Area based on sighting and distribution data (Table 5). These are the dwarf and pygmy sperm whales (*Kogia sima and K breviceps*), northern bottlenose whale (*hyperoodon ampullatus*), cuvier’s beaked whale (*Ziphius cavirostris*), four species of Mesoplodont beaked whales (*Mesoplodon densitostris, M. europaeus, M. mirus, and M. bidens*), killer whale (*Orcinus orca*), false killer whale (*Pseudorca crassidens*), pygmy killer whale (*Feresa attenuate*), short-finned pilot whale (*Globicephalus Macrohynchus*), melon-headed whale (*Peponocephala electra*), Fraser’s dolphin (*Lagenodelphis hosei*), white-beaked dolphin (*Lagenorhynchus albirotris*), pantropical spotted dolphin (*Stenella attenuate*), Clymene dolphin (*Stenella Clymene*), striped dolphin (*Stenella coeruleoalba*), spinner dolphin (*Stenella longirostris*), rough-toothed dolphin (*Steno bredanensis*), common bottlenose dolphin (*Tursiops truncatus truncatus*), harp seal (*Pagophilus groenlandicus*), hooded seal (*Cystophora cristata*), and the Florida manatee (*Trichechus manatus latirostris*) (Kenney and Vigness-Raposa 2010; Kraus et al. 2016; Roberts et al. 2016; Roberts et al. 2017; Roberts et al. 2018; Hayes et al. 2019, 2020; Roberts et al. 2020, 2021).

Due to their limited occurrence in the Project Area, the likelihood that individuals from one of these species would be taken by harassment during the construction activities is negligible so they are not carried forward in this ITR Application.

Table 5. Marine Mammals with geographic ranges that include the Northeastern U.S. region and their relative occurrence in the Project area. NA means not available.

Common name; species name; and stock	**MMPA and ESA Status[a]**	**Relative Occurrence in the RWF[b]**	**Relative Occurrence in the RWEC[b]**	**Habitat[c]**	**Seasonality in Offshore Project Area[b]**	**Abundance[d] (NOAA Fisheries best available)**
Blue Whale *Balaenoptera musculus musculus* Western North Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Uncommon	Uncommon	Pelagic and coastal	Spring and summer	402
Fin Whale *Balaenoptera physalus physalus* Western North Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Common	Common	Slope, pelagic	Year-round, but mainly spring and summer	6,802
Humpback Whale *Megaptera novaeangliae* Gulf of Maine Stock	MMPA Non-strategic	Common	Common	Mainly nearshore and banks	Year-round, but mainly spring and early summer (March to July)	1,396
Minke Whale *Balaenoptera acutorostrata acutorostrata* Canadian East Coast Stock	MMPA Non-strategic	Common	Common	Coastal, shelf	Mainly spring and summer	21,968
North Atlantic Right Whale *Eubalaena glacialis* Western Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Common	Common	Coastal, shelf, offshore	Year-round, but mainly winter and spring (December-April)	368
Sei Whale *Balaenoptera borealis borealis* Nova Scotia Stock	ESA Endangered MMPA Depleted and Strategic	Regular	Uncommon	Mostly pelagic	Spring and summer (March to July)	6,292
Atlantic Spotted Dolphin *Stenella frontalis* Western North Atlantic Stock	MMPA Non-strategic	Uncommon	Uncommon	Continental shelf, slope	Summer and fall	39,921
Atlantic White-Sided Dolphin *Lagenorhynchus acutus* Western North Atlantic Stock	MMPA Non-strategic	Common	Common	Offshore, slope	Year-round, but more abundant in the spring and summer	93,233
Clymene dolphin Stenella clymene Western North Atlantic Stock	MMPA Non-strategic	Not Expected	Not Expected	Off continental shelf	NA	4,237

Common Bottlenose Dolphin *Tursiops truncatus truncatus* Western North Atlantic Offshore Stock	MMPA Non-strategic	Common	Common	Coastal, shelf, deep	Year-round	62,851
Common Bottlenose Dolphin *Tursiops truncatus truncatus* Western North Atlantic, Northern migratory coastal	MMPA Depleted and Strategic	Rare	Rare	Coastal, shelf, deep	Year-round	6,639
Common Dolphin *Delphinus delphis* Western North Atlantic Stock	MMPA Non-strategic	Common	Common	Shelf, pelagic	Year-round, but more abundant in summer	172,974
Cuvier's Beaked Whale *Ziphius cavirostris* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Pelagic	NA	21,818
Dwarf Sperm Whale *Kogia sima* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Deep, shelf, slope	NA	7,750
False Killer Whale *Pseudorca crassidens* Western North Atlantic Stock	MMPA Depleted and Strategic	Rare	Rare	Pelagic	NA	1,791
Fraser's Dolphin *Lagenodelphis hosei* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Pelagic, shelf	NA	Unknown
Harbor Porpoise *Phocoena phocoena* Gulf of Maine/Bay of Fundy Stock	MMPA Non-strategic	Common	Common	Shelf	Year-round, but less abundant in summer	95,543
Killer Whale *Orcinus orca* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Widely distributed	NA	Unknown
Melon-headed whale *Peponocephala electra* Western North Atlantic Stock	MMPA Non-strategic	Not expected	Not expected	Pelagic	NA	Unknown
Mesoplodont Beaked Whales *Mesoplodon densitostris, M.*	MMPA Depleted and Strategic	Rare	Rare	Slope, offshore	NA	10,107[g]

europaeus, M. mirus, and M. bidens Western North Atlantic Stock						
Northern Bottlenose Whale *Hyperoodon ampullatus* Western North Atlantic Stock	MMPA Non-strategic	Not expected	Not expected	Deep, pelagic	NA	Unknown
Pantropical spotted dolphin Stenella attenuata Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Pelagic, slope	NA	6,593
Pilot Whale, Long-Finned *Globicephalus melas* Western North Atlantic Stock	MMPA Depleted and Strategic	Common	Uncommon	Continental shelf edge, high relief	Year-round, with peak occurrence in the spring	39,215
Pilot Whale, Short-Finned *Globicephalus macrorhynchus* Western North Atlantic Stock	MMPA Depleted and Strategic	Rare	Rare	Pelagic, high relief	Year-round	28,924
Pygmy Killer Whale *Feresa attenuate* Western North Atlantic Stock	MMPA Non-strategic	Not expected	Not expected	Pelagic	NA	Unknown
Pygmy Sperm Whale *Kogia breviceps* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Deep, off shelf	NA	7,750
Risso's Dolphin *Grampus griseus* Western North Atlantic Stock	MMPA Non-strategic	Common	Uncommon	Shelf, slope	Year-round, but more abundant in summer	35,215
Rough Toothed Dolphin *Steno bredanensis* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Pelagic, nearshore	NA	136
Sperm Whale *Physeter macrocephalus* North Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Common	Common	Pelagic, steep topography	Year-round, but mainly summer and fall	4,349
Spinner dolphin Stenella longirostris Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Pelagic, deep	NA	4,102
Striped Dolphin *Stenella coeruleoalba* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Off continental shelf	NA	67,036

White-beaked dolphin *Lagenorhynchus albirotris* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Continental shelf, offshore	NA	536,016
Gray Seal *Halichoerus grypus atlantica* Western North Atlantic Stock	MMPA Non-strategic	Regular	Regular	Nearshore, shelf	Year-round	27,300
Harbor Seal *Phoca vitulina vitulina* Western North Atlantic Stock	MMPA Non-strategic	Regular	Regular	Coastal	Year-round, with peak abundance (April to May)	61,336
Harp Seal *Pagophilus groenlandicus* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Nearshore	Spring and winter	7.6 M
Hooded seal *Cystophora cristata* Western North Atlantic Stock	MMPA Non-strategic	Rare	Rare	Pelagic, offshore	Spring and Winter	Unknown
Sirenia						
Florida manatee[f] *Trichechus manatus latirostris*	ESA Threatened MMPA Depleted and Strategic	Rare	Rare	Coastal, nearshore	NA	Unknown

ESA = Endangered Species Act; MMPA = Marine Mammal Protection Act; Project Area = includes the Revolution Wind Farm (RWF), Revolution Wind Export Cable (RWEC) – Outer Continental Shelf (OCS) and RWEC – Rhode Island (RI) state waters, and Onshore Facilities; SGCN = Species of Greatest Conservation Need.

NA = Not Applicable and/or insufficient data available to determine seasonal occurrence in the offshore project area.

[a] Special status accorded by the US Endangered Species Act (ESA), NMFS (Hayes et al. 2019, 2020), and Rhode Island Endangered Species Act (RI.gov 2021).

[b] Occurrence and seasonality were mainly derived from (Kenney and Vigness-Raposa 2010; Kraus et al. 2016).

[c] Habitat descriptions from the 2019 Marine Mammal Stock Assessment Report (Hayes et al. 2019).

[d] "Best Available" abundance estimate is from the 2019 Marine Mammal Stock Assessment Report, published by NMFS on the Federal Register on 27 November 2019 (84 FR 65353); the 2020 Marine Mammal Stock Assessment Report (Hayes et al. 2020); and the draft 2021 Marine Mammal Stock Assessment Report (Hayes et al. 2021).

[e] Abundance estimates are from habitat-based density modeling of the entire Atlantic EEZ from (Roberts et al. 2016; Roberts et al. 2017; Roberts et al. 2018; Roberts et al. 2020, 2021)

[f] Under management jurisdiction of United States Fish and Wildlife Service rather than National Marine Fisheries Service and therefore not included in 2019 or the 2020 Stock Assessment Report; currently no reliable abundance estimate is available for this population

[g] Mesoplodont beaked whale abundance estimate accounts for all undifferentiated beaked whale species within the Western Atlantic (Hayes et al. 2019)

4 Affected Species Status and Distribution

Of the 40 marine mammal species and/or stocks with geographic ranges that include areas offshore of the Northeastern U.S., 15 species can be expected to reside, traverse, or routinely visit the Project Area in densities that could result in acoustic exposures from proposed activities, and therefore, be considered potentially affected species. Of the species with relative occurrence considered "not expected" or "rare" (Table 5) , the likelihood of exposure is deemed low. Therefore, these species are not carried forward in the modelling analysis of this ITR Application as the chances for take are negligible. The 15 potentially affected species include:

- Blue whale
- Fin whale;
- Sei whale;
- North Atlantic right whale;
- Minke whale;
- Humpback whale;
- Sperm whale;
- Long-finned pilot whale
- Atlantic spotted dolphin;
- Atlantic white-sided dolphin;
- Common dolphin;
- Risso's dolphin;
- Common bottlenose dolphin;
- Harbor porpoise;
- Harbor seal; and
- Grey seal.

The following subsections summarize the information available on the life history, hearing and communication frequencies, habitat preferences, distribution, abundance, and status of marine mammals expected to occur in the Project Area and be potentially affected. The expected occurrence for each species within the RWF area and RWEC corridor (including both the RWEC–OCS and RWEC–RI areas) was assessed separately.

4.1 Mysticetes

4.1.1 *Blue Whale (Balaenoptera musculus musculus)*

The blue whale is the largest cetacean, although its size range overlaps with that of fin and sei whales. Most adults of this subspecies are 23 to 27 m (75 to 90 feet in length (Jefferson et al. 2008). Blue whales feed almost exclusively on krill (Kenney and Vigness-Raposa 2010).

Blue whales are considered low-frequency cetaceans in terms of their classification in the acoustic categories assigned by NMFS for the purposes of assessment of the potential for harassment or injury arising from exposure to anthropogenic noise sources, a group whose hearing is estimated to range from 7 Hz to 35 kHz (NMFS 2018b). Peak frequencies of blue whale vocalizations range from roughly 10 to 120 Hz; an analysis of calls recorded since the 1960s indicates that the tonal frequency of blue whale calls has decreased over the past several decades (McDonald et al. 2009).

4.1.1.1 Distribution

Blue whales are found in all oceans, including at least two distinct populations inhabiting the eastern and western North Atlantic Ocean (Sears et al. 2005). Although blue whales spend most of their time in deep open ocean waters, there are summertime feeding aggregations of western North Atlantic blue whales in the Gulf of St. Lawrence, where animals target krill swarms in accessible shallow waters (McQuinn et al. 2016). Data from animals tagged in the St. Lawrence estuary indicate that blue whales use other summer feeding grounds off of Nova Scotia and Newfoundland and also feed sporadically during the winter in the Mid-Atlantic Bight, occasionally venturing to waters along or shoreward of the continental shelf break (Lesage et al. 2017; Lesage et al. 2018). Tagging studies show blue whale movements from the Gulf of St. Lawrence to North Carolina, including both on- and off-shelf waters, extending into deeper waters around the New England Seamounts (Lesage et al. 2017; Davis et al. 2020). Acoustic detections of blue whales have occurred in deep waters north of the West Indies and east of the U.S. EEZ, indicating that their southern range limit is unknown (Clark 1995; Nieukirk et al. 2004; Davis et al. 2020).

Recent deployment of passive acoustic devices in the New York Bight yielded detections of blue whales about 20 nm southeast of the entrance to New York Harbor during the months of January, February, and March (Muirhead et al. 2018). Blue whale vocalizations have been detected in the RWF area during acoustic surveys (Kraus et al. 2016). However, these detections could have originated at large distances from the receivers, meaning the detections in or near the Lease Area do not necessarily mean presence within the Lease Area. Three sightings of three individual blue whales were observed in the Project Area during the AMAPPS surveys (Palka et al. 2017). More recently, during three years of monthly area surveys in the New York Bight from 2017–2020, Zoidis et al. (2021) reported 3 sightings of 5 individuals. Additional sightings of blue whales off the coast of Virginia were recorded including a vessel sighting of a juvenile in April 2018 (Engelhaupt et al. 2019), and a sighting of an adult whale off the coast of Virginia made in February 2019 during a systematic aerial survey (Cotter 2019). The aerial sighting was recorded in deep waters beyond the shelf break, but the vessel sighting was over the shelf near the 50-m isobath. Both sightings are considered extremely rare and constitute the southernmost sightings of blue whales off the U.S. east coast in the U.S. EEZ.

4.1.1.2 Abundance

The current minimum estimate of the western North Atlantic population, based on photo-identification efforts in the St. Lawrence estuary and the northwestern Gulf of St. Lawrence, is 402 animals (Sears and Calambokidis 2002; Ramp and Sears 2013; Hayes et al. 2020). This work led to a suggestion that between 400–600 individuals may be found in the western North Atlantic (Hayes et al. 2020).

4.1.1.3 Status

The blue whale is listed as Endangered under the ESA and the western North Atlantic stock of blue whales is considered Strategic and Depleted under the MMPA. Human induced threats to blue whales include entanglement in fishing gear, ship-strikes, pollution, and disruptions of pelagic food webs in response to changes in ocean temperatures and circulation processes (Hayes et al. 2020). There is no designated critical habitat for this species within the proposed survey area (Hayes et al. 2020).

4.1.2 *Fin Whale (Balaenoptera physalus)*

Fin Whales are the second largest species of baleen whale in the Northern Hemisphere (NMFS 2021f), with a maximum length of about 22.8 m (75 ft). These whales have a sleek, streamlined body with a V-shaped head that makes them fast swimmers. This species has a distinctive coloration pattern: the dorsal and lateral sides of the body are black or dark brownish-gray, and the ventral surface is white. The lower jaw is dark on the left side and white on the right side. Fin whales feed on krill (*Euphausiacea*), small schooling fish (e.g., Herring [*Clupea harengus*], Capelin [*Mallotus villosus*], Sand Lance [*Ammodytidae* spp.]), and squid (*Teuthida* spp.) by lunging into schools of prey with their mouths open (Kenney and Vigness-Raposa 2010).

Fin whales produce characteristic vocalizations that can be distinguished during passive acoustic monitoring (PAM) surveys (BOEM 2013; Erbe et al. 2017). The most commonly observed calls are the “20-Hz signals,” a short down sweep falling from 30 to 15 Hz over a 1-sec period. Fin whales can also produce higher frequency sounds up to 310 Hz, and SLs as high as 195 dB re 1 µPa @ 1 m $\mathrm{SPL}_{\mathrm{rms}}$ have been reported, making it one of the most powerful biological sounds in the ocean (Erbe et al. 2017). Anatomical modeling based on fin whale ear morphology suggests their greatest hearing sensitivity is between 20 Hz and 20 kHz (Cranford and Krysl 2015; Southall et al. 2019).

4.1.2.1 Distribution

Fin whales have a wide distribution and can be found in the Atlantic and Pacific Oceans in both the Northern and Southern Hemisphere (Hayes et al. 2020). The population is divided by ocean basins; however, these boundaries are arbitrary as they are based on historical whaling patterns rather than biological evidence (Hayes et al. 2020). Fin Whales off the eastern US, Nova Scotia, and the southeastern coast of Newfoundland are believed to constitute a single stock under the present International Whaling Commission (IWC) management scheme (Donovan 1991), which has been called the Western North Atlantic stock.

Fin whales transit between summer feeding grounds in the high latitudes and the wintering, calving, or mating habitats in low latitudes or offshore. However, acoustic records indicate that fin whale populations may be less migratory than other mysticetes whose populations make distinct annual migrations (Watkins et al. 2000). Fin whales typically feed in New England waters on fishes (e.g., sea lance, capelin, herring), krill, copepods, and squid in deeper waters near the edge of the continental shelf (90 to 180 m [295 to 591 ft]) but will migrate towards coastal areas following prey distribution. However, fin whales’ habitat use has shifted in the southern Gulf of Maine, most likely due to changes in the abundance of sand lance and herring, both of which are prey for the fin whale (Vigness-Raposa et al. 2010). While fin whales typically feed in the Gulf of Maine and the waters surrounding New England, mating and calving (and general wintering) areas remain largely unknown (Hayes et al. 2020). Between October 2018 and February 2021, there were 24 sightings of 26 individual fin whales recorded during HRG surveys conducted within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Two well-known feeding grounds for fin whales are present near the RWF. These include the Great South Channel and Jeffrey’s Ledge and waters directly east of Montauk, New York (Kenney and Vigness-Raposa 2010; Hayes et al. 2020). The highest occurrences of fin whales in this region are identified south of Montauk Point, New York to south of Nantucket, Massachusetts (Kenney and

Vigness-Raposa 2010). Results of acoustic data collected in NMFS Region 7 (Southern New England where the Project Area is located) indicate the greatest number of acoustic detections from August through April with a decrease in fin whale presence in the summer (Davis et al. 2020). However, the data based on aerial surveys show visual detections to be greatest in the summer (Kraus et al. 2016). Because of their regular occurrences in OCS waters in this region, it is likely that fin whales will be present within the RWF area, potentially occurring during all seasons.

RWEC

Fin whales are common in Rhode Island state waters and adjacent OCS waters in this area, and aggregations of fin whales are often reported between Block Island, Rhode Island, and Montauk Point, New York (Kenney and Vigness-Raposa 2010). They are typically centered along the 100-m isobath off the U.S. East Coast, but sightings have occurred in both shallower and deeper waters and they have been observed in Rhode Island state waters (Kenney and Vigness-Raposa 2010; RI-DEM 2020). Because of their regular occurrence in this area, a large number of whale watching boats also frequent this area (Kenney and Vigness-Raposa 2010). Fin whale sightings are greatest in the spring and summer, but they are known to occur in all four seasons in inner shelf waters (Kenney and Vigness-Raposa 2010). Therefore, it is highly likely that fin whales will be present within the RWEC corridor.

4.1.2.2 *Abundance*

The best abundance estimate available for the Western North Atlantic stock is 6,802 based on data from NOAA shipboard and aerial surveys and the 2016 NEFSC and Department of Fisheries and Oceans Canada (DFO) surveys (Hayes et al. 2020). A population trend analysis does not currently exist for this species because of insufficient data; however, based on photographic identification, the gross annual reproduction rate is 8% with a mean calving interval of 2.7 years (Agler et al. 1993; Hayes et al. 2020).

4.1.2.3 *Status*

Fin whales are listed as Endangered under the ESA and are listed as Vulnerable by the International Union for Conservation of Nature (IUCN) Red List (Hayes et al. 2020; IUCN 2020). This stock is listed as strategic and depleted under the MMPA due to its Endangered status (Hayes et al. 2020). Potential Biological Removal (PBR) for the western North Atlantic fin whale is 11 (Hayes et al. 2020). PBR being the product of minimum population size, one-half the maximum net productivity rate and recovery factor for endangered, depleted, threatened, or stocks of unknown status relative to the optimal sustainable population (OSP) (Hayes et al. 2020). Annual human-caused mortality and serious injury for the period between 2015 and 2019 was estimated to be 1.8 per year (Hayes et al. 2021). This estimate includes incidental fishery interactions (i.e., bycatch/entanglement) and vessel collisions, but other threats to fin whales include contaminants in their habitat and potential climate-related shifts in distribution of prey species (Hayes et al. 2020). There is no designated critical habitat for this species in or near the Project Area.

4.1.3 *Sei Whale (Balaenoptera borealis)*

Sei Whales are a baleen whale that can reach lengths of about 12–18 m (40–60 ft) (NMFS 2021n). This species has a long, sleek body that is dark bluish gray to black in color and pale underneath (NMFS 2021n). Their diet is comprised primarily of plankton, schooling fish, and cephalopods. Sei whales generally travel in small groups (two to five individuals), but larger groups are observed on feeding grounds (NMFS 2021n).

Although uncertainties still exist with distinguishing sei whale vocalizations during PAM surveys, they are known to produce short duration (0.7 to 2.2 sec) upsweeps and downsweeps between 20 and 600 Hz. SLs for these calls can range from 147 to 183 dB re 1 µPa @ 1 m SPL_{rms} (Erbe et al. 2017). No auditory sensitivity data are available for this species (Southall et al. 2019).

4.1.3.1 *Distribution*

Sei whales occur in all the world's oceans and migrate between feeding grounds in temperate and sub-polar regions to wintering grounds in lower latitudes (Kenney and Vigness-Raposa 2010; Hayes et al. 2020). In the Western North Atlantic, most of the population is concentrated in northerly waters along the Scotian Shelf. Sei whales are observed in the spring and summer, utilizing the northern portions of the U.S. Atlantic Exclusive Economic Zone (EEZ) as feeding grounds, including the Gulf of Maine and Georges Bank. The highest concentration is observed during the spring along the eastern margin of Georges Bank and in the Northeast Channel area along the southwestern edge of Georges Bank. Passive acoustic monitoring (PAM) conducted along the Atlantic Continental Shelf and Slope in 2004-2014 detected sei whales calls from south of Cape Hatteras to the Davis Strait with evidence of distinct seasonal and geographic patterns. Davis et al. (2020) detected peak call occurrence in northern latitudes during summer indicating feeding grounds ranging from Southern New England (SNE) through the Scotian Shelf. Sei whales were recorded in the southeast on Blake's Plateau in the winter months, but only on the offshore recorders indicating a more pelagic distribution in this region. Persistent year-round detections in SNE and the New York Bight highlight this as an important region for the species (Hayes et al. 2021). In general, sei whales are observed offshore with periodic incursions into more shallow waters for foraging (Hayes et al. 2020). Between October 2018 and February 2021, there was 1 sighting of 1 individual sei whales recorded during HRG surveys conducted within the area surrounding the Revolution Wind Lease Area and Export Cable Route all recorded in May 2020 (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

CETAP surveys observed sei whales along the continental shelf edge only during the spring (237 sightings) and summer (101 sightings) (CeTAP 1982). This agrees with the Kraus et al. (2016) study, where sei whales were also only observed in the RI-MA WEA during the spring and summer. No sightings were reported during the fall and winter. A small cluster of five individuals was reported south of Montauk Point, New York, and Block Island, Rhode Island, in July 1981, August 1982, and May 2003 (Kenney and Vigness-Raposa 2010). Davis et al. (2020) CETAP surveys observed sei whales along the continental shelf edge only during the spring (237 sightings) and summer (101 sightings) (CeTAP 1982). This agrees with the Kraus et al. (2016) study, where sei whales were also only observed in the RI-MA WEA during the spring and summer. No sightings were reported during the fall and winter. A small cluster of five individuals was reported south of Montauk Point, New York, and Block Island, Rhode Island, in July 1981, August 1982, and May 2003 (Kenney and Vigness-Raposa 2010). Davis et al. (2020) found acoustic detections of sei whales nearly year-round in Southern New England, but the greatest number of acoustic detections were recorded between March and July. Therefore, sei whales are expected to be present seasonally in the RFW, primarily in the spring and summer.

RWEC

Sei whales are primarily associated with the deeper waters along the continental shelf edge and are only observed in shallower waters when foraging. In the spring and summer, sei whales are seen in feeding habitats in Nova Scotia and Cape Cod north of the RWEC corridor (Hayes et al. 2020). Sei whales are therefore unlikely to be encountered in shallower waters along the RWEC corridor.

4.1.3.2 Abundance

Prior to 1999, sei whales in the Western North Atlantic were considered a single stock. Following the suggestion of the Scientific Committee of the International Whaling Commission (IWC), two separate stocks were identified for this species: a Nova Scotia stock and a Labrador Sea stock. Only the Nova Scotia stock can be found in U.S. waters, and the current abundance estimate for this population is 6,292 derived from recent surveys conducted between Halifax, Nova Scotia and Florida (Hayes et al. 2020). Population trends are not available for this stock because of insufficient data (Hayes et al. 2020).

4.1.3.3 Status

Sei whales are listed as Endangered under the ESA and by the IUCN Red List (Hayes et al. 2020; IUCN 2020). This stock is listed as strategic and depleted under the MMPA due to its Endangered status (Hayes et al. 2020). Annual human-caused mortality and serious injury from 2015 to 2019 was estimated to be 0.8 per year (Hayes et al. 2021). The PBR for this stock is 6.2 (Hayes et al. 2020). Like fin whales, major threats to sei whales include fishery interactions, vessel collisions, contaminants, and climate-related shifts in prey species (Hayes et al. 2020). There is no designated critical habitat for this species in or near the Project Area.

4.1.4 *North Atlantic Right Whale (Eubalaena glacialis)*

NARWs are among the rarest of all marine mammal species in the Atlantic Ocean. They average approximately 15 m (50 ft) in length (NMFS 2021l). They have stocky, black bodies with no dorsal fin, and bumpy, coarse patches of skin on their heads called callosities. NARWs feed mostly on zooplankton and copepods belonging to the *Calanus* and *Pseudocalanus* genera (Hayes et al. 2020). NARWs are slow-moving grazers that feed on dense concentrations of prey at or below the water's surface, as well as at depth (NMFS 2021l). Research suggests that NARWs must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx 1990). These dense zooplankton patches are a primary characteristic of the spring, summer, and fall NARW habitats (Kenney et al. 1995). NARWs are usually observed in groups of less than 12 individuals, and most often as single individuals or pairs. Larger groups may be observed in feeding or breeding areas (Jefferson et al. 2008).

NARW vocalizations most frequently observed during PAM studies include upsweeps rising from 30 to 450 Hz, often referred to as "upcalls," and broadband (30 to 8,400 Hz) pulses, or "gunshots," with SLs between 172 and 187 dB re 1 µPa @ 1 m SPL_{rms} (Erbe et al. 2017). However, recent studies have shown that mother-calf pairs reduce the amplitude of their calls in the calving grounds, possibly to avoid detection by predators (Parks et al. 2019). Modeling conducted using right whale ear morphology suggest that the best hearing sensitivity for this species is between 16 Hz and 25 kHz (Ketten et al. 2014; Southall et al. 2019).

4.1.4.1 Distribution

The NARW is a migratory species that travels from high-latitude feeding waters to low-latitude calving and breeding grounds, though this species has been observed feeding in winter in the mid-Atlantic region and has been recorded off the coast of New Jersey in all months of the year (Whitt et al. 2013). These whales undertake a seasonal migration from their northeast feeding grounds (generally spring, summer, and fall habitats) south along the US east coast to their calving grounds in the waters of the southeastern US (Kenney and Vigness-Raposa 2010).

NARWs are considered to be comprised of two separate stocks: Eastern and Western Atlantic stocks. The Eastern North Atlantic stock was largely extirpated by historical whaling (Aguilar 1986). NARWs in US waters belong to the Western Atlantic stock. This stock ranges primarily from calving grounds in coastal waters of the southeastern US to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence (Hayes et al. 2018). Since 2010, NARWs have been declining in and around once key habitats in the Gulf of Maine and the Bay of Fundy (Davies et al. 2015; Davis et al. 2017), while sightings have increased in other areas including Cape Cod Bay, Massachusetts Bay, the Mid-Atlantic Bight, and the Gulf of St. Lawrence (Whitt et al. 2013; Davis et al. 2017; Mayo et al. 2018; Davies and Brillant 2019; Ganley et al. 2019; Charif et al. 2020). An 8-year analysis of NARW sightings within SNE show that the NARW distribution has been shifting (Quintana-Rizzo et al. 2021). The study area of SNE (shores of Martha's Vineyard and Nantucket to and covering all the offshore wind lease sites of Massachusetts and Rhode Island) recorded sightings of NARWs in almost all months of the year with the highest sighting rates occurring during winter months into early spring (Quintana-Rizzo et al. 2021).

The winter distribution of NARWs is largely unknown; however, between October 2018 and February 2021, during recent HRG surveys within the area surrounding the Revolution Wind Lease Area and Export Cable Route, 4 sightings of 4 individual NARWs recorded in November 2020 and January 2021 (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021). Some evidence provided through acoustic monitoring suggests that not all individuals of the population participate in annual migrations, with a continuous presence of NARWs occupying their entire habitat rage throughout the year, particularly north of Cape Hatteras (Davis et al. 2017). These data also recognize changes in population distribution throughout the NARW habitat range that could be due to environmental or anthropogenic effects, a response to short-term changes in the environment, or a longer-term shift in the NARW distribution cycle (Davis et al. 2017). A clime-driven shift in the Gulf of Maine/western Scotian Shelf region occurred in 2010 and impacted the foraging environment, habitat use, and demography of the NARW population (Meyer-Gutbrod et al. 2021). In 2010, the number of NARWs returning to the traditional summertime foraging grounds in the eastern Gulf of Maine/Bay of Fundy region began to decline rapidly (Davies et al. 2019; Davies and Brillant 2019; Record et al. 2019). Despite considerable survey effort, the location of most of the population during the 2010-2014 foraging seasons are largely unknown; however, sporadic sightings and acoustic detections in Canadian waters suggest a dispersed distribution (Davies et al. 2019) and a significant increase in the presence of whales in the southern Gulf of St. Lawrence beginning in 2015 (Simard et al. 2019).

Surveys demonstrate the existence of seven areas where NARWs congregate seasonally: the coastal waters of the southeastern US, the Great South Channel, Jordan Basin, Georges Basin along the northeastern edge of Georges Bank, Cape Cod and Massachusetts Bays, the Bay of Fundy, and the Roseway Basin on the Scotian Shelf (Hayes et al. 2018). National Oceanic and Atmospheric Administration (NOAA) Fisheries has designated two critical habitat areas for the NARW under the ESA: the Gulf of Maine/Georges Bank region, and the southeast calving grounds from North Carolina to Florida (DoC 2016). Two additional critical habitat areas in Canadian waters, Grand Manan Basin and Roseway Basin, were identified in Canada's final recovery strategy for the NARW (Brown et al. 2009).

RWF

Kraus et al. (2016) only observed NARWs in the RI-MA WEA during the winter and spring. Davis et al. (2017) analyzed 10 years of passive acoustic data and found a similar trend in the data collected in Southern New England, where NARW detections were highest in the winter through early summer. However, the NARW has the potential to occur within the waters off Rhode Island and Massachusetts any time of the year. Typically, in this region, right whale sightings begin in December and continue through April. A total of 77 individuals were sighted in the WEA from October 2011 to June 2015. The greatest numbers are seen in March. The Muskeget Channel and south of Nantucket, both located within the RI-MA WEA, were also identified as right whale hotspots during the spring (Kraus et al. 2016). Seasonal management areas (SMAs) exist within the vicinity of the RWF, including the Great South Channel SMA (April 1–July 31), Cape Cod Bay SMA (January 1–May 15), Off Race Point SMA (March 1-April 30), and Block Island SMA (November 1–April 30) (NMFS 2020b); therefore, right whales are likely to occur within the RWF.

RWEC

NARWs are known to occur within both Rhode Island state and adjacent OCS waters year-round, although primarily in the winter and spring. Kraus et al. (2016) reported a seasonal cluster of NARWs south of Martha’s Vineyard, Massachusetts, and east of Nantucket, Massachusetts, during the winter. This area is also designated as the Block Island SMA from November 1 through April 20. Therefore, it is likely NARWs would occur seasonally within the RWEC corridor.

4.1.4.2 *Abundance*

The Western North Atlantic population size was estimated to be 368 individuals in the most recent draft 2020 SAR, which used data from the photo-identification database maintained by the New England Aquarium that were available in October 2019 (Hayes et al. 2020, 2021). However, the Right Whale Consortium 2020 Report Card estimates the NARW population to be 368 individuals (Pettis et al. 2021). A population trend analysis conducted on the abundance estimates from 1990 to 2011 suggest an increase at about 2.8% per year from an initial abundance estimate of 270 individuals in 1998 (Hayes et al. 2020). However, modeling conducted by Pace et al. (2017) showed a decline in annual abundance after 2011, which has likely continued as evidenced by the decrease in the abundance estimate from 451 in 2018 (Hayes et al. 2019) to 412 in 2020 (Hayes et al. 2020). Highly variable data exists regarding the productivity of this stock. Over time, there have been periodic swings of per capita birth rates (Hayes et al. 2020). Net productivity rates do not exist as the Western North Atlantic stock lacks any definitive population trend (Hayes et al. 2020).

4.1.4.3 *Status*

The NARW is listed as Endangered under the ESA and are listed as Critically Endangered by the IUCN Red List (Hayes et al. 2020; IUCN 2020; RI-DEM 2020). NARWs are considered to be the most critically Endangered large whales in the world (Hayes et al. 2019). The average annual human-related mortality/injury rate exceeds that of the calculated PBR of 0.7, classifying this population as strategic and depleted under the MMPA (Hayes et al. 2021). Estimated human-caused mortality and serious injury between 2015 and 2019 was 7.7 whales per year (Hayes et al. 2021). Using refined methods of Pettis et al. (2021), the estimated annual rate of total mortality for the period of 2014-2018 was 27.4, which is 3.4 times larger than the 8.15 total derived from reported mortality and serious injury for the same period (Hayes et al. 2021).

The predominant threats to NARWs are entanglement and vessel collisions. Available data from 2000 to 2017 suggest an increase in the percent of injuries and mortalities (per capita) caused by entanglement (Hayes et al. 2020). There have been elevated numbers of mortalities reported since 2017 and continuing to through 2021 totaling 34 dead NARWs which prompted NMFS to designate an Unusual Mortality Event (UME) for NARWs (NMFS 2021c). This includes 21 dead stranded whales in Canada and 13 in the United States. The leading category for the cause of death for this UME is "human interaction", specifically from entanglements or vessel strikes" (NMFS 2021c). In addition to the documented mortalities, since 2017, seventeen individuals have been documented with serious injury resulting from entanglement and two have been reported with serious injury resulting from a vessel strike (NMFS 2021c).

To protect this species from ship strikes, NOAA Fisheries designated SMAs in US waters in 2008 (73 FR 60173 2008). All vessels greater than 19.8 m (65 ft) in overall length must operate at speeds of 10 knots (5.1 meters per second [m/s]) or less within these areas from November 1 through April 30 when NARWs are most likely to pass through these waters. In addition, the rule provides for the establishment of Dynamic Management Areas (DMAs) when and where NARWs are sighted outside SMAs. DMAs are generally in effect for two weeks and the 10 knots (5.1 m/s) or less speed restriction is voluntary.

4.1.5 *Minke Whale (Balaenoptera acutorostrata)*

Minke whales are a baleen whale species reaching 10 m (35 ft) in length. The minke whale is common and widely distributed within the US Atlantic EEZ and is the third most abundant great whale (any of the larger marine mammals of the order Cetacea) in the EEZ (CeTAP 1982). A prominent morphological feature of the minke whale is the large, pointed median ridge on top of the rostrum. The body is dark gray to black with a pale belly, and frequently shows pale areas on the sides that may extend up onto the back. The flippers are smooth and taper to a point, and the middle third of each flipper has a conspicuous bright white band that can be distinguished during visual surveys (Kenney and Vigness-Raposa 2010). Its diet is comprised primarily of crustaceans, schooling fish, and copepods. Minke Whales generally travel in small groups (one to three individuals), but larger groups have been observed on feeding grounds (NMFS 2021k).

In the North Atlantic, minke whales commonly produce pulse trains lasting 10 to 70 sec with a frequency range between 10 and 800 Hz. SLs for this call type have been reported between 159 and 176 dB re 1 µPa @ 1 m $\mathrm{SPL}_{\mathrm{rms}}$ (Erbe et al. 2017). Some minke whales also produce a unique "boing" sound which is a train of rapid pulses often described as an initial pulse followed by an undulating tonal (Rankin and Barlow 2005; Erbe et al. 2017). The "boing" ranges from 1 to 5 kHz with an SLs of approximately 150 dB re 1 µPa @ 1 m $\mathrm{SPL}_{\mathrm{rms}}$ (Rankin and Barlow 2005; Erbe et al. 2017). Auditory sensitivity for this species based on anatomical modeling of minke whale ear morphology is best between 10 Hz and 34 kHz (Ketten et al. 2014; Southall et al. 2019).

4.1.5.1 <u>Distribution</u>

Minke whales prefer the colder waters in northern and southern latitudes, but they can be found in every ocean in the world. Available data suggest that minke whales are distributed in shallower waters along the continental shelf between the spring and fall and are located in deeper oceanic waters between the winter and spring (Hayes et al. 2020). They are most abundant in New England waters in the spring, summer, and early fall (Hayes et al. 2020). Acoustic detections show that minke whales migrate sound in mid-October to early November and return from wintering grounds starting in March through early April

(Risch et al. 2014). Between October 2018 and February 2021, there were 13 sightings of 16 individual minke whales recorded during recent HRG surveys within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens and Mills 2021).

RWF

During previous studies conducted in the RI-MA WEA, 103 minke whales were sighted within the area (Kraus et al. 2016). Spring observations included the most individuals followed by summer, and fall. Minke whales are therefore likely to occur in the spring and summer within the RWF area.

RWEC

Minke whales have been sighted offshore Rhode Island in both state and OCS waters in all four seasons (Kenney and Vigness-Raposa 2010). A large proportion of these sightings were reported from whale watching boats. A dense concentration was seen between Block Island, Rhode Island, and Montauk Point, New York, in the spring and summer (Kenney and Vigness-Raposa 2010), making it likely that this species could occur within the RWEC.

4.1.5.2 Abundance

The best available current global abundance estimates for the common minke whale, compiled by the IUCN Red List, is around 200,000 (Graham and Cooke 2008). The most recent population estimate for the Canadian East Coast stock which occurs in the Project Area is 21,968 minke whales, derived from surveys conducted by NOAA and the Department of Fisheries and Oceans Canada between Labrador and central Virginia (Hayes et al. 2020). There are no current population trends or net productivity rates for this species due to insufficient data.

4.1.5.3 Status

Minke whales are not listed under the ESA or classified as strategic under the MMPA. They are list as Least Concern on the IUCN Red List (Hayes et al. 2020; IUCN 2020). The estimated annual human-caused mortality and serious injury from 2014 to 2018 was 10.55 per year attributed to fishery interactions, vessel strikes, and non-fishery entanglement in both the U.S. and Canada (Hayes et al. 2020), and a UME was declared for this species in January 2017, which is ongoing (NMFS 2021b). As of June 2021, a total of 107 strandings have been reported, with 7 of those occurring in Rhode Island (NMFS 2021b). The PBR for this stock is estimated to be 170 (Hayes et al. 2020). Minke whales may also be vulnerable to climate-related changes in prey distribution, although the extent of this effect on minke whales remains uncertain (Hayes et al. 2020). No designated critical habitat for this stock currently exists in the Project Area.

4.1.6 *Humpback Whale (Megaptera novaengilae)*

Humpback whale females are larger than males and can reach lengths of up to 18 m (60 ft) (NMFS 2021i). Humpback Whale body coloration is primarily dark gray, but individuals have a variable amount of white on their pectoral fins, belly, and flukes. These distinct coloration patterns are used by scientists to identify individuals. These baleen whales feed on small prey often found in large concentrations, including krill and fish such as Herring and Sand Lance (Kenney and Vigness-Raposa 2010). Humpback whales use unique behaviors, including bubble nets, bubble clouds, and flicking of their flukes and fins, to herd and capture prey (NMFS 1991).

During migration and breeding seasons, male humpback whales are often recorded producing vocalizations arranged into repetitive sequences termed “songs” that can last for hours or even days. These songs have been well studied in the literature to document changes over time and geographic differences. Generally, the frequencies produced during these songs range from 20 Hz to over 24 kHz. Most of the energy is focused between 50 and 1,000 Hz and reported SLs range from 151 to 189 dB re 1 µPa @ 1 m SPL_{rms} (Erbe et al. 2017). Other calls produced by humpbacks, both male and female, include pulses, moans, and grunts used for foraging and communication. These calls are lower frequency (under 2 kHz) with SLs ranging from 162 to 190 dB re 1 µPa @ 1 m SPL_{rms} (Thompson et al. 1986; Erbe et al. 2017). Anatomical modeling based on humpback whale ear morphology indicate that their best hearing sensitivity is between 18 Hz and 15 kHz (Ketten et al. 2014; Southall et al. 2019).

4.1.6.1 Distribution

The humpback whale can be found worldwide in all major oceans from the equator to sub-polar latitudes. In the summer, humpbacks are found in higher latitudes feeding in the Gulf of Maine and Gulf of Alaska. During the winter months, humpbacks migrate to calving grounds in subtropical or tropical waters, such as the Dominican Republic in the Atlantic and Hawaiian Islands in the Pacific (Hayes et al. 2020). Humpback whales from the North Atlantic feeding areas mate and calve in the West Indies (Hayes et al. 2020). In the summer, humpback whales in the Western North Atlantic are typically observed in the Gulf of Maine and along the Scotian Shelf, and there have also been numerous winter sightings in the Southeastern U.S. (Hayes et al. 2020). Feeding behavior has also been observed in New England off Long Island, New York, and survey data from NOAA suggests a potential increase in humpback whale abundance off New Jersey and New York (Hayes et al. 2020). Between October 2018 and February 2021, 53 sightings of 78 individual humpback whales were recorded during recent HRG surveys within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Kraus et al. (2016) reported humpback whale sightings in the RI-MA WEA during all seasons, with peak abundance during the spring and early summer, but their presence within the region varies between years. Increased presence of sand lance (*Ammodytes* spp.) appear to correlate with the years in which most whales were observed, suggesting that humpback whale distribution and occurrences could largely be influenced by prey availability (Kenney and Vigness-Raposa 2010; 2016)appear to correlate with the years in which most whales were observed, suggesting that humpback whale distribution and occurrences could largely be influenced by prey availability (Kenney and Vigness-Raposa 2010). The greatest number of sightings of humpbacks in the RI-MA WEA occurred during April (33 sightings); their presence increased starting in March and continued through July. Seasonal abundance estimates of humpback whales in the RI-MA WEA range from 0 to 41 (Kraus et al. 2016), with higher estimates observed during the spring and summer. Acoustic detections within Southern New England analyzed by Davis et al. (2020) found the greatest number of acoustic detections in the winter and spring with a noticeable decrease in acoustic detections during most summer and fall months. Based on these data, humpback whales are likely to occur in the RWF area, predominantly during winter, spring, and early summer.

RWEC

In the 1980s, numerous sightings of humpbacks were reported between Long Island, New York, and Martha’s Vineyard, Massachusetts, by Montauk and Galilee whale watching boats. Montauk boats reported 2 sightings in 1986 and 63 sightings in 1987 (Kenney and Vigness-Raposa 2010). Recently, multiple humpbacks were reported feeding off Long Island, New York, during July 2016 and near New York City during November and December 2016 (Hayes et al. 2020). Humpback strandings were also reported along the southern shore of eastern Long Island, New York, in February 1992, November 1992, October 1993, August 1997, and April 2004.

Humpbacks are known to occur within Rhode Island state and adjacent OCS waters; however, their presence is relatively unpredictable and may be strongly influenced by prey availability (Kenney and Vigness-Raposa 2010). They are expected to have a greater presence in the offshore portions of the RWEC corridor, but have been observed in state waters and therefore could be encountered anywhere along the RWEC corridor.

4.1.6.2 *Abundance*

The best available abundance estimate of the Gulf of Maine stock is 1,396, derived from modeled sighting histories constructed using photo-identification data collected through October 2016 (Hayes et al. 2020). Available data indicate that this stock is characterized by a positive population trend, with an estimated increase in abundance of 2.8% per year (Hayes et al. 2020).

4.1.6.3 *Status*

NMFS revised the listing status for humpback whales under the ESA in 2016 (81 FR 62260 2016). Globally, there are 14 distinct population segments (DPSs) recognized for humpback whales, four of which are listed as Endangered. The Gulf of Maine stock (formerly known as the Western North Atlantic stock) which occurs in the Project Area is considered non-strategic under the MMPA and does not coincide with any ESA-list DPS (Hayes et al. 2020). This stock is considered non-strategic because the detected level of U.S. fishery-caused mortality and serious injury derived from the available records do not exceed the calculated PBR of 22, with a set recovery factor at 0.5 (Hayes et al. 2019). Because the observed mortality is estimated to be only 20% of all mortality, total annual mortality may be 60-70 animals in this stock (Hayes et al. 2019). If anthropogenic causes are responsible for as little as 31% of potential total mortality, this stock could be over PBR. While detected mortalities yield an estimated minimum fraction anthropogenic mortality at 0.85, additional research is being done before apportioning mortality to anthropogenic versus natural causes for undetected mortalities and making a potential change to the MMPA status of this stock. A UME was declared for this species in January 2016, which as of June 2021 has resulted in 150 stranded humpback whales, with 6 of those occurring in Rhode Island (Hayes et al. 2020; NMFS 2021a). Major threats to humpback whales include vessel strikes, entanglement, and climate-related shifts in prey distribution (Hayes et al. 2020). There is no designated critical habitat for this stock in the Project Area.

4.2 Odontocetes

4.2.1 *Sperm Whale (Physeter macrocephalus)*

The sperm whale is the largest of all toothed whales; males can reach 16 m (52 ft) in length and weigh over 40,823 kilograms (“kg” [45 US tons]), and females can attain lengths of up to 11 m (36 ft) and weigh over 13,607 kg (15 tons) (Whitehead 2009). Sperm whales have extremely large heads, which account for 25–35% of the total length of the animal. This species tends to be uniformly dark gray in color, though lighter spots may be present on the ventral surface. sperm whales frequently dive to depths of 400 m (1,300 ft) in search of their prey, which includes large squid, fishes, octopus, sharks, and skates

(Whitehead 2009). This species can remain submerged for over an hour and reach depths as great as 1,000 m (3,280 ft). Sperm whales form stable social groups and exhibit a geographic social structure; females and juveniles form mixed groups and primarily reside in tropical and subtropical waters, whereas males are more solitary and wide-ranging and occur at higher latitudes (Whitehead 2002; Whitehead 2003).

Unlike mysticete whales that produce various types of calls used solely for communication, sperm whales produce clicks that are used for echolocation and foraging as well as communication (Erbe et al. 2017). Sperm whale clicks have been grouped into five classes based on the click rate, or number of clicks per second; these include “squeals,” “creaks,” “usual clicks,” “slow clicks,” and “codas.” In general, these clicks are broadband sounds ranging from 100 Hz to 30 kHz with peak energy centered around 15 kHz. Depending on the class, SLs for sperm whale calls range between approximately 166 and 236 dB re 1 µPa @ 1 m SPL_{rms} (Erbe et al. 2017). Hearing sensitivity data for this species are currently unavailable (Southall et al. 2019).

4.2.1.1 *Distribution*

Sperm whales can be found throughout the world’s oceans. They can be found near the edge of the ice pack in both hemispheres and are also common along the equator. The North Atlantic stock is distributed mainly along the continental shelf-edge, over the continental slope, and mid-ocean regions, where they prefer water depths of 600 m or more and are less common in waters <300 m deep (Waring et al. 2015; Hayes et al. 2020). In the winter, sperm whales are observed east and northeast of Cape Hatteras. In the spring, sperm whales are more widely distributed throughout the Mid-Atlantic Bight and southern portions of George’s Bank (Hayes et al. 2020). In the summer, sperm whale distribution is similar to the spring, but they are more widespread in Georges Bank and the Northeast Channel region and are also observed inshore of the 100-m isobath south of New England (Hayes et al. 2020). Sperm whale occurrence on the continental shelf in areas south of New England is at its highest in the fall (Hayes et al. 2020).

RWF

Sperm whales were the fifth most commonly sighted large whale in the CETAP study area and were observed in all four seasons. The study sighted 341 individuals, which accounted for only 8% of the total large whale sightings during their survey period (CeTAP 1982). Kraus et al. (2016) reported sightings of sperm whales in the RI-MA WEA during the summer and fall months; five individuals in August 2012, one in September 2012, and three in June 2015. There have also been occasional strandings in Massachusetts and Long Island (Kenney and Vigness-Raposa 2010). Although accounts of sperm whales in the area are low, their occurrence within the RWF and surrounding waters is possible.

RWEC

CETAP reported that the distribution of sperm whales primarily centers at about the 1,000-m depth contour. However, their distribution can also extend shoreward, inshore of the 100-m contour, particularly in the summer and fall (CeTAP 1982; Hayes et al. 2020). Although relatively infrequent, sightings have been reported in waters as shallow as 60 m. Southern New England is one of the few locations in the world in which sperm whales frequent inshore areas (Kenney and Vigness-Raposa 2010). Many reported sightings take place in a narrow band just south of Block Island, Rhode Island, Martha’s Vineyard, Massachusetts, and Nantucket, Massachusetts, from May through November, in which the RWEC corridor would intersect. This high occurrence of sperm whales is believed to be related to the presence of spawning squid (CeTAP 1982). Given their preference for deeper waters, sperm whales are only likely to occur in offshore areas of the RWEC corridor, but may also occur in shallower waters seasonally in the summer and fall.

4.2.1.2 *Abundance*

The IWC recognizes only one stock of sperm whales for the North Atlantic, and Reeves and Whitehead (1997) and Dufault et al. (1999) suggest that sperm whale populations lack clear geographic structure. The best and most recent abundance estimate based on 2016 surveys conducted between the lower Bay of Fundy and Florida is 4,349 (Hayes et al. 2020). No population trend analysis is available for this stock.

4.2.1.3 *Status*

The Western North Atlantic stock is considered strategic under the MMPA due to its listing as Endangered under the ESA, and the global population is listed as Vulnerable on the IUCN Red List (Hayes et al. 2020; IUCN 2020). Between 2013 and 2017, 12 sperm whale strandings were documented along the U.S. East Coast, but none of the strandings showed evidence of human interactions (Hayes et al. 2020). A moratorium on sperm whale hunting was adopted in 1986 and currently no hunting is allowed for any purposes in the North Atlantic. Occasionally, sperm whales will become entangled in fishing gear or be struck by ships off the east coast of the U.S. However, this rate of mortality is not believed to have biologically significant impacts. The current PBR for this stock is 6.9, and because the total estimated human-caused mortality and serious injury is <10% of this calculated PBR, it is considered insignificant (Hayes et al. 2020). Other threats to sperm whales include contaminants, climate-related changes in prey distribution, and anthropogenic noise, although the severity of these threats on sperm whales is currently unknown (Hayes et al. 2020). There is no designated critical habitat for this population in the Project Area.

4.2.2 *Long-Finned Pilot Whale (Globicephala melas)*

Two species of pilot whale occur within the Western North Atlantic: the long-finned pilot whale and the short-finned pilot whale. These species are difficult to differentiate at sea and cannot be reliably distinguished during most surveys (Rone et al. 2012; Hayes et al. 2017). Both short-finned and long-finned pilot whales are similar in coloration and body shape. Pilot Whales have bulbous heads, are dark gray, brown, or black in color, and can reach approximately 7.3 m (25 ft) in length (NMFS 2021j). However, long-finned pilot whales can be distinguished by their long flippers, which are 18 to 27% of the body length with a pointed tip and angled leading edge (Jefferson et al. 1993). These whales form large, relatively stable aggregations that appear to be maternally determined (ACS 2018). Pilot whales feed primarily on squid, although they also eat small to medium-sized fish and octopus when available (NMFS 2021j).

Like dolphin species, long-finned pilot whales can produce whistles and burst-pulses used for foraging and communication. Whistles typically range in frequency from 1 to 11 kHz while burst-pulses cover a broader frequency range from 100 Hz to 22 kHz (Erbe et al. 2017). Auditory evoked potential (AEP) measurements conducted by Pacini et al. (2010) indicate that the hearing sensitivity for this species ranges from <4 kHz to 89 kHz.

4.2.2.1 *Distribution*

Because it is difficult to differentiate between the two pilot whale species in the field, sightings are usually reported to genus level only (CeTAP 1982; Hayes et al. 2020). However, short-finned pilot whales are a southern or tropical species and pilot whale sightings above approximately 42° N are most likely long-finned pilot whales. Short-finned pilot whale occurrence in the Project Area is considered rare (CeTAP 1982; Hayes et al. 2020). Long-finned pilot whales are distributed along the continental shelf waters off the Northeastern U.S. in the winter and early spring. By late spring, pilot whales migrate into more northern waters including Georges Bank and the Gulf of Maine and will remain there until fall (Hayes et al. 2020). The two species' ranges overlap spatially along the shelf break between the southern flank of Georges Bank and New Jersey (Rone et al. 2012; Hayes et al. 2019).

RWF

CETAP surveys reported long-finned pilot whales as the third most commonly sighted small whale in their study area with 12,438 individuals (CeTAP 1982). Long-finned pilot whales have been observed in OCS waters off Rhode Island in all four seasons, with peak occurrences in the spring. There are 43 records of long-finned pilot whales and 226 records of non-specific pilot whales in this area. Nine sightings during the summer and three sightings in the spring were reported from whale watching data for pilot whales (Kenney and Vigness-Raposa 2010).

Within the RI-MA WEA, no sightings of pilot whales were observed during the summer, fall, or winter (Kraus et al. 2016). Long-finned pilot whales are relatively common in the area; therefore, they may potentially occur in the RWF area. However, the likelihood of occurrences would be highest in the spring.

RWEC

Long-finned pilot whales prefer deep pelagic temperate to subpolar oceanic waters; therefore, they are not likely to occur within the RWEC corridor (Hayes et al. 2020).

4.2.2.2 *Abundance*

The best available estimate of long-finned pilot whales in the Western North Atlantic is 39,215 based on recent surveys covering waters between Labrador and Central Virginia (Hayes et al. 2020). A trend analysis has not been conducted for this stock due to the relatively imprecise abundance estimates (Hayes et al. 2020).

4.2.2.3 *Status*

Long-finned pilot whales are not listed under the ESA and are classified as Least Concern by the IUCN Red List (Hayes et al. 2020; IUCN 2020). Long-finned pilot whales have a propensity to mass strand in U.S. waters, although the role of human activity in these strandings remains unknown (Hayes et al. 2020). The PBR for this stock is 306, and the annual human-caused mortality and serious injury was estimated to be 9 whales between 2015 and 2019 (Hayes et al. 2021). Threats to this population include entanglement in fishing gear, contaminants, climate-related shifts in prey distribution, and anthropogenic noise (Hayes et al. 2020). There is no designated critical habitat for this stock in the Project Area.

4.2.3 *Atlantic Spotted Dolphin (Stenella frontalis)*

Atlantic spotted dolphins can reach 2.3 m (7.5 ft) in length and their body shape resembles that of a common bottlenose dolphin (Jefferson et al. 2008). They start out with no spotting and resemble slender bottlenose dolphins. Large spotting develops as the animals age making it easier to distinguish them in visual surveys (Jefferson et al. 2008).

Atlantic spotted dolphins have an estimated auditory bandwidth of 150 Hz to 160 kHz and vocalizations typically range from 100 Hz to 130 kHz (Navy 2007; Southall et al. 2007a). No auditory sensitivity data are available for this species (Southall et al. 2019).

4.2.3.1 *Distribution*

Atlantic spotted dolphins are found in tropical and warm temperate waters. In the Western North Atlantic, their distribution ranges from the Northeastern U.S. to the Gulf of Mexico and the Caribbean to Venezuela (Hayes et al. 2020). They are regularly seen in continental shelf and slope waters. There are two Atlantic spotted dolphin ecotypes which may be distinct sub-species. The larger heavily spotted ecotype inhabits shelf waters inside or near the 200-m isobath south of Cape Hatteras. The smaller form is less spotted and is found further offshore and only occurs in the Atlantic. Recent genetic data also suggests that they may be genetically distinct populations (Hayes et al. 2020). Both ecotypes can occur in the Northeastern U.S.; however, they are difficult to differentiate at sea and are therefore not distinguished in this assessment.

RWF

There are few reported occurrences of spotted dolphins (*Stenella* spp.) in the Project Area. CETAP described spotted dolphins as the seventh most commonly sighted cetaceans in the study area, with 126 sightings over the course of a 3-year study. The 1982 CETAP data observed 40 individuals south of Block Island, Rhode Island (CeTAP 1982). NMFS shipboard surveys conducted during June to August between central Virginia and the Lower Bay of Fundy reported 542 to 860 individual sightings from two separate visual teams (Palka et al. 2017). Atlantic spotted dolphins tend to be a more subtropical and offshore species, so while they may be encountered in the RWF area, this would be an uncommon occurrence.

RWEC

Atlantic spotted dolphins north of Cape Hatteras tend to be observed near or offshore of the continental slope; therefore, their presence in the RWEC corridor is unlikely.

4.2.3.2 *Abundance*

The best population estimate available for this species is 39,921 based on surveys conducted in summer 2016 between the lower Bay of Fundy and Florida (Hayes et al. 2020). A population trend analysis of available abundance estimates from 2004, 2011, and 2016 indicate a linear decrease in abundance, however interannual variability in abundance is a key uncertainty in this trend analysis (Hayes et al. 2020).

4.2.3.3 *Status*

Atlantic spotted dolphins are not listed under the ESA and are classified as Least Concern by the IUCN Red List (Hayes et al. 2020; IUCN 2020). The PBR for this stock is 320, and the estimated annual human-caused mortality and serious injury from 2013 to 2017 was presumed to be zero (Hayes et al. 2020). Twenty-one Atlantic spotted dolphins were reported stranded between North Carolina and Florida during this period; however, no definitive evidence of human interaction was found (Hayes et al. 2020). Major threats to this population include anthropogenic noise; offshore development, particularly south of Cape Hatteras where this species inhabits inshore shelf waters; contaminants; and climate-related shifts in prey distribution (Hayes et al. 2020). There is no designated critical habitat for this stock in the Project Area.

4.2.4 *Atlantic White-Sided Dolphin (Lagenorhynchus acutus)*

The Atlantic white-sided dolphin is robust and attains a body length of approximately 2.8 m (9 ft) (Jefferson et al. 2008). It is characterized by a strongly "keeled" tail stock and distinctive, white-sided color pattern (BOEM 2014a). Atlantic white-sided dolphins form groups of varying sizes, ranging from a few individuals to over 500 (NMFS 2021d). They feed mostly on small schooling fishes, shrimps, and squids, and are often observed feeding in mixed-species groups with pilot whales and other dolphin species (Jefferson et al. 2008; Cipriano 2018).

Like most dolphin species, Atlantic white-sided dolphins produce clicks, buzzes, calls, and whistles. Their clicks are broadband sounds ranging from 30 to 40 kHz that can contain frequencies over 100 kHz and are often produced during foraging and for orientation within the water column. Buzzes and calls are not as well studied, and they may be used for socialization as well as foraging. Whistles are primarily for social communication and group cohesion and are characterized by a down sweep followed by an upsweep with an approximate starting frequency of 20 kHz and ending frequency of 17 kHz (Hamran 2014). No hearing sensitivity data are currently available for this species (Southall et al. 2019).

4.2.4.1 Distribution

Atlantic white-sided dolphins migrate between the temperate and polar waters of the North Atlantic Ocean, but usually maintain migration routes over outer shelf or slope waters. This is the most abundant dolphin in the Gulf of Maine and the Gulf of St. Lawrence; they are rarely seen off the coast of Nova Scotia (Kenney and Vigness-Raposa 2010). The species occurs year-round between central West Greenland to North Carolina primarily in continental shelf waters to the 100-m depth contour (Hayes et al. 2020). There are seasonal shifts in the distribution of the Atlantic white-sided dolphins off the northeastern US coast, with low abundance in winter between Georges Basin and Jeffrey's Ledge and very high abundance in the Gulf of Maine during spring. During summer, Atlantic white-sided dolphins are most abundant between Cape Cod and the lower Bay of Funday. And during fall, the distribution of the species is similar to that in summer, with less overall abundance (DoN (U.S. Department of the Navy) 2005). Behaviorally, this species is highly social, but not as demonstrative as some other common dolphins. They typically form pods of around 30 to 150 individuals but have also been seen in very large pods of 500 to 2,000 individuals (Hayes et al. 2020). It is common to find these pods associated with the presence of other white-beaked dolphins, pilot whales, fin whales, and humpback whales. Between October 2018 and February 2021, one sighting of 18 individual Atlantic white-sided dolphins was recorded in May 2020 during recent HRG surveys conducted within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Seasonal abundances off the Northeast U.S. in spring through fall are estimated to be 38,000 to 42,000 animals (CeTAP 1982; Kenney and Vigness-Raposa 2010). Over the course of BOEM's study in the RI-MA WEA, 185 individual Atlantic white-sided dolphins were sighted within the Lease Area; most were observed during summer (112 sightings) followed by fall (70 sightings) (Kraus et al. 2016). Atlantic white-sided dolphins are one of the most likely delphinids that would occur seasonally within the RWF area.

RWEC

Atlantic white-sided dolphins are one of three odontocetes primarily inhabiting OCS waters shoreward of the 100-m depth contour (CeTAP 1982; Hayes et al. 2020). Most of the sightings (90%) were seen within an estimated depth range of 38 to 271 m. Sightings are concentrated in coastal waters near Cape May, New Jersey, and in shallow waters within the Gulf of Maine (CeTAP 1982). The Gulf of Maine population is commonly seen from the Hudson Canyon to Georges Bank. Sightings south of Georges Bank and Hudson Canyon occur year-round; however, at lower densities (Hayes et al. 2020).

Offshore Rhode Island, Atlantic white-sided dolphins are common in OCS waters, with a slight tendency to occur in shallower state waters in the spring (Kenney and Vigness-Raposa 2010). Records indicate that there is an aggregation of sightings southeast of Montauk Point, New York, during the spring and summer. Strandings of white-sided dolphins in Rhode Island are relatively rare; from 2001 to 2005, there was an average of 1.2 strandings per year (Kenney and Vigness-Raposa 2010). Atlantic white-sided dolphins occur in seasonably high numbers in nearshore areas during the spring and summer; therefore, they could potentially occur within the RWEC corridor.

4.2.4.2 Abundance

The best abundance estimate currently available for the Western North Atlantic stock is 93,233 based on surveys conducted between Labrador to Florida (Hayes et al. 2020). A trend analysis is not currently available for this stock due to insufficient data (Hayes et al. 2020).

4.2.4.3 Status

Atlantic white-sided dolphins are not listed under the ESA or considered a strategic stock under the MMPA. They are classified as Least Concern on the IUCN Red List (Hayes et al. 2020; IUCN 2020). The PBR for this stock is 544 and the annual rate of human-caused mortality and serious injury from 2015 to 2019 was estimated to be 27 dolphins (Hayes et al. 2021). This estimate is based on observed fishery interactions, but Atlantic white-sided dolphins are also threatened by contaminants in their habitat, and climate-related shifts in prey distribution (Hayes et al. 2020). There is no designated critical habitat for this stock in the Project Area.

4.2.5 *Short-Beaked Common Dolphin (Delphinus delphis delphis)*

Two common dolphin species were previously recognized: the long-beaked common dolphin (*Delphinus capensis*) and the short-beaked common dolphin (*Delphinus delphis)*; however, Cunha et al. (2015) summarized the relevant data and analyses along with additional molecular data and analysis, and recommended that the long-beaked common dolphin not be further recognized in the Atlantic Ocean. Short-beaked common dolphins can reach 2.7 m (9 ft) in length and have a distinct color pattern with a white ventral patch, yellow or tan flank, and dark gray dorsal “cape” (NMFS 2021o). This species feeds on schooling fish and squid found near the surface at night (NMFS 2021o). They have been known to feed on fish escaping from fishermen’s nets or fish that are discarded from boats (NMFS 1993). This highly social and energetic species usually travels in large pods consisting of 50 to >1,000 individuals (Cañadas and Hammond 2008). The common dolphin can frequently be seen performing acrobatics and interacting with large vessels and other marine mammals.

Common dolphin clicks are broadband sounds between 17 and 45 kHz with peak energy between 23 and 67 kHz. Burst-pulse sounds are typically between 2 and 14 kHz while the key frequencies of common dolphin whistles are between 3 and 24 kHz (Erbe et al. 2017). No hearing sensitivity data are available for this species (Southall et al. 2019).

4.2.5.1 *Distribution*

Short-beaked common dolphins in the US Atlantic EEZ belong to the Western North Atlantic stock, generally occurring from Cape Hatteras, North Carolina to the Scotian Shelf (Hayes et al. 2018). Short-beaked common dolphins are a highly seasonal, migratory species. In the US Atlantic EEZ this species is distributed along the continental shelf between the 200–2,000 m (650–6,561.6 ft) isobaths and is associated with Gulf Stream features (CeTAP 1982; Payne and Selzer 1989; Hamazaki 2002; Hayes et al. 2018). Short-beaked common dolphins occur from Cape Hatteras northeast to Georges Bank (35° to 42°N) during mid-January to May and move as far north as the Scotian Shelf from mid-summer to fall (Payne and Selzer 1989; Hayes et al. 2020). Migration onto the Scotian Shelf and continental shelf off Newfoundland occurs when water temperatures exceed 11°C (51.8°F) (Sergeant et al. 1970; Gowans and Whitehead 1995). Breeding usually takes place between the months of June and September and females have an estimated calving interval of two to three years (Hayes et al. 2018). Between October 2018 and February 2021, 560 sightings of 5,634 individual short-beaked common dolphins were recorded during recent HRG surveys within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Kraus et al. (2016) observed 3,896 common dolphins within the RI-MA WEA. Most were observed during summer surveys followed by fall, winter, then spring. This was the highest number of individual sightings of all the small cetaceans; therefore, it is anticipated to be one of the most frequent delphinids to occur seasonally within the RWF area.

RWEC

Since the common dolphin has a wide distribution and can be found in both nearshore and offshore waters of the Pacific and Atlantic Oceans, they could potentially occur within the RWEC corridor.

4.2.5.2 *Abundance*

The best population estimate in the US Atlantic EEZ for the Western North Atlantic short-beaked common dolphin is 70,184 (Hayes et al. 2018) while Roberts et al. (2016) habitat-based density models provide an abundance estimate of 86,098 short-beaked common dolphins in the US Atlantic EEZ. The current best abundance estimate for the entire Western North Atlantic stock is 172,974 based on recent surveys conducted between Newfoundland and Florida (Hayes et al. 2020). A trend analysis was not conducted for this stock because of the imprecise abundance estimate and long survey intervals (Hayes et al. 2020).

4.2.5.3 *Status*

The common dolphin is not listed under the ESA and is classified as Least Concern by the IUCN Red List (Hayes et al. 2020; IUCN 2020). Historically, this species was hunted in large numbers for food and oil. Currently, they continue to suffer incidental mortality from vessel collisions and Eastern North American fishing activities within the Atlantic, most prominently yellowfin tuna (*Thunnus albacares*) nets, driftnets, and bottom-set gillnets (Kraus et al. 2016; Hayes et al. 2020). The common dolphin faces anthropogenic threats because of its utilization of nearshore habitat and highly social nature, but it is not considered a strategic stock under the MMPA because the average annual human-caused mortality and serious injury does not exceed the calculated PBR of 1,452 for this stock (Hayes et al. 2020). The annual estimated human-caused mortality and serious injury for 2015 to 2019 was 390.4, which included fishery-interactions and research takes (Hayes et al. 2021). Other threats to this species include contaminants in their habitat and climate-related changes in prey distribution (Hayes et al. 2020). There is no designated critical habitat for this stock in the Project Area.

4.2.6 *Risso's Dolphin (Grampus griseus)*

The Risso's Dolphin attains a body length of approximately 2.6–4 m (8.5–13 ft) (NMFS 2021m). Unlike most other dolphins, Risso's dolphins have blunt heads without distinct beaks. Coloration for this species ranges from dark to light grey. Adult Risso's dolphins are typically covered in white scratches and spots that can be used to identify the species in field surveys (Jefferson et al. 1993). The Risso's dolphin forms groups ranging from 10 to 30 individuals and primarily feed on squid, but also fish such as anchovies (*Engraulidae*), krill, and other cephalopods (NMFS 2021m).

Whistles for this species have frequencies ranging from around 4 kHz to over 22 kHz with estimated SLs between 163 and 210 dB re 1 µPa @ 1 m SPL_{rms} (Erbe et al. 2017). Studies using both behavioral and AEP methods have been conducted for this species, which show greatest auditory sensitivity between <4 kHz to >100 kHz (Nachtigal et al. 1995; Nachtigal et al. 2005).

4.2.6.1 *Distribution*

Risso's dolphins in the US Atlantic EEZ are part of the Western North Atlantic Stock. The Western North Atlantic stock of Risso's dolphins inhabits waters from Florida to eastern Newfoundland (Leatherwood et al. 1976; Baird and Stacey 1991). Off the Northeastern U.S. Coast, Risso's dolphins are primarily concentrated along the continental shelf edge, but they can also be found swimming in shallower waters to the mid-shelf (Hayes et al. 2020). During spring, summer, and fall, Risso's dolphins are distributed along the continental shelf edge from Cape Hatteras northward to Georges Bank (CeTAP 1982; Payne et al. 1984). During the winter, the distribution extends outward into oceanic waters (Payne et al. 1984). The stock may contain multiple demographically independent populations that should themselves be stocks because the current stock spans multiple eco-regions (Longhurst 1998; Spalding et al. 2007). Between October 2018 and February 2021, 2 sightings of 14 individual Risso's dolphins were recorded all during the month of July 2020 during recent HRG surveys within the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Risso's dolphins have been observed in OCS waters offshore Rhode Island year-round, with most sightings during the summer. Sighting data primarily shows that this species is found along the shelf edge, with only a few individuals seen in waters shallower than 100 m. Only one sighting in the Rhode Island Ocean Special Area Management Plan study area was reported in the spring (Kenney and Vigness-Raposa 2010). Kraus et al. (2016) only observed two Risso's dolphins in the RI-MA WEA, also during the spring. Risso's dolphins do occur in the area; however, because of the infrequent sightings in shallower waters and more concentrated distribution along the continental shelf, the likelihood of encountering Risso's dolphins in the RWF area is relatively low.

RWEC

Risso's dolphins are unlikely to occur within the RWEC corridor since they primarily remain in deeper waters along the shelf edge (Hayes et al. 2020).

4.2.6.2 *Abundance*

The best abundance estimate in the Western North Atlantic is 35,215 based on the 2016 NEFSC and Department of Fisheries and Oceans Canada (DFO) surveys (Hayes et al. 2021). A trend analysis was not conducted on this species, because there are insufficient data to generate this information.

4.2.6.3 *Status*

Risso's dolphins are not listed under the ESA and are classified as a species of Least Concern on the IUCN Red List (Hayes et al. 2020; IUCN 2020). PBR for this stock is 301, and the annual human-caused mortality and injury for 2015 to 2019 was estimated to be 34 (Hayes et al. 2021). This stock is not classified as strategic under the MMPA because mortality does not exceed the calculated PBR. Threats to this stock include fishery interactions, non-fishery related human interaction, contaminants in their habitat, and climate-related shifts in prey distribution (Hayes et al. 2020). There is no designated critical habitat for this stock in the Project Area.

4.2.7 *Common Bottlenose Dolphin (Tursiops truncatus truncatus)*

Bottlenose Dolphins are one of the most well-known and widely distributed species of marine mammals. These dolphins reach 2–4 m (6–12.5 ft) in length (NMFS 2021e). The snout is stocky and set off from the head by a crease. They are typically light to dark grey in color with a white underside (Jefferson et al. 1993). Bottlenose dolphins are commonly found in groups of two to 15 individuals, though aggregations in the hundreds are occasionally observed (NMFS 2021e). They are considered generalist feeders and consume a wide variety of organisms, including fish, squid, and shrimp and other crustaceans (Jefferson et al. 2008).

Whistles produced by bottlenose dolphins can vary over geographic regions, and newborns are thought to develop "signature whistles" within the first few months of their lives that are used for intraspecific communication. Whistles generally range in frequency from 300 Hz to 39 kHz with SLs between 114 and 163 dB re 1 µPa @ 1 m SPL_{rms} (Erbe et al. 2017). Bottlenose dolphins also make burst-pulse sounds and echolocation clicks, which can range from a few kHz to over 150 kHz. As these sounds are used for locating and capturing prey, they are directional calls; the recorded frequency and sound level can vary depending on whether the sound was received head-on or at an angle relative to the vocalizing dolphin. SLs for burst-pulses and clicks range between 193 and 228 dB re 1 µPa @ 1 m SPL_{rms} (Erbe et al. 2017). There are sufficient available data for bottlenose dolphin hearing sensitivity using both behavioral and AEP methods as well as anatomical modeling studies, which show hearing for the species is most sensitive between approximately 400 Hz and 169 kHz (Southall et al. 2019).

4.2.7.1 *Distribution*

In the Western North Atlantic, there are two morphologically and genetically distinct common bottlenose morphotypes, the Western North Atlantic Northern Migratory Coastal stock and the Western North Atlantic Offshore stock. The offshore stock is primarily distributed along the outer shelf and slope from Georges Bank to Florida during spring and summer and has been observed in the Gulf of Maine during late summer and fall (Hayes et al. 2020), whereas the northern migratory coastal stock is distributed along the coast between southern Long Island, New York, and Florida (Hayes et al. 2018).

Given their distribution, only the offshore stock is likely to occur in the Project Area and is the only stock included in this application. The western North Atlantic offshore stock is distributed primarily along the OCS and continental slope, from Georges Bank to Cape Hatteras during spring and summer (CeTAP 1982). Between October 2018 and February 2021, 9 sightings of 200 individual common bottlenose dolphins were recorded during the months of May and July of 2020 during recent HRG surveys within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Common bottlenose dolphins were reported in the RI-MA WEA during all seasons. Although relatively stable across seasons, the highest seasonal abundance estimates were observed during the summer and fall, with lower estimates in the spring and winter (Kraus et al. 2016). The greatest concentrations of common bottlenose dolphins were observed in the southernmost portion of the RI-MA WEA study area (Kraus et al. 2016). Therefore, common bottlenose dolphins are likely to occur in the RWF.

RWEC

As previously discussed, common bottlenose dolphins that occur within the nearshore areas of the Project Area are likely to come from the offshore stock, despite its predominantly offshore distribution, as the seasonal stranding records match the temporal patterns of the offshore stock rather than the coastal stock (Kenney and Vigness-Raposa 2010). Therefore, the offshore stock can be expected to occur in the RWEC corridor.

4.2.7.2 Abundance

The best abundance estimate for the Western North Atlantic offshore stock is 62,851 based on recent surveys between the lower Bay of Fundy and Florida (Hayes et al. 2020). A population trend analysis for this stock was conducted using abundance estimates from 2004, 2011, and 2016, which show no statistically significant trend (Hayes et al. 2020).

4.2.7.3 Status

Common bottlenose dolphins are not listed under the ESA and are classified as Least Concern on the IUCN Red List (Hayes et al. 2020; IUCN 2020). The PBR for this stock is 519, and the average annual human-cause mortality and serious injury from 2013 to 2017 was estimated to be 28, attributed to fishery interactions (Hayes et al. 2020). Because annual mortality does not exceed PBR, this stock is not classified as strategic under the MMPA. In addition to fisheries, threats to common bottlenose dolphins include non-fishery related human interaction; anthropogenic noise; offshore development; contaminants in their habitat; and climate-related changes in prey distribution (Hayes et al. 2020). There is no designated critical habitat for either stock in the Project Area.

4.2.8 *Harbor Porpoise (Phocoena phocoena)*

This species is among the smallest of the toothed whales and is the only porpoise species found in Northeastern U.S. waters. A distinguishing physical characteristic is the dark stripe that extends from the flipper to the eye. The rest of its body has common porpoise features; a dark gray back, light gray sides, and small, rounded flippers (Jefferson et al. 1993). It reaches a maximum length of 1.8 m (6 ft) and feeds on a wide variety of small fish and cephalopods (Reeves and Read 2003; Kenney and Vigness-Raposa

2010). Most harbor porpoise groups are small, usually between five and six individuals, although they aggregate into large groups for feeding or migration (Jefferson et al. 2008).

Harbor porpoises produce high frequency clicks with a peak frequency between 129 and 145 kHz and an estimated SLs that ranges from 166 to 194 dB re 1 µPa @ 1 m SPL_{rms} (Villadsgaard et al. 2007). Available data estimating auditory sensitivity for this species suggest that they are most receptive to noise between 300 Hz and 160 kHz (Southall et al. 2019).

4.2.8.1 *Distribution*

The harbor porpoise is mainly a temperate, inshore species that prefers to inhabit shallow, coastal waters of the North Atlantic, North Pacific, and Black Sea. Harbor porpoises mostly occur in shallow shelf and coastal waters. In the summer, they tend to congregate in the Northern Gulf of Maine, Southern Bay of Fundy, and around the southern tip of Nova Scotia (Hayes et al. 2020). In the fall and spring, harbor porpoises are widely distributed from New Jersey to Maine (Hayes et al. 2020). In the winter, intermediate densities can be found from New Jersey to North Carolina, with lower densities from New York to New Brunswick, Canada (Kenney and Vigness-Raposa 2010). In cooler months, harbor porpoises have been observed from the coastline to deeper waters (>1,800 m), although the majority of sightings are over the continental shelf (Hayes et al. 2020). Between October 2018 and February 2021, one sighting of 5 individual harbor porpoises was recorded in May 2020 during recent HRG surveys conducted within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Over the course of a three-year study on ambient noise in the RI-MA WEA, Kraus et al. (2016) observed 121 individual harbor porpoises. Fall observations included the most individuals, followed by winter, spring, and summer. Vertical camera detections of all small cetaceans showed that the most commonly detected species over time was the harbor porpoise (Kraus et al. 2016). The preferred habitat of the harbor porpoise further increases the likelihood of encountering them seasonally in fall, winter, and spring within the RWF area (BOEM 2013; Hayes et al. 2020).

RWEC

Harbor porpoise occurrence offshore Rhode Island is highly seasonal with most sightings occurring in winter and spring and relatively few in summer and fall (Kenney and Vigness-Raposa 2010). Strandings are reported all along the southern shore of Long Island, New York, and along both sides of Long Island Sound. They are most commonly reported in Eastern Long Island Sound, Gardiner's Bay, and Peconic Bay during the winter, west of the RWEC corridor. They have the greatest abundance in Rhode Island waters during the spring when they are known to migrate from their offshore wintering habitat in the mid-Atlantic to their summer feeding grounds in the Gulf of Maine (Kenney and Vigness-Raposa 2010). Therefore, harbor porpoises are likely to occur within the RWEC corridor.

4.2.8.2 *Abundance*

The best available abundance estimate for the Gulf of Maine/Bay of Fundy stock occurring in the Project Area is 95,543 based on combined survey data from NOAA and the Department of Fisheries and Oceans Canada between the Gulf of St. Lawrence/Bay of Fundy/Scotian Shelf and Central Virginia (Hayes et al. 2020). A population trend analysis is not available because data are insufficient for this species (Hayes et al. 2019).

4.2.8.3 Status

This species is not listed under the ESA and is considered non-strategic under the MMPA (Hayes et al. 2020). Harbor porpoise is listed as Least Concern by the IUCN Red List (IUCN 2020). The PBR for this stock is 851, and the estimated human-caused annual mortality and serious injury from 2015 to 2019 was 164 harbor porpoises per year (Hayes et al. 2021). This species faces major anthropogenic impacts because of its nearshore habitat. Historically, Greenland populations were hunted in large numbers for food and oil. Currently, they continue to suffer incidental mortality from Western North Atlantic fishing activities such as gillnets and bottom trawls (Hayes et al. 2020). Harbor porpoises also face threats from contaminants in their habitat, vessel traffic, habitat alteration due to offshore development, and climate-related shifts in prey distribution (Hayes et al. 2020). There is no designated critical habitat for this species near the Project Area.

4.3 Pinnipeds

Two species of pinnipeds occur in the Atlantic Ocean near the Project Area: The harbor seal and the gray seal. Both pinniped species are likely to occur in the region year-round.

The Draft 2021 SAR mentions an increase of sightings and stranding data for harp seals off of the east coast of the United States from Maine to New Jersey (Hayes et al. 2021). However, these appearances usually occur from January–May during their southernmost point of migration (Hayes et al. 2021). With the majority of the RWF offshore construction occurring between Q2-Q3, it is unlikely for harp seals to be present in the Project area during the construction phase of the Project. Although export cable route installation pushes into the start of Q1, minimal sightings data suggests a low potential of overlap within the project area. Additionally, assessment of the Ocean Biodiversity Information System (OBIS 2021) database found only records of stranding for the harp seal. Although the presence of stranded animals indicates some level of occurrence in the regions, it does not necessarily reflect the likely encounter of free-ranging animals in the area of planned activities.

4.3.1 *Harbor Seal (Phoca vitulina vitulina)*

The harbor seal is one of the smaller pinnipeds, and adults are often light to dark grey or brown with a paler belly and dark spots covering the head and body (Jefferson et al. 1993; Kenney and Vigness-Raposa 2010). This species is approximately 2 m (6 ft) in length (NMFS 2021h). Harbor seals complete both shallow and deep dives during hunting, depending on the availability of prey (Tollit et al. 1997). Harbor seals consumes a variety of prey, including fish, shellfish, and crustaceans (Bigg 1981; Reeves 1992; Burns 2002; Jefferson et al. 2008). They commonly occur in coastal waters and on coastal islands, ledges, and sandbars (Jefferson et al. 2008).

Male harbor seals have been documented producing an underwater roar call which is used for competition with other males and attracting mates. These are relatively short calls with a duration of about 2 sec and a peak frequency between 1 and 2 kHz (Van Parijs et al. 2003). Behavioral audiometric studies for this species estimate peak hearing sensitivity between 100 Hz and 79 kHz (Southall et al. 2019).

4.3.1.1 Distribution

The harbor Seal is found throughout coastal waters of the Atlantic Ocean and adjoining seas above 30°N and is the most abundant pinniped in the US Atlantic EEZ (Hayes et al. 2018). Harbor seals, also known as common seals, are one of the most widely distributed seal species in the Northern Hemisphere. They can be found inhabiting coastal and inshore waters from temperate to polar latitudes. Harbor seals occur seasonally along the coast during winter months from southern New England to New Jersey, typically from September through late May (Kenney and Vigness-Raposa 2010; Hayes et al. 2020). In recent years, this species has been seen regularly as far south as North Carolina, and regular seasonal haul-out sites of up to 40-60 animals have been documented on the eastern shore of Virginia and the Chesapeake Bay (Jones and Rees 2020). During the summer, most harbor seals can be found north of New York, within the coastal waters of central and northern Maine, as well as the Bay of Fundy (DoN (U.S. Department of the Navy) 2005; Hayes et al. 2020). Genetic variability from different geographic populations has led to five subspecies being recognized. Peak breeding and pupping times range from February to early September, and breeding occurs in open water (Temte 1994). Between October 2018 and February 2021, 9 sightings of 9 individual harbor seals were recorded during the months of November and December in 2018 and 2020 during recent HRG surveys within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Harbor seals can be found along the coast of Rhode Island and the RI-MA WEA, as well as in surrounding waters. Several haul-out sites are located on Block Island, Rhode Island, which is close to the western end of the RWF area (BOEM 2013). Survey data collected from NMFS and the Provincetown Center for Coastal Research reported 151 harbor seal sightings, a large concentration of which were observed near the coast from eastern Long Island, New York, to Buzzards Bay and Vineyard Sound. There were occurrences of harbor seal offshore; however, the level of abundance was lower than what was observed near haul-out sites (Kenney and Vigness-Raposa 2010). Therefore, harbor seals could be encountered in the RWF area.

RWEC

Harbor seals are regularly observed in coastal areas; however, there are few records from shipboard and aerial surveys. Harbor seals are difficult to detect as the only sighting cue available would be seeing the seal's head above the water. CETAP excluded seals from their data collection efforts specifically for this reason (CeTAP 1982). Most available records are of strandings and haul-out counts. Harbor seals are known to inhabit Southern New England waters year-round, although the population steadily increases in April and then abruptly declines in May.

Harbor seals are regularly observed around coastal areas throughout Rhode Island. While there are no known pupping grounds in this area, six haul-out sites have been identified in Narragansett Bay. They are most commonly observed at the Dumplings off Jamestown at Rome Point in North Kingstown, Rhode Island (Kenney and Vigness-Raposa 2010). Nearly all the haul-outs within Narragansett Bay are rocky ledges or isolated rocks with the exception of Spar Island, which is a man-made dredge spoil (Kenney and Vigness-Raposa 2010). Harbor seals can likely be found in the nearshore areas along the proposed RWEC corridor.

4.3.1.2 *Abundance*

The best available abundance estimate for harbor seals in the Western North Atlantic is 61,366, with global population estimates reaching 610,000 to 640,000 (Bjørge et al. 2010; Hayes et al. 2020; IUCN 2020; Hayes et al. 2021). Estimates of abundance are based on surveys conducted during the pupping season, when most of the population is assumed to be congregated along the Maine coast. Abundance estimates do not reflect the portion of the stock that might pup in Canadian waters (Hayes et al. 2021). Trend in population from 1993 to 2018 was estimated for non-pups and pups using a Bayesian hierarchical model to account for missing data both within and between survey years. The estimated mean change in non-pup harbor seal abundance per year was a positive from 2001 to 2004, but close to zero or negative between 2005 and 2018 (Hayes et al. 2021). After 2005, mean change in pup abundance was steady or declining until 2018 but these changes were not significant (Hayes et al. 2021).

4.3.1.3 *Status*

Harbor seals are not listed under the ESA, are listed as Least Concern by the IUCN Red List and are considered non-strategic because anthropogenic mortality does not exceed PBR (Hayes et al. 2020; IUCN 2020). The PBR for this population is 1,729 and the annual human-caused mortality and serious injury from 2015 to 2019 was estimated to be 399 seals per year (Hayes et al. 2021). This mortality and serious injury was attributed to fishery interactions, non-fishery related human interactions, and research activities (Hayes et al. 2020). Until 1972, harbor seals were commercially and recreationally hunted. Currently, only Alaska natives can hunt harbor seals for sustenance and the creation of authentic handicrafts. Other threats to harbor seals include disease and predation (Hayes et al. 2020). There is no designated critical habitat for this species in the Project Area.

4.3.2 *Gray Seal (Halichoerus grypus atlantica)*

Gray Seals are the second most common pinniped in the US Atlantic EEZ (Jefferson et al. 2008). This species inhabits temperate and sub-arctic waters and lives on remote, exposed islands, shoals, and unstable sandbars (Jefferson et al. 2008). Gray Seals are large, reaching 2–3 m (7.5–10 ft) in length, and have a silver-gray coat with scattered dark spots (NMFS 2021g). These seals are generally gregarious and live in loose colonies while breeding (Jefferson et al. 2008). Though they spend most of their time in coastal waters, Gray Seals can dive to depths of 300 m (984 ft), and frequently forage on the outer shelf (Hammill et al. 2001; Jefferson et al. 2008). These opportunistic feeders primarily consume fish, crustaceans, squid, and octopus (Bonner et al. 1971; Reeves 1992; Jefferson et al. 2008). They often co-occur with Harbor Seals because their habitat and feeding preferences overlap (NMFS 2021g).

Two types of underwater vocalizations have been recorded for male and female gray seals; clicks and hums. Clicks are produced in a rapid series resulting in a buzzing noise with a frequency range between 500 Hz and 12 kHz. Hums, which is described as being similar to that of a dog crying in its sleep, are lower frequency calls, with most of the energy <1 kHz (Schusterman et al. 1970). AEP studies indicate that hearing sensitivity for this species is greatest between 140 Hz and 100 kHz (Southall et al. 2019).

4.3.2.1 *Distribution*

The eastern Canadian population of gray seals ranges from New Jersey to Labrador and is centered at Sable Island, Nova Scotia (Davies 1957; Mansfield 1966; Richardson and Rough 1993; Hammill et al. 2001). There are three breeding concentrations in eastern Canada: Sable Island, the Gulf of St. Lawrence, and along the east coast of Nova Scotia (Lavigueur and Hammill 1993). In US waters, gray seals currently pup at four established colonies from late December to mid-February: Muskeget and Monomoy Islands in Massachusetts, and Green and Seal Islands in Maine (Center for Coastal Studies 2017; Hayes et al. 2018). Pupping was also observed in the early 1980s on small islands in Nantucket-Vineyard Sound and more recently at Nomans Island (Hayes et al. 2018). Following the breeding season, gray seals may spend several weeks ashore in the late spring and early summer while undergoing a yearly molt. Between October 2018 and February 2021, 11 sightings of 11 individual gray seals were recorded all during the months of September between May 2018 and January 2021 during recent HRG surveys within the area surrounding the Revolution Wind Lease Area and Export Cable Route (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021).

RWF

Overall, the occurrence of gray seals within the RWF is expected to be relatively low; occasionally young pups have been found stranded off Long Island, New York, and Rhode Island beaches. The AMAPPS surveys identified 11 individuals during their winter aerial surveys (Palka et al. 2017). Two breeding and pupping grounds are located in Nantucket Sound at Monomoy and Muskeget Island. Gray seals live there year-round and exhibit minimal migration patterns; however, recent tagging studies observed increased movement between the U.S. and Canada. The overall time spent in U.S. waters remains uncertain, but the updated U.S. population estimates make it possible that these seals will be seen in the RWF area (Hayes et al. 2020).

RWEC

Historically, gray seals were relatively absent from Rhode Island and nearby OCS waters. However, with the recent recovery of the Massachusetts and Canadian populations, their occurrence has increased in Southern New England and the Mid-Atlantic U.S. (Kenney and Vigness-Raposa 2010). Records of gray seal strandings are primarily observed in the spring and are distributed broadly along ocean-facing beaches in Long Island, New York, and Rhode Island. In New York, gray seals are typically seen alongside harbor seal haul-outs. Two frequent sighting locations include Great Gull Island and Fisher's Island, New York (Kenney and Vigness-Raposa 2010). Even though sightings are not as frequent as harbor seals, gray seals do occur in Rhode Island waters; therefore, these seals may be present in the RWEC corridor.

4.3.2.2 *Abundance*

Estimates of the entire Western North Atlantic gray seal population are not available. Some estimates are available for portions of the stock, although recent genetic evidence suggests that all Western North Atlantic gray seals may actually comprise a single stock (Hayes et al. 2020). The best available current abundance estimate for gray seals of the Canadian gray seal stock is 424,300 and the current U.S. population estimate is 27,300 (Hayes et al. 2021). The population of gray seals is likely increasing in the U.S. Atlantic EEZ; recent data show approximately 28,000 to 40,000 gray seals were observed in Southeastern Massachusetts in 2015 (Hayes et al. 2020). A population trend is not currently available for this stock, although the observed increase in the number of pops born in U.S. pupping colonies between 1991 and 2019 is currently being evaluated (Hayes et al. 2020).

4.3.2.3 *Status*

This species is not listed under the ESA and is non-strategic under the MMPA because anthropogenic mortality does not exceed PBR (Hayes et al. 2020). Gray seal is listed as Least Concern by the IUCN Red List (IUCN 2020). The PBR for this population is 1,458, and the annual human-caused mortality and serious injury between 2015 and 2019 was estimated to be 4,453 in both the U.S. and Canada (Hayes et al. 2021). Like harbor seals, the gray seal was commercially and recreationally hunted until 1972. Mortality is currently attributed to fishery interactions, non-fishery related human interactions and hunting, research activities, Canadian commercial harvest, and removals of nuisance animals in Canada (Hayes et al. 2020). Other threats to this population include disease, predation, and natural phenomena like storms (Hayes et al. 2020). There is no designated critical habitat for this species in the Project Area.

5 Type of Incidental Take Authorization Requested

Revolution Wind is requesting the promulgation of incidental take regulations and issuance of a Letter of Authorization pursuant to section 101(a)(5)(A) of the MMPA for incidental take by Level A and Level B harassment of small numbers of marine mammals during the construction and operations activities described in Sections 1 and 2 in and around OCS-A 0486 and along the Export Cable Route to Quonset Point, North Kingstown, Rhode Island (Figure 1).

The construction and operations activities have the potential to take by “Level B” harassment marine mammals as a result of sound energy introduced to the marine environment. Sounds that may “harass” marine mammals include pulsed sounds generated by impact pile driving, HRG survey equipment, and potential in-situ MEC/UXO disposal as well as non-impulsive sounds from vibratory pile driving. The potential effects will depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the received level (RL) of the sound. Disturbance reactions are likely to vary among some of the marine mammals in the general vicinity of the sound source. The mitigation and monitoring activities described in Section 11, including noise attenuation systems and advanced monitoring technologies such as passive acoustic recorders, infrared cameras, and night vision devices will be implemented so that the amount of Level B take is reduced to the lowest practicable level.

Certain construction activities, including monopile foundation installation and in-situ MEC/UXO disposal, have a small chance of causing Level A “take” for some marine mammal species. The planned monitoring and mitigation measures will reduce, but cannot eliminate, this possibility. Therefore, Level A takes are also requested as described below.

6 Take Estimates for Marine Mammals

Nearly all anticipated takes would be “takes by harassment”, involving temporary changes in behavior (i.e., Level B harassment). That is, acoustic exposure could result in temporary displacement of marine mammals from within ensonified zones or other temporary changes in behavioral state. The mitigation measures to be applied will reduce the already very low probability of Level A take, but for certain species and activities, some potential Level A takes could occur. The planned construction and operations activities are not expected to “take” more than small numbers of marine mammals and will have a negligible impact on the affected species or stocks. In the sections below, we describe the methods used to estimate “take by harassment” and present the resulting estimates of the numbers of marine mammals that might be affected during the planned activities.

6.1 Basis for Estimating Potential "Take"

The amount of potential "take by harassment" is calculated in two separate ways, depending on the activity. For WTG and OSS monopile foundation installation, sound exposure modeling was conducted to more accurately account for the movement and behavior of marine mammals and their exposure to the underwater sound fields produced during impact pile driving. Sound exposure modeling involves the use of a three-dimensional computer simulation in which simulated animals (animats) move through the modeled marine environment over time in ways that are defined by the known or assumed movement patterns for each species derived from visual observation, animal borne tag, or other similar studies. The sound field produced by the activity, in this case impact pile driving, is then added to the modeling environment at the location and for the duration of time anticipated for one or more pile installations. At each time step in the simulation, each animat records the received sound levels at its location resulting in a sound exposure history for each animat. These exposure histories are then analyzed to determine whether and how many animats were exposed above threshold levels. Finally, the density of animats used in the modeling environment, which is usually much higher than the actual density of marine mammals in the activity area so that the results are more statistically robust, is compared to the actual density of marine mammals anticipated to be in the activity area. The results are then used to scale the animat exposure estimates to the actual density estimates. A more detailed description of this method is available in Appendix A, including results for some species if avoidance of anthropogenic sounds (aversion) is included in the exposure modeling. However, the exposure modeling results including aversion are not used in the estimates of potential take included in this application.

For landfall construction activities, HRG surveys, and potential in-situ MEC/UXO disposal takes are calculated by multiplying the expected densities of marine mammals in the activity area(s) by the area of water likely to be ensonified above the NMFS defined threshold levels in a single day (24-hour period). The result is then multiplied by the number of days on which the activity is expected to occur resulting in a density-based estimated take for each activity.

In both take calculation methods, the densities of marine mammals (individuals per unit area) expected to occur in the activity areas were calculated from habitat-based density modeling results reported by Roberts et al. (2016; 2017; 2018; 2021) (Table 6). Those data provide abundance estimates for species or species guilds within 10 km x 10 km grid cells (100 km^2) (except NARW which are provided in a 5 km x 5 km grid (Roberts et al. 2021)) on a monthly or annual basis, depending on the species. The average monthly abundance for each species in each activity area was calculated as the mean value of the grid cells within each survey area in each month and then converted to density (individuals / 1 km^2) by dividing by 100 km^2. The grid cells used for the density calculations of each activity area are described separately in the sections below.

Table 6. Marine mammal density model version number, release date, and report citation for densities used in density-based take calculations.

Species	Scientific Name	Density Model Version Used	Model Release Date	Report Citation
Mysticetes				
Blue Whale*	*Balaenopter musculus*	1.3	09-26-2015	Roberts et al. 2016
Fin Whale*	*Balaenoptera physalus*	11	04-22-2018	Roberts et al. 2018
Humpback Whale	*Megaptera novaeangliae*	10	06-01-2017	Roberts et al. 2017
Minke Whale	*Balaenoptera acutorostrata*	9	06-01-2017	Roberts et al. 2017
North Atlantic Right Whale*	*Eubalaena glacialis*	11.1	11-22-2021	Roberts et al. 2021
Sei Whale*	*Balaenoptera borealis*	8	04-22-2018	Roberts et al. 2018
Odontocetes				
Atlantic Spotted Dolphin	*Stenella frontalis*	8	04-14-2018	Roberts et al. 2018
Atlantic White-Sided Dolphin	*Lagenorhynchus acutus*	3	04-14-2018	Roberts et al. 2018
Bottlenose Dolphin	*Tursiops truncatus*	5	04-14-2018	Roberts et al. 2018
Common Dolphin	*Delphinus delphis*	4	04-14-2018	Roberts et al. 2018
Harbor Porpoise	*Phocoena phocoena*	4	06-01-2017	Roberts et al. 2017
Pilot Whales	*Globicephala* spp.	6	08-08-2017	Roberts et al. 2017
Risso's Dolphin	*Grampus griseus*	4	04-14-2018	Roberts et al. 2018
Sperm Whale*	*Physeter macrocephalus*	7	06-01-2017	Roberts et al. 2017
Pinnipeds				
Seals (Harbor and Gray)	*Phocidae* spp.	4	04-14-2018	Roberts et al. 2018

* Denotes species listed under the Endangered Species Act

For some species, observational data from Protected Species Observers (PSOs) aboard HRG survey vessels indicate that the density-based take estimates may be insufficient to account for the number of individuals of a species that may be encountered during the planned activities. PSO data from HRG surveys conducted in the area surrounding the Lease Area and Export Cable Route from October 2018 through February 2021 (AIS-Inc. 2019; Bennett 2021; Stevens et al. 2021; Stevens and Mills 2021) were analyzed to determine the average number of individuals of each species observed per vessel day. To account for individuals not identified to the species level by PSOs (i.e. those recorded as "unidentified whale", "unidentified dolphin", "unidentified seal", etc.), the proportion of identified individuals of each species within each taxonomic group was calculated as shown in the column "Proportion of Total Individuals of Species Within Each Species Group" within Table 7. The proportion of each species was then multiplied by the total number of "unidentified" individuals belonging to that taxonomic group so that the unassigned individuals were re-assigned to the identified species proportional to the identified individuals within each taxonomic as shown in the column "Unidentified Individuals Assigned to Species" column in Table 7. The identified and re-assigned unidentified individuals for each species was then summed as shown in the "Total Individuals Including Proportion of Unidentified" column of Table 7. This value was then divided by the number of vessel days during which observations were conducted in 2018–2021 HRG surveys (470 days) to calculate the number of individuals observed per vessel day as shown in the final column in Table 7.

Table 7. The number of individual marine mammals observed, with and without inclusion of unidentified individuals, and the estimated number of individuals observed per vessel day during HRG surveys in 2018–2021.

Species	Identified Individuals	Proportion of Total Individuals Identified to Specie Within Each Species Group	Unidentified Individuals Assigned to Species	Total Individuals Including Proportion of Unidentified	Individuals Observed Per Vessel Day
Mysticetes	**125**				
Blue Whale*	0	-	-	-	-
Fin Whale*	26	0.21	32.9	58.9	0.25
Humpback Whale	78	0.62	98.6	176.6	0.74
Minke Whale	16	0.13	20.2	36.2	0.15
North Atlantic Right Whale*	4	0.03	5.1	9.1	0.04
Sei Whale*	1	0.01	1.3	2.3	0.01
Unidentified Mysticetes	**158**				
Unidentified Mysticete Whale	124				-
Unidentified Whale	34				-
Odontocetes	**5871**				
Atlantic Spotted Dolphin	0	-	-	-	-
Atlantic White-Sided Dolphin	18	0.00	4.8	22.8	0.10
Bottlenose Dolphin	200	0.03	53.6	253.6	1.06
Common Dolphin	5634	0.96	1508.5	7142.5	29.76
Harbor Porpoise	5	0.00	1.3	6.3	0.03
Pilot Whales	0	-	-	-	-
Risso's Dolphin	14	0.00	3.7	17.7	0.07
Sperm Whale*	0	-	-	-	-
Unidentified Odontocetes	**1572**				
Unidentified Dolphin	1562				-
Unidentified Dolphin or Porpoise	10				-
Pinnipeds	**20**				
Harbor Seal	9	0.45	8.1	17.1	0.07
Gray Seal	11	0.55	9.9	20.9	0.09
Unidentified Pinniped	**18**				
Unidentified Pinniped	18				-

* Denotes species listed under the Endangered Species Act

For other less-common species, the predicted densities from Roberts et al. (2016; 2017; 2018) are very low and the resulting density-based take estimate is less than a single animal or a typical group size for the species. In such cases, the mean group size was used instead of the density-based take estimate to account for potential impacts on a group during an activity. Mean group sizes for each species were calculated from recent aerial and/or vessel-based surveys as shown in Table 8. The largest resulting value of the three take estimate methods described above (density based, PSO data based, or mean group size) was then carried forward as the estimated take for each activity.

Table 8. Mean group sizes of species for which incidental take is being requested.

Species	Individuals	Sightings	Mean Group Size	Source
Mysticetes				
Blue Whale*	3	3	1.0	Palka et al. (2017)
Fin Whale*	155	86	1.8	Kraus et al. (2016)
Humpback Whale	160	82	2.0	Kraus et al. (2016)
Minke Whale	103	83	1.2	Kraus et al. (2016)
North Atlantic Right Whale*	145	60	2.4	Kraus et al. (2016)
Sei Whale*	41	25	1.6	Kraus et al. (2016)
Odontocetes				
Atlantic Spotted Dolphin	1334	46	29.0	Palka et al. (2017)
Atlantic White-Sided Dolphin	223	8	27.9	Kraus et al. (2016)
Bottlenose Dolphin	259	33	7.8	Kraus et al. (2016)
Common Dolphin	2896	83	34.9	Kraus et al. (2016)
Harbor Porpoise	121	45	2.7	Kraus et al. (2016)
Pilot Whales	117	14	8.4	Kraus et al. (2016)
Risso's Dolphin	1215	224	5.4	Palka et al. (2017)
Sperm Whale*	208	138	1.5	Palka et al. (2017)
Pinnipeds				
Seals (Harbor and Gray)	201	144	1.4	Palka et al. (2017)

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6.2 Acoustic Thresholds

To assess potential auditory injury or permanent threshold shift (PTS), Level A harassment, NMFS has provided technical guidance (NMFS 2018a) that establishes dual criteria for five different marine mammal hearing groups, four of which occur in the Lease Area (Table 9). The two criteria are based on different acoustic metrics, or ways of measuring sound, the peak sound pressure level (SPL_{pk}) and the cumulative sound exposure level (SEL_{cum}). The SPL_{pk} metric captures the potential for auditory injury caused by very strong, instantaneous sounds while the SEL_{cum} metric captures the potential for injury caused by fatiguing of the auditory system from sounds received over time (in this case, a maximum 24-hr period).

The marine mammal hearing groups are based on the frequencies of sound to which species in that group are most sensitive. The frequency-dependent hearing sensitivities of each group are characterized by frequency weighting functions that are applied to the sounds being modeled and effective filter out sound energy at frequencies of less importance to species. Frequency weighting is applied when calculating distances to the SEL_{cum} threshold and some behavioral thresholds while SPL_{pk} is not frequency weighted, which is commonly referred to as unweighted or flat-weighted (Table 9).

Scientific recommendations for revisions to these classifications were recently published by Southall et al. (2019). This publication proposes a new nomenclature and classification for the marine mammal hearing groups, but the proposed thresholds and weighting functions do not differ in effect from those in NMFS (2018a). The hearing groups and nomenclature proposed by Southall et al. (2019) have not yet been incorporated into the NMFS guidelines.

Table 9. Marine mammal functional hearing groups and PTS (Level A harassment) and TTS thresholds as defined by NMFS (2018a) for species present in the survey area.

Marine Mammal Hearing Group	Generalized Hearing Range	PTS onset (Level A) Thresholds (Impulsive Sounds)	TTS onset Thresholds (Impulsive Sounds)
Low-frequency cetaceans (LF)	7 Hz to 35 kHz	$L_{\mathrm{pk,flat}}$: 219 dB $L_{\mathrm{E,LF,24h}}$: 183 dB	$L_{\mathrm{pk,flat}}$: 213 dB $L_{\mathrm{E,LF,24h}}$: 168 dB
Mid-frequency cetaceans (MF)	150 Hz to 160 kHz	$L_{\mathrm{pk,flat}}$: 230 dB $L_{\mathrm{E,LF,24h}}$: 185 dB	$L_{\mathrm{pk,flat}}$: 224 dB $L_{\mathrm{E,LF,24h}}$: 170 dB
High-frequency cetaceans (HF)	275 Hz to 160 kHz	$L_{\mathrm{pk,flat}}$: 202 dB $L_{\mathrm{E,LF,24h}}$: 155 dB	$L_{\mathrm{pk,flat}}$: 196 dB $L_{\mathrm{E,LF,24h}}$: 140 dB
Phocid pinnipeds (underwater) (PW)	50 Hz to 86 kHz	$L_{\mathrm{pk,flat}}$: 218 dB $L_{\mathrm{E,LF,24h}}$: 185 dB	$L_{\mathrm{pk,flat}}$: 212 dB $L_{\mathrm{E,LF,24h}}$: 170 dB

In the case of potential in-situ MEC/UXO disposal, additional thresholds for mortality and non-auditory injury to lung and gastrointestinal organs from the blast shock wave and/or onset of high peak pressures are also relevant (at relatively close ranges). These criteria have been developed by the U.S. Navy (DoN (U.S. Department of the Navy) 2017a; Hannay and Zykov 2021) and are based on the mass of the animal and the depth at which it is present in the water column. This means that specific decibel levels for each hearing group are not provided and instead the criteria are presented as equations that allow for incorporation of specific mass and depth values. Two separate sets of equations are available, the first is less conservative and reflects when mortality or non-auditory injury is more likely to occur (Table 10), while the second is more conservative and reflect the onset of potential effects (Table 11).

Table 10. U.S. Navy impulse and peak pressure threshold equations for estimating at what levels marine mammals may experience mortality or injury due to underwater explosions (DoN (U.S. Department of the Navy) 2017a; Hannay and Zykov 2021). M is animal mass (in kg) and D is animal depth (m).

Impact Assessment Criterion	Threshold
Mortality- Impulse	$144M^{1/3}(1+\frac{D}{10.1})^{1/6}$ Pa-s
Injury- Impulse	$65.8M^{1/3}(1+\frac{D}{10.1})^{1/6}$ Pa-s
Injury- Peak Pressure	243 dB re 1 μPa peak

Table 11. U.S. Navy impulse and peak pressure threshold equations for estimating distances to onset of potential mortality and slight lung injury non-auditory injury to marine mammals (DoN (U.S. Department of the Navy) 2017a; Hannay and Zykov 2021). M is animal mass (in kg) and D is animal depth (m).

Onset Effect for Mitigation Consideration	Threshold
Onset Mortality- Impulse	$103M^{1/3}(1+\frac{D}{10.1})^{1/6}$ Pa-s
Onset Injury- Impulse (Non-auditory)	$47.5M^{1/3}(1+\frac{D}{10.1})^{1/6}$ Pa-s
Onset Injury- Peak Pressure (Non-auditory)	237 dB re 1 µPa peak

The received level at which marine mammals may behaviorally respond to anthropogenic sounds varies by numerous factors including the frequency content, predictability, and duty cycle of the sound as well as the experience, demography, and behavioral state of the marine mammals (Richardson et al. 1995; Southall et al. 2007b; Ellison et al. 2012). Despite this variability, there is a practical need for a reasonable and specific threshold. NMFS currently defines the threshold for behavioral harassment, Level B take, as 160 dB re 1 µPa SPL_{rms} [unless otherwise noted, all dB values hereafter are referenced to 1 µPa] for impulsive or intermittent sounds such as those produced by impact pile driving and some HRG survey equipment. For non-impulsive sounds, such as vibratory pile driving, NMFS defines the threshold for behavioral harassment at 120 dB SPL_{rms}.

For MEC/UXO detonations, a single blast per day is not considered to cause behavioral harassment at the 160 dB level noted above. Instead, behavioral effects (Level B take) are expected if received sounds rise above temporary threshold shift (TTS) levels. As with PTS onset levels used to define Level A take thresholds, TTS criteria use both SPL_{pk} and SEL_{cum} criteria as shown in Table 9.

6.3 WTG and OSS Monopile Foundation Installation

Monopile foundations for WTGs and the OSSs will be installed using an impact pile driver with a maximum hammer energy of up to 4,000 kJ. WTG monopile foundations will be up to 12 m in diameter while the OSS foundations will be up to 15 m in diameter. As summarized in Section 6.1, the take estimates for foundation installations were calculated using the animal exposure modeling process. Additional details regarding this method are available in Appendix A.

6.3.1 *Marine Mammal Densities*

Monthly mean densities for each species were calculated from Roberts et al. (2016; 2017; 2018; 2020) habitat-based density predictions (Table 12). Density data for the calculations were selected from all grid cells within a 50 km distance from the outer perimeter of the lease area (Figure 6; Appendix A). The 50 km distance was used since it provides a large sample of grid cells and represents the largest distance at which behavioral responses are likely to occur (Dunlop et al. 2017). Since the precise timing of foundation installation is not currently known but will likely occur over at least two months, the exposure calculations were performed using the mean densities from the two months with the highest density estimates for each species (Table 13). Due to differences in seasonal migration patterns, the two months selected are different for each species. Densities for the blue whale in this area were considered too low to be relevant for animal exposure modeling.

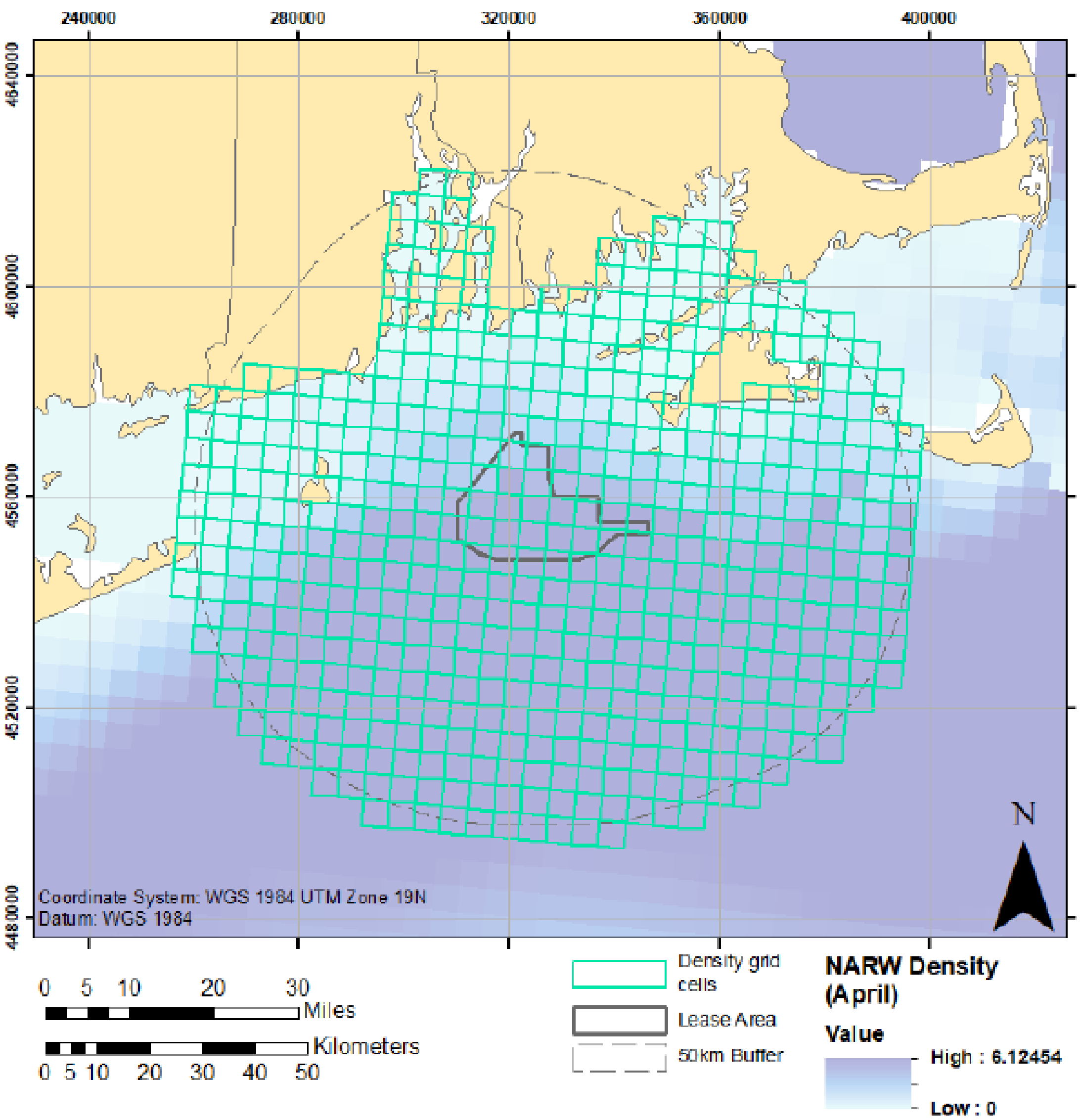

Figure 6. North Atlantic right whale density map showing highlighted grid cells from Roberts et al. (2021) used to calculate mean monthly density estimates within 50 km of OCS-A 0486 (reproduced from Figure 6 in Appendix A).

Table 12. Average monthly marine mammal densities within 50 km of the Lease Area perimeter.

	Monthly Average Densities (Individuals/1 km^2)											
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mysticetes												
Blue Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fin Whale*	0.0012	0.0011	0.0012	0.0022	0.0020	0.0021	0.0024	0.0023	0.0020	0.0012	0.0009	0.0010
Humpback Whale	0.0005	0.0003	0.0003	0.0012	0.0010	0.0011	0.0008	0.0007	0.0021	0.0013	0.0004	0.0008
Minke Whale	0.0004	0.0005	0.0005	0.0011	0.0016	0.0014	0.0005	0.0003	0.0003	0.0005	0.0002	0.0003
North Atlantic Right Whale*	0.0035	0.0042	0.0047	0.0053	0.0018	0.0001	0.0000	0.0000	0.0000	0.0001	0.0003	0.0015
Sei Whale*	0.0000	0.0000	0.0000	0.0002	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Odontocetes												
Atlantic Spotted Dolphin	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0004	0.0006	0.0006	0.0007	0.0004	0.0001
Atlantic White-Sided Dolphin	0.0192	0.0107	0.0119	0.0256	0.0419	0.0390	0.0247	0.0135	0.0155	0.0225	0.0226	0.0281
Bottlenose Dolphin	0.0050	0.0004	0.0001	0.0067	0.0111	0.0434	0.0953	0.0844	0.0749	0.0384	0.0200	0.0129
Common Dolphin	0.0960	0.0191	0.0075	0.0179	0.0347	0.0382	0.0378	0.0573	0.0930	0.1093	0.0825	0.1586
Harbor Porpoise	0.0382	0.0712	0.1046	0.0561	0.0315	0.0048	0.0033	0.0032	0.0028	0.0048	0.0291	0.0318
Pilot Whales	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
Risso's Dolphin	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0003	0.0002	0.0001	0.0001	0.0002
Sperm Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000
Pinnipeds												
Seals (Harbor and Gray)	0.1975	0.1586	0.0893	0.1208	0.1347	0.0478	0.0120	0.0053	0.0074	0.0158	0.0386	0.1649

* Denotes species listed under the Endangered Species Act

Table 13. Maximum and second highest average monthly marine mammal densities within 50 km of the lease area perimeter.

Species	Maximum Monthly Density (Ind./km^2)	Maximum Density Month	2nd Highest Monthly Density (Ind./km^2)	2nd Highest Density Month
Mysticetes				
Blue Whale*	N/A		N/A	
Fin Whale*	0.0024	July	0.0023	August
Humpback Whale	0.0021	September	0.0013	October
Minke Whale	0.0016	May	0.0014	June
North Atlantic Right Whale*	0.0053	April	0.0047	March
Sei Whale*	0.0002	April	0.0002	May
Odontocetes				
Atlantic Spotted Dolphin	0.0007	October	0.0006	September
Atlantic White-Sided Dolphin	0.0419	May	0.0390	June
Bottlenose Dolphin	0.0953	July	0.0844	August
Common Dolphin	0.1586	December	0.1093	October
Harbor Porpoise	0.1046	March	0.0712	February
Pilot Whales	0.0052	Annual	0.0052	Annual
Risso's Dolphin	0.0003	August	0.0002	September
Sperm Whale*	0.0003	July	0.0002	August
Pinnipeds				
Seals (Harbor and Gray)	0.1975	January	0.1649	December

* Denotes species listed under the Endangered Species Act

6.3.2 *Area Potentially Exposed to Sounds Above Threshold Levels from WTG and OSS Monopile Foundation Installation*

Sounds produced by installation of the 12 m WTG monopiles were modeled at two locations: one in the northwest section of the RWF area and one in the southeast section (Figure 7). The OSS monopile foundations were modeled at three proposed installation locations in the central portions of the RWF area (Figure 7). All piles were assumed to be vertical and driven to a maximum expected penetration depth of 40 m for the WTG monopiles and 50 m for the OSS monopiles. For the WTG monopiles, 6,500 total hammer strikes were assumed, with hammer energy increasing from 1,000 to 4,000 kJ during the assumed 3-4 hr installation time. The larger OSS monopiles were assumed to require 11,500 total strikes with hammer energy similarly increasing over the 6-7 hr installation time. Forcing functions for impact pile driving were computed for each pile type using GRLWEAP (Pile-Dynamics 2010). The resulting forcing functions were used as inputs to JASCO's impact pile driving source model (PDSM) to characterize the sounds generated by the piles. Acoustic sound fields were estimated using JASCO's Marine Operations Noise model (MONM) and Full Wave Range Dependent Acoustic Model (FWRAM). To account for the likely minimum sound reduction resulting from noise abatement systems (NAS) such as bubble curtains, the modeling study included hypothetical broadband attenuation levels of 0, 6, 10, and 15 dB for all impact pile driving acoustic modeling results.

For exposure analysis, it was assumed that up to 3 WTG monopiles may be driven in a day, and up to 2 OSS monopiles may be driven per day. However, installation of two OSS in a single day is very unlikely due to the distance between the planned locations, so only the results for one OSS installation per day are included in this application. Due to seasonal changes in the water column, sound propagation is likely to differ at different times of the year. To capture this variability, acoustic modeling was conducted using an average sound speed profile for a "summer" period including the months of May through November, and a "winter" period including December through April. Additional details on modeling inputs and assumptions are described in Appendix A.

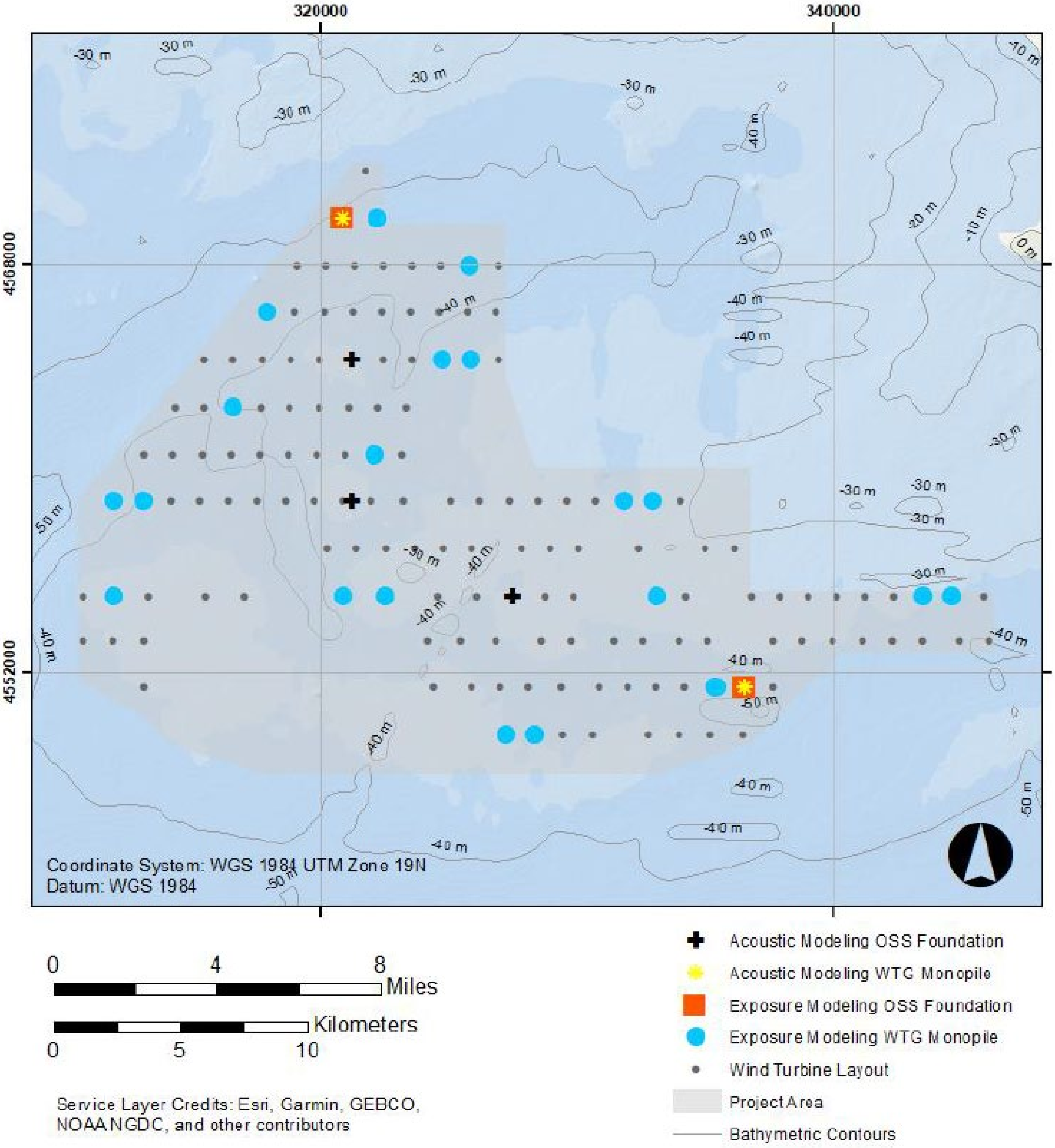

Figure 7. Location of acoustic propagation and animal exposure modeling for WTG and OSS monopile foundations (reproduced from Figure 2 in Appendix A).

The acoustic modeling included assumptions about the potential effectiveness of one or more noise abatement system (NAS), such as bubble curtains, evacuated sleeve systems, encapsulated bubble systems (HydroSound Dampers), and Helmholtz resonators (AdBm) in reducing sounds propagated into the surrounding marine environment. Several recent studies summarizing the effectiveness of NAS have shown that broadband sound levels are likely to be reduced by anywhere from 7 to 17 dB, depending on the environment, pile size, and the size, configuration and number of systems used (Buehler et al. 2015; Bellmann et al. 2020a). The single bubble curtain applied in shallow water environments regularly achieves 7-8 dB broadband attenuation (Lucke et al. 2011; Rustemeier et al. 2012; Bellmann 2014, 2019). More recent in situ measurements during installation of large monopiles (~8 m) for WTGs in comparable water depths and conditions indicate that attenuation levels of 10 dB are readily achieved for a single bubble curtain (Bellmann 2019; Bellmann et al. 2020b). Large bubble curtains tend to perform better and more reliably, particularly when deployed with two rings (Koschinski and Ludemann 2013; Bellmann 2014; Nehls et al. 2016). A California Department of Transportation study tested several small, single, bubble curtain systems and found that the best attenuation systems resulted in 10-15 dB of attenuation (Buehler et al. 2015). Buehler et al. (2015) concluded that attenuation greater than 10 dB could not be reliably predicted from small, single, bubble curtains because sound transmitted through the seabed and re-radiated into the water column is the dominant sound in the water for bubble curtains deployed immediately around the pile. Combinations of systems (e.g., double big bubble curtain, hydrodimer plus single big bubble curtain) potentially achieve much higher attenuation. The type and number of NAS to be used during construction have not yet been determined but will consist of at a minimum a single bubble curtain paired with an additional sound attenuation device or a double big bubble curtain. Based on prior measurements this combination of NAS are reasonably expected to achieve far greater than 10 dB broadband attenuation of impact pile driving sounds. The results shown here include the 10 dB reduction provided by use of one or more NAS, while modeling results for no attenuation and up to 20 dB of attenuation are provided in Appendix A.

The ranges to threshold levels resulting from the acoustic modeling are reported using two different terminologies to reflect the underlying assumptions of the modeling. The term “acoustic range” is used to refer to acoustic modeling results that are based only on sound propagation modeling and not animal movement modeling. Acoustic ranges assume receivers of the sound energy (marine mammals) are stationary throughout the duration of the exposure. These are most applicable to thresholds where any single instantaneous exposure above the threshold is considered to cause a take, such as the Level A SPL_{pk} thresholds and the Level B SPL_{rms} threshold. For SEL_{cum} based thresholds, acoustic ranges represent the maximum distance at which a receiver would be exposed above the threshold level if it remained present during the entire sound producing event or 24 hours, whichever is less. Since receivers are likely to move in and out of the threshold distance over the course of an exposure, these distances are more difficult to interpret. To address this, results from animal movement modeling are used to estimate an “exposure range”. This involves analyzing the movements and resulting accumulated sound energy during the exposure modeling and identifying the ranges within which most animals (95%) were exposed above the threshold level if they occurred within that range at any point in time. Therefore, the exposure ranges provide a more realistic assessment of the distances within which animals would need to occur in order to accumulate enough sound energy to cross the applicable SEL_{cum} threshold.

The acoustic ranges to the SPL_{pk} and $R_{95\%}$ SEL_{cum} thresholds for WTG and OSS foundations assuming various reductions in sound levels through use of a NAS are shown in Table 14, Table 15, and Table 16. The SPL_{pk} ranges in Table 14 are from modeling performed using a winter season sound speed profile which resulted in slightly longer distances for HF-cetaceans than in the summer season and no difference for the other hearing groups (Appendix A). Results for both summer and winter seasons are shown for acoustic ranges to $\mathrm{SEL_{cum}}$ thresholds in Table 15 and Table 16, respectively. The distances to the unweighted and frequency-weighted (Southall et al. 2007b) 160 dB $\mathrm{SPL_{rms}}$ Level B harassment threshold in summer and winter seasons and assuming 10 dB of noise attenuation are provided in Table 17. As described in Section 6.2, NMFS currently uses the unweighted threshold for assessing potential Level B harassment of marine mammals, while the frequency-weighted thresholds take into account the hearing abilities of marine mammals relative to the sounds produced by the activity. Thus, the frequency-weighted ranges provide a more realistic indication of the distances at which sounds perceived by marine mammals within each hearing group might reach the established threshold. Distances to threshold levels are different than those for similar nearby projects (e.g. South Fork Wind). While it is expected that larger piles produce greater sound levels, the sound generated depends on many factors. The greatest determining factor is the force at which the pile is struck, and the comparison made between South Fork and Revolution is for the same hammer (IHC S-4000) operating at the same hammer energy (4000 kJ). Nonetheless, the estimated source level for pile driving for South Fork Wind was approximately 2 dB higher than for Revolution Wind. Larger piles do have larger radiating surfaces but there may be loading/damping differences in the modeling assumptions – such as choice of representative penetration depths. Other modeling parameters, like geoacoustics, and modeling processes, such as convergence during calculation and spacing of the monopole array representing the distributed source, may also affect the estimation of sound levels. In this case, the small difference between the source levels (~2 dB) likely comes from a combination of modeling parameters and modeling process choices.

Table 14. Acoustic ranges to Level A peak sound pressure level ($\mathrm{SPL_{pk}}$) thresholds for marine mammals from WTG (7-12 m) and OSS (7-15 m) monopile installation using an IHC S-4000 hammer and assuming 10 dB of broadband noise attenuation and the winter sound speed profile.

		Range (m)	
Hearing Group	**$\mathrm{SPL_{pk}}$ Threshold (dB re 1 µPa)**	**WTG Monopile Foundation**	**OSS Monopile Foundation**
Low-frequency	219	5	6
Mid-frequency	230	-	-
High-frequency	202	200	260
Phocid pinniped	218	6	7

Table 15. Acoustic ranges ($R_{95\%}$) to Level A cumulative sound exposure level (SEL_{cum}) thresholds for marine mammals from installation of a single 12 m WTG monopile (6,500 strikes) and a single 15 m OSS monopile (11,500 strikes) in the summer (May – November) using an IHC S-4000 hammer and assuming increasing levels of broadband noise attenuation.

Hearing Group	SEL_{cum} Threshold (dB re 1 µPa^2)	Range (km)							
		WTG Monopile Foundation				OSS Monopile Foundation			
		0	6	10	15	0	6	10	15
Low-frequency	183	9.065	6.27	4.656	2.952	10.603	7.835	5.97	4.032
Mid-frequency	185	0.595	0.122	0.08	0.028	0.689	0.206	0.09	0.029
High-frequency	155	6.756	4.6	3.42	2.246	7.608	5.401	4.048	2.758
Phocid pinniped	185	2.985	1.471	0.81	0.3	3.81	2.058	1.154	0.582

Table 16. Acoustic ranges ($R_{95\%}$) to Level A cumulative sound exposure level (SEL_{cum}) thresholds for marine mammals from installation of a single 12 m monopile WTG (6,500 strikes) and a single 15 m OSS monopile (11,500 strikes) in the winter (December – April) using an IHC S-4000 hammer and assuming increasing levels of broadband noise attenuation.

Hearing Group	SEL_{cum} Threshold (dB re 1 µPa^2)	Range (km)							
		WTG Monopile Foundation				OSS Monopile Foundation			
		0	6	10	15	0	6	10	15
Low-frequency	183	24.415	13.061	8.663	4.847	28.983	16.273	11.121	6.646
Mid-frequency	185	0.511	0.206	0.089	0.028	0.72	0.253	0.119	0.063
High-frequency	155	13.885	7.94	5.246	2.709	16.353	9.437	6.475	3.706
Phocid pinniped	185	4.907	2.226	1.134	0.428	6.72	2.773	1.583	0.698

Table 17. Acoustic ranges ($R_{95\%}$) to the Level B, 160 dB re 1 µPa sound pressure level (SPL_{rms}) threshold impact pile driving during WTG (7-12 m) and OSS (7-15 m) monopile installation using an IHC S-4000 hammer and assuming 10 dB of broadband noise attenuation. Frequency-weighting functions from Southall et al.(2007a).

	Range (km)			
	WTG Monopile Foundation		OSS Monopile Foundation	
Hearing Group	Summer	Winter	Summer	Winter
Unweighted	3.833	4.271	4.1	4.698
Low-frequency	3.825	4.26	4.093	4.671
Mid-frequency	2.235	3.24	2.379	3.216
High-frequency	1.771	2.772	1.843	2.597
Phocid pinnipeds	3.282	3.785	3.545	3.838

Exposure ranges ($ER_{95\%}$) to Level A SEL_{cum} thresholds resulting from animal exposure modeling assuming various pile installation scenarios and 10 dB of attenuation by a NAS are summarized in Table 18. By incorporating animal movement into the calculation of ranges to time-dependent thresholds (SEL metrics), these provide a more realistic assessment of the distances within which acoustic thresholds may be exceeded. This also means that different species within the same hearing group can have different exposure ranges as a result of differences in movement patterns for each species. Meaningful differences (greater than 500 m) between species within the same hearing group occurred for LF-cetaceans, so exposure ranges are shown separately for those species (Table 18). For mid-frequency cetaceans and pinnipeds, the largest value from any single species was selected (Table 18).

Table 18. Exposure ranges[1] ($ER_{95\%}$) to Level A cumulative sound exposure level (SEL_{cum}) thresholds for marine mammals from installation of one and three 7-12 m WTG monopiles (6,500 strikes each) or one 7-15 m OSS monopile (11,500 strikes) in one day during the summer and winter seasons using a IHC S-4000 hammer and assuming 10 dB of broadband noise attenuation.

		Range (km)					
	SEL_{cum} Threshold (dB re 1 $\mu Pa^2 \cdot s$)	**WTG Monopile 1-Piles/Day**		**WTG Monopile 3-Piles/Day**		**OSS Monopile 1 pile/Day**	
Hearing Group		**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**
Low-frequency	183						
Fin Whale*		2.15	3.53	2.23	4.38	1.57	2.68
Humpback Whale		2.46	4.88	2.66	6.29	1.79	3.56
Minke Whale		1.32	3.03	1.51	3.45	0.94	1.81
NA Right Whale*		1.85	3.42	1.93	3.97	1.25	2.66
Sei Whale*		1.42	2.82	1.81	3.67	1.22	2.05
Mid-frequency	185	0	0.01	0.02	0.02	0	0
High-frequency	155	1.28	2.29	1.34	2.33	0.83	1.25
Phocid pinnipeds	185	0.6	0.73	0.44	0.81	0.37	0.37

* Denotes species listed under the Endangered Species Act

[1] Exposure ranges are a result of animal movement modelling.

Exposure ranges ($ER_{95\%}$) to Level A SEL_{cum} thresholds and Level B SPL_{rms} resulting from animal exposure modeling assuming 3 WTG monopiles installed in one day and various levels of attenuation from 0 to 20 dB in the summer are shown in Table 19 and in the winter are shown in Table 20. Any activities conducted in the winter season (December) will utilize monitoring and mitigation measures based on the exposure ranges ($ER_{95\%}$) calculated using winter sound speed profiles as shown in Table 20. Exposure ranges assuming 1 or 2 monopiles installed per day as well as OSS pile installations are available in Appendix A.

Table 19. Exposure ranges[1] ($ER_{95\%}$) to Level A cumulative sound exposure levels (SEL_{cum}) and Level B sound pressure level (SPL_{rms}) thresholds for marine mammals from installation of three 7-12 m WTG (6,500 strikes each) monopiles in one day during the summer season using an IHC S-4000 hammer and assuming various levels of broadband noise attenuation.

	Injury										**Behavior**				
	SEL_{cum}					**SPL_{pk}**					**SPL_{rms}**				
	Attenuation (dB)					**Attenuation (dB)**					**Attenuation (dB)**				
Hearing Group	**0**	**6**	**10**	**15**	**20**	**0**	**6**	**10**	**15**	**20**	**0**	**6**	**10**	**15**	**20**
Low-frequency															
Fin Whale*	5.53	3.37	2.23	1.03	0.52	0.07	0	0	0	0	5.68	4.11	3.76	2.92	1.86
Humpback Whale	6.24	4.01	2.66	1.49	0.51	0.04	<0.01	<0.01	<0.01	0	5.73	4.06	3.72	2.89	1.83
Minke Whale	4.39	2.4	1.51	0.54	0.06	0.04	<0.01	<0.01	0	0	5.6	4.08	3.63	2.79	1.76
NA Right Whale*	4.88	3.02	1.93	0.84	0.24	0.05	0	0	0	0	5.54	3.98	3.67	2.87	1.8
Sei Whale*	4.87	2.85	1.18	0.64	0.18	0.03	0	0	0	0	5.7	4.01	3.67	2.88	1.82
Mid-frequency	0.02	0.02	0.02	0	0	<0.01	0	0	0	0	5.63	4.05	3.67	2.8	1.81
High-frequency	3.68	2.15	1.34	0.57	0.09	0.54	0.29	0.16	0.07	<0.01	5.58	4.03	3.62	2.84	1.82
Phocid pinnipeds	1.96	0.96	0.44	0.21	0	0	0	0	0	0	5.9	4.2	3.8	3.05	1.95

* Denotes species listed under the Endangered Species Act

[1] Exposure ranges are a result of animal movement modelling.

Table 20. Exposure ranges[1] ($ER_{95\%}$) to Level A cumulative sound exposure levels (SEL_{cum}) and Level B sound pressure level (SPL_{rms}) thresholds for marine mammals from installation of three 7-12 m WTG (6,500 strikes each) monopiles in one day during the winter season using an IHC S-4000 hammer and assuming various levels of broadband noise attenuation.

	Injury										**Behavior**				
	SEL_{cum}					**SPL_{pk}**					**SPL_{rms}**				
	Attenuation (dB)					**Attenuation (dB)**					**Attenuation (dB)**				
Hearing Group	**0**	**6**	**10**	**15**	**20**	**0**	**6**	**10**	**15**	**20**	**0**	**6**	**10**	**15**	**20**
Low-frequency															
Fin Whale*	17	7.49	4.38	2.09	0.81	0.07	0	0	0	0	9.84	5.78	4.09	3.43	2.63
Humpback Whale	23.5	10.3	6.29	3	1.13	0.04	<0.01	<0.01	<0.01	0	9.69	5.86	4.11	3.5	2.54
Minke Whale	15.6	6.45	3.45	1.46	0.41	0.04	<0.01	<0.01	0	0	9.41	5.7	4.07	3.34	2.48
NA Right Whale*	17.1	7.44	3.97	1.9	0.61	0.05	0	0	0	0	9.55	5.68	3.95	3.31	2.54
Sei Whale*	15	6.62	3.67	1.65	0.54	0.05	0	0	0	0	9.69	5.78	4.02	3.42	2.53
Mid-frequency	0.09	0	0	0	0	<0.01	0	0	0	0	9.57	5.68	4.03	3.39	2.15
High-frequency	8.29	4.07	2.33	1.16	0.29	0.62	0.28	0.16	0.07	<0.01	9.54	5.7	4.03	3.39	2.51
Phocid pinnipeds	4.35	1.32	0.5	0.05	0	0.06	0	0	0	0	10.1	6.09	4.23	3.53	2.68

* Denotes species listed under the Endangered Species Act

[1] Exposure ranges are a result of animal movement modelling.

6.3.3 *Estimated Takes from WTG and OSS Monopile Foundation Installation*

The exposure modeling was conducted at 2 different WTG monopile sites and 3 different OSS monopile sites (Appendix A). Results from the site that produced the highest exposure estimates for WTG and OSS was selected and used in the following way to estimate the total potential take from the installations. The density from the highest month for each species was used to calculate exposures from installing 90 WTG monopiles (3 per day for 30 days). Then the density from the second highest month for each species was used to calculate the take from installing 10 WTG monopiles (3 per day for 3 days plus 1 on 1 day). Then the density from the second highest month was used to calculate exposures from installing 2 OSSs (1 per day for 2 days). The results of these three separate calculations were then summed to arrive at the total estimated exposure from WTG and OSS monopile foundations. Sound exposure modeling results showing potential Level A and Level B takes from installation of 100 WTG monopiles and 2 OSS monopile foundations are shown in Table 21.

The Level A estimates shown are only from the SEL_{cum} threshold as the very short distances to the SPL_{pk} thresholds (Table 14) resulted in no meaningful likelihood of take from exposure to those sound levels. Level B take estimates are shown from sound exposure modeling using the unweighted 160 dB SPL_{rms} criterion, not the frequency weighted Wood et al. (2012) criteria. For comparison, Level B take estimates were also calculated using the unweighted 160 dB distances shown in Table 17 to calculate the ensonified area around each foundation. This total area was then multiplied by the densities shown in Table 13 to estimate take without the use of animal movement modeling. For both exposure modeling results and the “static” estimates, when the species density in Table 13 occurred during one of the winter months (December through April), the appropriate winter sound field or threshold distance in Table 17 was used in the calculations and vice versa for summer months.

The estimated monthly density of seals provided in Roberts et al. (2018) includes all seal species present in the region as a single guild. To split the resulting “seal” density-based exposure estimate by species, we multiplied the estimate by the proportion of the combined abundance attributable to each species. Specifically, we summed the SAR N_{best} abundance estimates (Hayes et al. 2021) for the two species (gray seal = 27,300, harbor seal = 61,336; total = 88,636) and divided the total by the estimate for each species to get the proportion of the total for each species (gray seal = 0.308; harbor seal = 0.692). The total estimated exposure from the “seal” density provide by Roberts et al. (2018) was then multiplied by these proportions to get the species specific exposure estimates.

Table 21. Estimated Level A and Level B take from 100 (7-12 m) WTG and 2 (7-15 m) OSS monopile foundation installations using a IHC S-4000 hammer assuming 10 dB of noise attenuation. Level B exposure modeling[1] take estimates are based on the unweighted distances to the 160 dB level. "Static" Level B take estimates are from the standard density X area method described in the text, not from exposure modeling.

Species	Exposure Modeling Take Estimates		PSO Data Take Estimate	Mean Group Size	Highest Estimated Take
	Level A (SPL_{cum})	Level B (SPL_{rms})			
Mysticetes					
Blue Whale*	N/A	N/A	-	1.0	1
Fin Whale*	6.7	15.5	22.6	1.8	23
Humpback Whale	8.0	14.1	67.7	2.0	68
Minke Whale	6.8	21.3	13.9	1.2	22
North Atlantic Right Whale*	6.5	16.6	3.5	2.4	17
Sei Whale*	0.5	1.4	0.9	1.6	2
Odontocetes					
Atlantic Spotted Dolphin	0.0	0.0	-	29.0	29
Atlantic White-Sided Dolphin	0.3	598.8	8.7	27.9	599
Bottlenose Dolphin	0.0	898.7	97.2	7.8	899
Common Dolphin	0.0	3,401.4	2,738.0	34.9	3,402
Harbor Porpoise	238.6	507.0	2.4	2.7	508
Pilot Whales	0.0	49.9	-	8.4	50
Risso's Dolphin	0.0	3.5	6.8	5.4	7
Sperm Whale*	0.0	2.1	-	1.5	3
Pinnipeds					
Gray Seal	38.3	1,036.8	6.6	1.4	1,037
Harbor Seal	79.6	1,329.5	8.0	1.4	1,330

* Denotes species listed under the Endangered Species Act

[1] Exposure ranges are a result of animal movement modelling.

6.4 Export Cable Landfall Construction

Installation of the RWEC landfall will be accomplished using a horizontal directional drilling (HDD) methodology from shore to a point approximately ~250 m (800 ft) offshore for each of two separate cables. Where each borehole exits to the seabed surface, casing pipe supported by sheet pile "goal posts" may be temporarily installed to collect drilling mud from the borehole exit point. Alternatively, a temporary cofferdam made from sheet piles may be installed to allow for a dry environment in which to manage sediment, contaminated soil, and bentonite (drilling mud used during HDD operations).

If the casing pipe and goal post option is used, casing pipe would be installed from a construction barge using a pneumatic pipe ramming tool (e.g. Grundoram Taurus or similar). The casing pipe will require up to 3 hours per day of pneumatic hammering to install over a period of 2 days for each pipe.

Removal of each casing pipe may require use of the pipe ramming tool for the same amount of time as installation, so up to 4 days of use for each casing pipe or 8 days total for both casing pipes. Up to six goal posts may be installed to support the casing pipe between the barge and the penetration point on the seabed. Each goal post would be composed of 2 vertical sheet piles installed using a vibratory hammer such as an APE model 300 (or similar). A horizontal cross beam connecting the two sheet piles would then be installed to provide support to the casing pipe. Up to 10 additional sheet piles may be installed per borehole to help anchor the barge and support the construction activities. This results in a total of up to 22 sheet piles per borehole and two boreholes bringing the overall total to 44 sheet piles. Sheet piles used for the goal posts and supports would be up to 30 m (100 ft) long, 0.6 m (2 ft) wide, and 1 inch thick. Installation of the goal posts would require up to 3 days per borehole, or up to 6 days total for both boreholes. Removal of the goal posts would also involve the use of a vibratory hammer and likely require approximately the same amount of time as installation (6 days total for both boreholes). Thus, use of a vibratory pile driver to install and remove sheet piles may occur over a period of up to 12 days at the landfall location. All of the sheet pile goal posts would be installed first, followed by installation of the casing pipe.

If the cofferdam is constructed using sheet piles, a vibratory hammer would be used to drive the sheet piles into the seabed and also to remove them when the cable installation is complete. The installation and removal of sheet piles for a single cofferdam may require up to 28 days, or 56 days in total for both cable landfalls.

The overall sound levels associated with vibratory hammering are typically less than impact hammering, but the lower disturbance threshold (120 dB) for non-impulsive sounds means that vibratory pile driving activity will result in a larger area ensonified above that threshold (described below) and therefore a larger number of potential takes. Since the installation and removal of cofferdams would require the greatest number of days of vibratory pile driving, the take estimates calculated here are based on exposure to vibratory pile driving sounds.

6.4.1 *Marine Mammal Densities*

The export cable landfall construction will take place at Quonset Point in North Kingstown, Rhode Island which is within Narragansett Bay. However, the habitat-based marine mammal densities from Roberts et al. (2016; 2017; 2018; 2021) do not cover waters within Narragansett Bay. As an alternative, densities calculated from the area immediately outside of Narragansett Bay were used in the calculation of takes. This is a conservative approach since there have been few reported sightings of marine mammals, other than seals, within Narragansett Bay (Raposa 2009). Since mysticete whales are especially unlikely to occur within Narragansett Bay (Raposa 2009), incidental take of these species is not being requested.

To select marine mammal density grid cells from the Roberts et al. (2016; 2017; 2018; 2021) data representative of the area outside of Narragansett Bay a 10 km buffer from the mouth of Narragansett Bay was created in GIS (ESRI 2017). This buffer was then intersected with the density grid cells for each individual species to select those near the mouth of Narragansett Bay (Figure 8). An example of a single species (bottlenose dolphin in the month of August) and how the polygon was used to select the density grid cells is shown in Figure 8. The average density of each species in each month was then calculated from the selected grid cells (Table 22). Since the timing of landfall construction may vary somewhat, the maximum average monthly density for each species was selected (Table 23) and used to calculate potential takes from landfall construction.

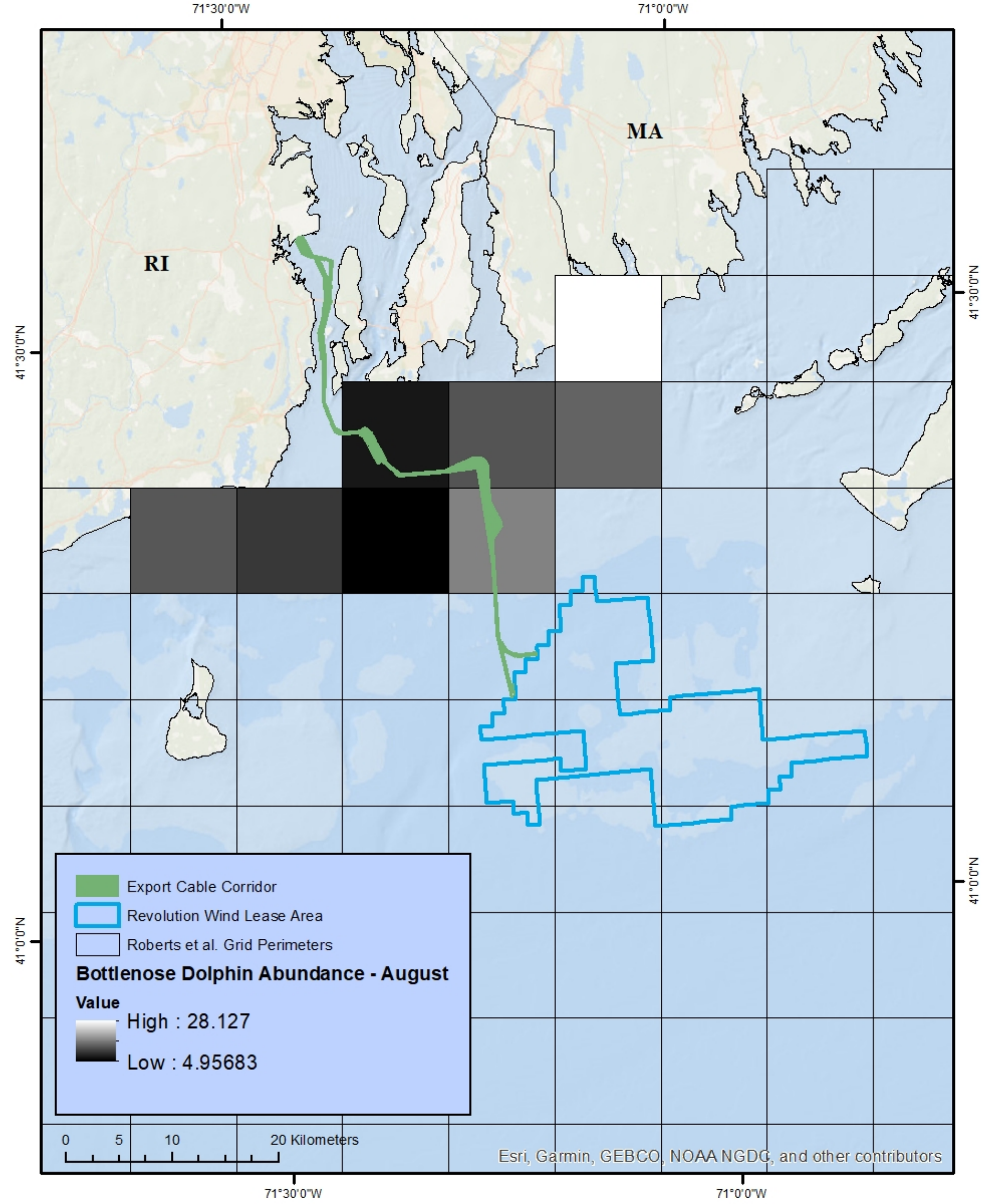

Figure 8. Location of the export cable corridor and the marine mammal density grid cells from Roberts et al. (2016; 2017; 2018; 2021) used for calculating monthly marine mammal densities. The cable corridor shown represents the area within which the cable will be micro sited and does not represent an area of potential impact.

Table 22. Average monthly marine mammal densities within 10 km of the mouth of Narragansett Bay.

	Monthly Average Densities (Individuals/km^2)											
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mysticetes												
Blue Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fin Whale*	0.0002	0.0002	0.0002	0.0006	0.0005	0.0006	0.0005	0.0007	0.0008	0.0005	0.0002	0.0001
Humpback Whale	0.0010	0.0004	0.0002	0.0002	0.0002	0.0001	0.0002	0.0001	0.0003	0.0006	0.0001	0.0018
Minke Whale	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
North Atlantic Right Whale*	0.0025	0.0027	0.0030	0.0035	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000	0.0002	0.0012
Sei Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Odontocetes												
Atlantic Spotted Dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000
Atlantic White-Sided Dolphin	0.0008	0.0007	0.0013	0.0028	0.0025	0.0026	0.0017	0.0013	0.0021	0.0034	0.0019	0.0015
Bottlenose Dolphin	0.0037	0.0001	0.0000	0.0064	0.0121	0.0520	0.1256	0.1340	0.0989	0.0220	0.0132	0.0175
Common Dolphin	0.0102	0.0018	0.0014	0.0042	0.0109	0.0115	0.0072	0.0076	0.0131	0.0218	0.0217	0.0440
Harbor Porpoise	0.0414	0.0432	0.0333	0.0085	0.0087	0.0009	0.0008	0.0012	0.0010	0.0039	0.0453	0.0434
Pilot Whales	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Risso's Dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sperm Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
Pinnipeds												
Seals (Harbor and Gray)	0.3222	0.2392	0.0597	0.0266	0.0402	0.0500	0.0174	0.0060	0.0082	0.0172	0.0239	0.1578

* Denotes species listed under the Endangered Species Act

Table 23. Maximum average monthly marine mammal densities near the mouth of Narragansett Bay and the month in which each maximum density occurs.

Species	Maximum Monthly Density (Ind/km^2)	Maximum Density Month
Mysticetes		
Blue Whale*	0.0000	Annual
Fin Whale*	0.0008	September
Humpback Whale	0.0018	December
Minke Whale	0.0002	May
North Atlantic Right Whale*	0.0035	April
Sei Whale*	0.0000	May
Odontocetes		
Atlantic Spotted Dolphin	0.0001	October
Atlantic White-Sided Dolphin	0.0034	October
Bottlenose Dolphin	0.1340	August
Common Dolphin	0.0440	December
Harbor Porpoise	0.0453	November
Pilot Whales	0.0001	Annual
Risso's Dolphin	0.0000	December
Sperm Whale*	0.0001	July
Pinnipeds		
Seals (Harbor and Gray)	0.3222	January

* Denotes species listed under the Endangered Species Act

6.4.2 *Area Potentially Exposed to Sounds Above Threshold Levels from Cable Landfall Construction*

The use of a Grundoram (or similar) pneumatic hammer with maximum hammer energy of 18 kJ to install and remove temporary casing pipe will produce impulsive sounds. To estimate distances to Level A and Level B thresholds acoustic modeling was recently performed for the Sunrise Wind project at that project's anticipated HDD exit pit location approximately 0.5 mi (800 m) offshore of Long Island, New York near Smith Point. This location has similar water depths and shallow substrate conditions as found at the landfall location in Narragansett Bay so the modeling results are expected to be applicable to the Revolution Wind project. Modeling methods were the same as those summarized above for impact pile driving of monopile foundations, including the use of GRLWEAP, PDSM and FWRAM models. The modeling used a winter sound speed profile and assumed up to 3 hours of pneumatic hammer use per day for 2 days to install each casing pipe. Assuming 180 strikes per minute over 3 hours of operations results in up to 32,400 total strikes per day. Additional information used in the modeling is provided in Table 24.

Table 24. Casing pipe installation acoustic modeling assumptions.

Parameter	Model Input
Hammer Energy	18 kJ
Pile Length	30 m
Pile Diameter	1.2 m
Pile Wall Thickness	2.54 cm
Seabed Penetration	10 m
Angle of Installation	11-12 degrees
Time to Install 1 Casing Pipe	6 hrs
Number of Casing Pipes per Day	0.5
Duration of Hammering per Day	3 hrs
Strikes per Minute	180
Number of Hammer Strikes per Day	32,400

Table 25. Acoustic ranges ($R_{95\%}$) in meters to Level A (PTS) and Level B disturbance thresholds for impact pile driving during casing pipe installation for marine mammal functional hearing groups assuming a winter sound speed profile.

	Range (m)	
Marine Mammal Hearing Group	**Level A SEL_{cum} Thresholds (dB re 1 $\mu Pa^2 \cdot s$)**	**Level B SPL_{rms} Threshold (160 dB re 1 μPa)**
Low-frequency	3,870	920
Mid-frequency	230	920
High-frequency	3,950	920
Phocid pinniped	1,290	920

For low-frequency cetaceans, high-frequency cetaceans, and seals, the estimated distances to Level A SEL_{cum} thresholds are larger than the Level B SPL thresholds (Table 25). This is due to the high strike rate of the pneumatic hammer resulting in a high number of strikes per day. However, low-frequency cetaceans are unlikely to occur close to this nearshore site and individuals of any species are not expected to remain within the estimated SEL_{cum} threshold distances for the entire duration of piling. With the implementation of planned monitoring and mitigation (see Section 11), no Level A takes are anticipated.

Acoustic modeling at the Sunrise Wind HDD exit pit location was also performed to determine threshold distances from installation of sheet piles to create the casing pipe support “goal posts” and support the construction barge. Modeling was conducted by JASCO using their MONM. The modeling assumed the use of an APE model 300 vibratory hammer to drive the sheet piles vertically to 10 m below the seabed. For modeling purposes, it was assumed that each pile would require 2 hours to install and up to 4 piles would be installed per day (Table 26). Results of the sheet pile installation acoustic modeling are shown in Table 27.

Table 26. Sheet pile installation acoustic modeling assumptions.

Parameter	**Model Input**
Vibratory Hammer	APE 300
Pile Type	Sheet Pile
Pile Length	30 m
Pile Width	0.6 m
Pile Wall Thickness	2.54 cm
Seabed Penetration	10 m
Time to Install 1 Pile	2 hrs
Number of Piles per Day	4

Table 27. Acoustic ranges ($R_{95\%}$) in meters to Level A (PTS) and Level B disturbance thresholds from vibratory pile driving during sheet pile installation for marine mammal functional hearing groups assuming a winter sound speed profile.

	Range (m)	
Marine Mammal Hearing Group	**Level A SEL_{cum} Thresholds (dB re 1 µPa²·s)**	**Level B SPL_{rms} Threshold (120 dB re 1 µPa)**
Low-frequency	5	9,740
Mid-frequency	-	9,740
High-frequency	190	9,740
Phocid pinniped	10	9,740

The estimated distance to the Level B threshold, 9.74 km, is much greater than the approximate 250 m (800 ft) distance to shore from the construction site. Since the landfall location is within Narragansett Bay and the area within this distance from the site includes land, a simple calculation of the area of a circle with a radius of 9.74 km is not appropriate. Accounting for the effects that nearby land will have on sound propagation results in an estimated area of 54.1 km^2 potentially being ensonified above the 120 dB threshold as shown in Figure 9. As a cautionary approach, this includes some areas beyond 9.74 km from the landfall location and reflects the maximum area potential ensonified above threshold levels from construction activities at that site, including if a larger vibratory pile driving hammer were to be used.

The distances to Level A SEL_{cum} thresholds from vibratory pile driving are relatively short and assume animals would remain within those distances for the entire 8-hour duration of pile driving in a day. This, in addition to the planned monitoring and mitigation around the landfall construction activities (see Section 11), means Level A takes are not anticipated or requested.

For take assessment purposes the cofferdam scenario is assessed in Section 6.4.3 of this application as the most conservative installation method. This is because more Level B take would be requested from the use of cofferdams than from casing pipes with goal post supports as summarized here and explained in greater detail in Section 6.4. Vibratory pile driving is expected to have a Level B threshold distance of 9.74 km while impact hammering (with a pneumatic pipe ramming tool) of casing pipe would have a level B distance of approximately 0.92 km. The cofferdam scenario would require up to 56 days of vibratory pile driving for installation and removal, while the casing pipe scenario would require up to 24 days of vibratory pile driving plus 8 days of impact pile driving (with a pneumatic pipe ramming tool). The larger number of total days of pile driving in the cofferdam scenario and the fact that all of those days would involve the larger Level B zone from vibratory pile driving means the anticipated Level B take from the cofferdam scenario would be higher and is therefore carried forward as the more conservative assumption.

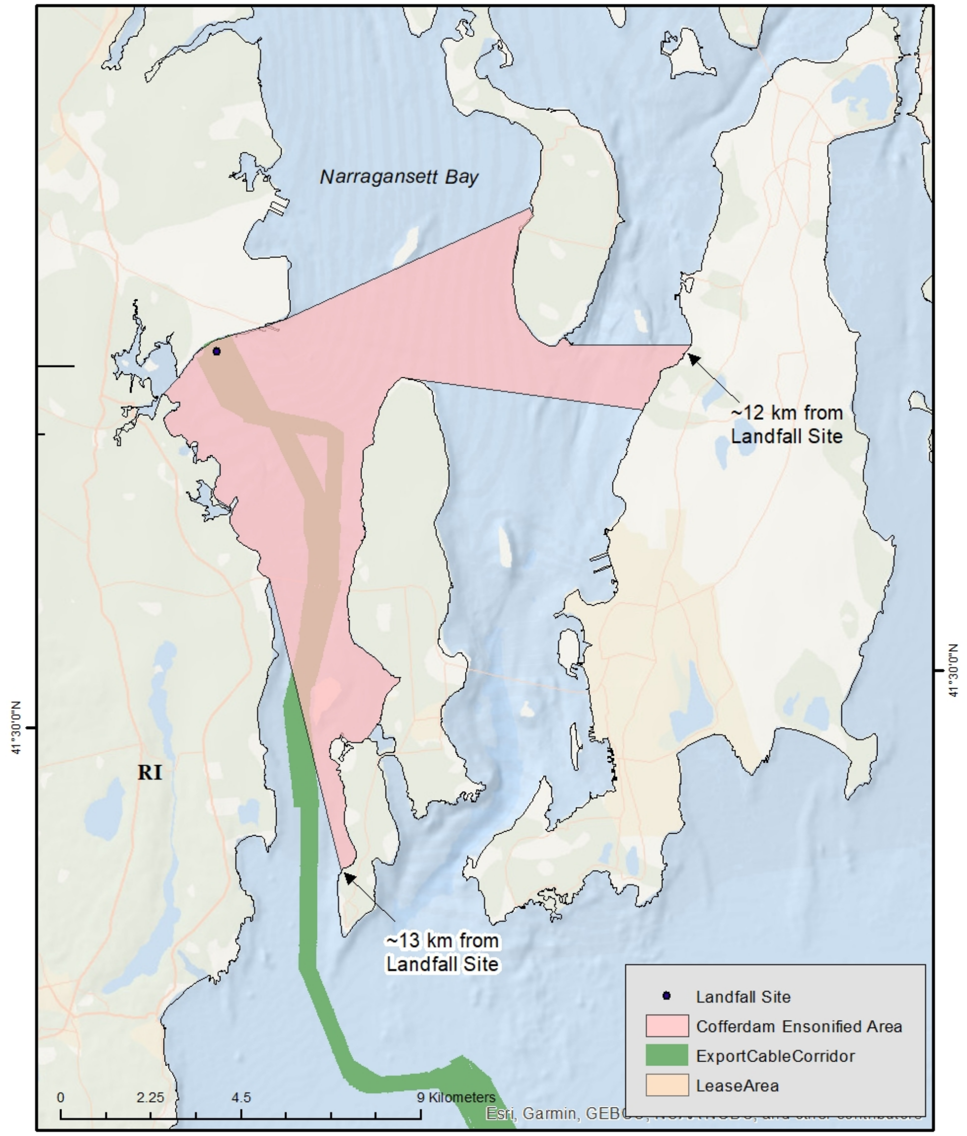

Figure 9. Map showing the maximum area potentially ensonified above the 120 dB Level B threshold criteria from vibratory pile driving. The cable corridor shown represents the area within which the cable will be micro sited and does not represent an area of potential impact.

6.4.3 *Estimated Takes from Cable Landfall Construction*

The marine mammal densities from Table 23 were multiplied by the daily ensonified area (54.1 km^2) to calculate the daily estimated take from construction activities at the landfall location. Since use of the vibratory pile driver during cofferdam installation and removal may occur on up to 56 days, the daily estimated take was multiplied by 56 to produce the results shown in Table 28. Since mysticete whales are especially unlikely to occur within Narragansett Bay (Raposa 2009), incidental take of these species is not being requested. No Level A takes for this activity are anticipated or requested.

Table 28. Estimated Level B take from Export Cable landfall construction.

Species	Density-based Take Estimate	PSO Data Take Estimate	Mean Group Size	Highest Level B Take
Odontocetes				
Atlantic Spotted Dolphin	0.3	-	29.0	29
Atlantic White-Sided Dolphin	10.3	5.3	27.9	28
Bottlenose Dolphin	405.9	59.2	7.8	406
Common Dolphin	133.3	1,666.6	34.9	1,667
Harbor Porpoise	137.1	1.5	2.7	138
Pilot Whales	0.3	-	8.4	9
Risso’s Dolphin	0.0	4.1	5.4	6
Sperm Whale*	0.2	-	1.5	2
Pinnipeds				
Gray Seal	300.7	4.0	1.4	301
Harbor Seal	675.5	4.9	1.4	676

* Denotes species listed under the Endangered Species Act

6.5 HRG Surveys – Construction Phase

HRG surveys will take place within the Lease Area as well as along the Export Cable Route. For some species, marine mammal densities may differ between the more nearshore areas along the Export Cable Route and the more offshore location of the Lease Area. For that reason, separate densities were calculated for the two areas and the total anticipated survey effort was similarly split between the two locations as described below.

6.5.1 *Marine Mammal Densities*

To select marine mammal density grid cells from the Roberts et al. (2016; 2017; 2018; 2021) data representative of the area around the RWEC route, a 10-km buffer of the cable route was created in GIS (ESRI 2017). This buffer was then intersected with the density grid cells to select those near the RWEC route (Figure 10). An example of a single species (bottlenose dolphin in the month of August) and how the polygon was used to select the density grid cells is shown in Figure 10. The average density of each species in each month was then calculated from the selected grid cells (Table 29) and an annual average density was calculated by averaging across all 12 months (Table 30).

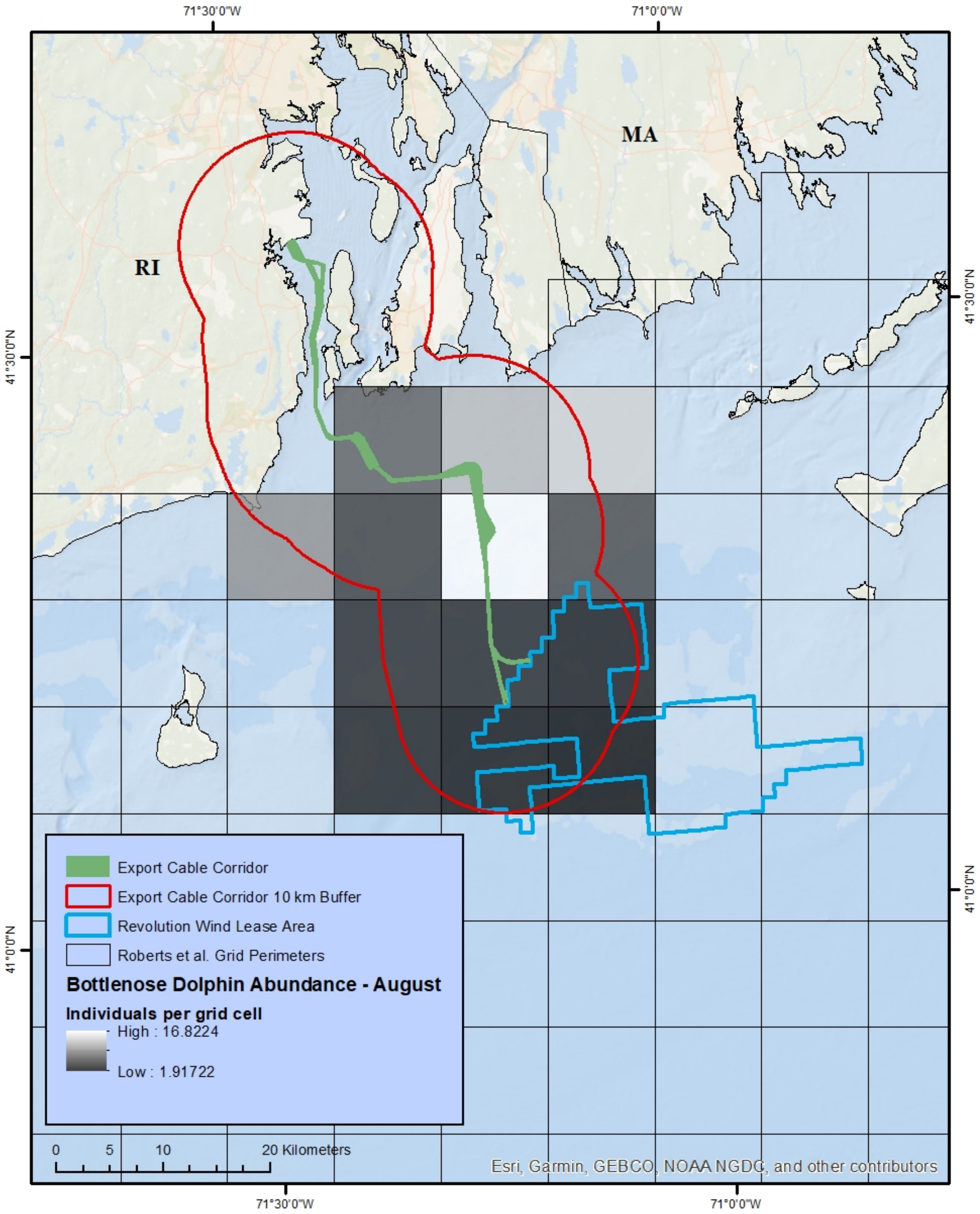

Figure 10. Location of the export cable corridor and the marine mammal density grid cells from Roberts et al. (2016; 2017; 2018; 2021) used for calculating monthly marine mammal densities. The cable corridor shown represents the area within which the cable will be micro sited and does not represent an area of potential impact.

Table 29. Average monthly marine mammal densities along the Export Cable Route.

	Monthly Average Densities (Individuals/km^2)											
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mysticetes												
Blue Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fin Whale*	0.0006	0.0005	0.0006	0.0012	0.0008	0.0010	0.0011	0.0012	0.0012	0.0009	0.0005	0.0005
Humpback Whale	0.0008	0.0004	0.0003	0.0007	0.0005	0.0006	0.0005	0.0008	0.0019	0.0014	0.0002	0.0012
Minke Whale	0.0003	0.0003	0.0003	0.0005	0.0006	0.0005	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002
North Atlantic Right Whale*	0.0025	0.0027	0.0030	0.0035	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000	0.0002	0.0012
Sei Whale*	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Odontocetes												
Atlantic Spotted Dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0002	0.0001	0.0000
Atlantic White-Sided Dolphin	0.0036	0.0020	0.0031	0.0067	0.0070	0.0070	0.0052	0.0035	0.0042	0.0069	0.0049	0.0065
Bottlenose Dolphin	0.0034	0.0001	0.0000	0.0031	0.0064	0.0281	0.0634	0.0689	0.0573	0.0160	0.0082	0.0109
Common Dolphin	0.0309	0.0047	0.0028	0.0079	0.0205	0.0217	0.0153	0.0180	0.0301	0.0447	0.0393	0.0920
Harbor Porpoise	0.0454	0.0847	0.0897	0.0259	0.0231	0.0015	0.0010	0.0012	0.0013	0.0045	0.0391	0.0362
Pilot Whales	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Risso's Dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sperm Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000
Pinnipeds												
Seals (Harbor and Gray)	0.1424	0.1761	0.0687	0.0312	0.0416	0.0399	0.0137	0.0049	0.0072	0.0142	0.0108	0.0542

* Denotes species listed under the Endangered Species Act

Table 30. Annual average marine mammal densities along the Export Cable Route.

Species	Annual Average Density (Ind/km^2)
Mysticetes	
Blue Whale*	0.0000
Fin Whale*	0.0008
Humpback Whale	0.0008
Minke Whale	0.0003
North Atlantic Right Whale*	0.0012
Sei Whale*	0.0000
Odontocetes	
Atlantic Spotted Dolphin	0.0001
Atlantic White-Sided Dolphin	0.0051
Bottlenose Dolphin	0.0221
Common Dolphin	0.0273
Harbor Porpoise	0.0295
Pilot Whales	0.0008
Risso's Dolphin	0.0000
Sperm Whale*	0.0001
Pinnipeds	
Seals (Harbor and Gray)	0.0504

* Denotes species listed under the Endangered Species Act

Marine mammal densities in and around the Lease Area were calculated to estimate takes from WTG and OSS foundation installations using a 50 km buffer around the Lease Area (Appendix A). This is appropriate given the larger zones of potential impact from the sounds produced by impact pile driving of the foundations. Since potential impacts from sounds produced by HRG survey equipment will be limited to much shorter distances, densities for the Lease Area were calculated using a 10 km buffer of the Lease Area. To select marine mammal density grid cells from the Roberts et al. (2016; 2017; 2018; 2021) data representative of the area within and immediately adjacent to the Lease Area, a 10-km buffer of the Lease Area was created in GIS (ESRI 2017). This buffer was then intersected with the density grid cells to select cells in and around the Lease Area (Figure 11). The average density of each species in each month was then calculated from the selected grid cells (Table 31) and an annual average density was calculated by averaging across all 12 months (Table 32). Since HRG surveys may occur at any time of year, the annual average density for each species was selected and used to calculated potential takes from HRG survey that may occur throughout the year (Table 32).

Table 31. Average monthly marine mammal densities within 10 km of the Lease Area.

	Monthly Average Densities (Individuals/km^2)											
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mysticetes												
Blue Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fin Whale*	0.0012	0.0010	0.0011	0.0021	0.0016	0.0017	0.0019	0.0020	0.0016	0.0014	0.0009	0.0010
Humpback Whale	0.0005	0.0003	0.0003	0.0016	0.0013	0.0014	0.0010	0.0016	0.0048	0.0023	0.0004	0.0007
Minke Whale	0.0004	0.0005	0.0005	0.0009	0.0012	0.0011	0.0004	0.0002	0.0002	0.0003	0.0002	0.0003
North Atlantic Right Whale*	0.0045	0.0049	0.0055	0.0065	0.0018	0.0001	0.0000	0.0000	0.0000	0.0001	0.0003	0.0021
Sei Whale*	0.0000	0.0000	0.0000	0.0002	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Odontocetes												
Atlantic Spotted Dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0003	0.0003	0.0002	0.0000
Atlantic White-Sided Dolphin	0.0109	0.0049	0.0062	0.0131	0.0184	0.0179	0.0135	0.0087	0.0087	0.0127	0.0107	0.0173
Bottlenose Dolphin	0.0041	0.0001	0.0000	0.0020	0.0042	0.0167	0.0360	0.0355	0.0392	0.0177	0.0082	0.0091
Common Dolphin	0.0688	0.0099	0.0050	0.0140	0.0342	0.0334	0.0287	0.0416	0.0678	0.0907	0.0736	0.1647
Harbor Porpoise	0.0358	0.0913	0.1293	0.0478	0.0354	0.0028	0.0019	0.0017	0.0018	0.0052	0.0269	0.0227
Pilot Whales	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
Risso’s Dolphin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001
Sperm Whale*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0003	0.0001	0.0001	0.0001	0.0000
Pinnipeds												
Seals (Harbor and Gray)	0.0659	0.1311	0.0714	0.0370	0.0533	0.0318	0.0096	0.0043	0.0064	0.0109	0.0055	0.0219

* Denotes species listed under the Endangered Species Act

Table 32. Annual average marine mammal densities within 10 km of the Lease Area.

Species	**Annual Average Density (Ind./km^2)**
Mysticetes	
Blue Whale*	0.0000
Fin Whale*	0.0015
Humpback Whale	0.0013
Minke Whale	0.0005
North Atlantic Right Whale*	0.0022
Sei Whale*	0.0000
Odontocetes	
Atlantic Spotted Dolphin	0.0001
Atlantic White-Sided Dolphin	0.0119
Bottlenose Dolphin	0.0144
Common Dolphin	0.0527
Harbor Porpoise	0.0336
Pilot Whales	0.0029
Risso’s Dolphin	0.0000
Sperm Whale*	0.0001
Pinnipeds	
Seals (Harbor and Gray)	0.0374

* Denotes species listed under the Endangered Species Act

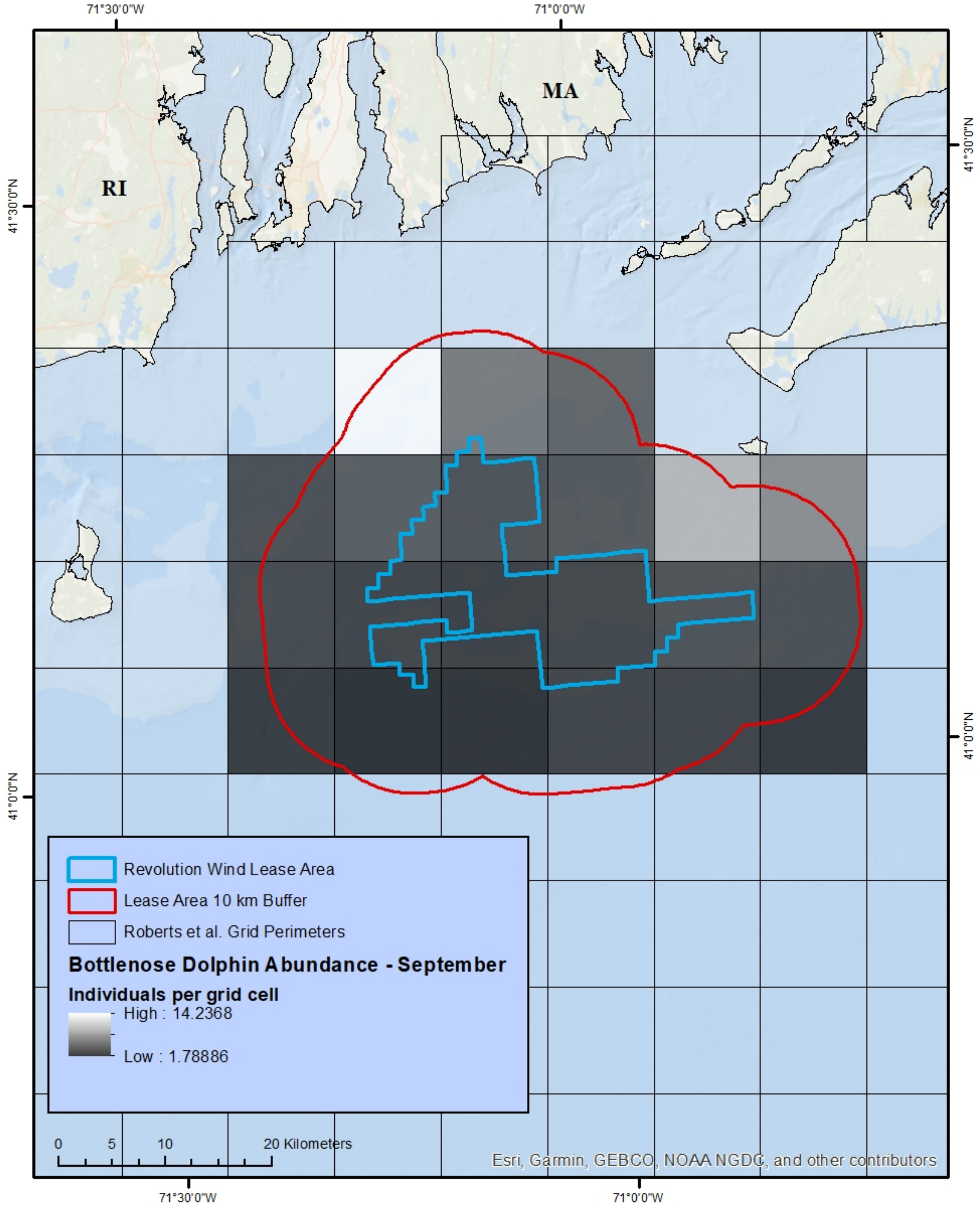

Figure 11. Location of the Lease Area and marine mammal density grid cells from Roberts et al. (2016; 2017; 2018; 2021) used for calculating representative monthly marine mammal densities.

6.5.2 *Area Potentially Exposed to Sounds Above Threshold Levels from HRG Surveys – Construction Phase*

As described in Section 1.1.4, several different types of equipment may be used during HRG surveys, including single-beam echosounders, multi-beam echosounders, side scan sonars, non-parametric sub-bottom profilers, parametric sub-bottom profilers, boomers, and sparkers. Only the sounds produced by sub-bottom profilers (SBPs), boomers, and sparkers have the potential to cause incidental take so representative instruments were modeled and distances to threshold levels determined as described below.

Shallow-penetration, non-impulsive, non-parametric SBPs (compressed high-intensity radiated pulses [CHIRP SBPs]) are used to map the near-surface stratigraphy (top 0 to 5 m (0 to 16 ft) of sediment below the seabed. A CHIRP SBP system emits "swept" sound pulses that increase in frequency from approximately 2 to 20 kHz over the duration of the pulse. The pulse length and frequency range can be adjusted to meet Project variables. These shallow-penetration SPBs are typically mounted on a pole, rather than towed, either over the side of the vessel or through a moon pool in the bottom of the hull, reducing the likelihood that an animal would be exposed to the signal.

Medium-penetration, impulsive boomers are used to map deeper subsurface stratigraphy as needed. A boomer is a broad-band sound source operating in the 3.5 Hertz (Hz) to 10 kHz frequency range. This system is commonly mounted on a sled and towed behind the vessel.

Medium-penetration, impulsive sparkers are used to map deeper subsurface stratigraphy as needed. Sparkers create acoustic pulses from 50 Hz to 4 kHz omnidirectionally from the source that can penetrate several hundred meters into the seafloor. Sparkers are typically towed behind the vessel with adjacent hydrophone arrays to receive the return signals.

Although the final equipment choices will vary depending on the final survey design, vessel availability, make and model updates, and survey contractor selection, all sources that are representative of those that could be employed during the HRG surveys and have the expected potential to result in exposure of marine mammals and potentially result in take, are provided in Table 32. Annual average marine mammal densities within 10 km of the Lease Area. along with details of the parameters used in acoustic analyses.

The Dura-spark measurements and specifications provided in Crocker and Fratantonio (2016) were used for all sparker systems proposed for the survey. These include variants of the Dura-spark sparker system and various configurations of the GeoMarine Geo-Source sparker system. The data provided in Crocker and Fratantonio (2016) represent the most applicable data for similar sparker systems with comparable operating methods and settings when manufacturer or other reliable measurements are not available. Crocker and Fratantonio (2016) provide S-Boom measurements using two different power sources (CSP–D700 and CSP–N). The CSP–D700 power source was used in the 700 J measurements but not in the 1,000 J measurements. The CSP–N source was measured for both 700 J and 1,000 J operations but resulted in a lower SL; therefore, the single maximum SL value was used for both operational levels of the S-Boom.

Table 33. Summary of representative HRG Survey equipment and operating parameters used to calculate distances to incidental take threshold levels.

Equipment Type	Representative Model	Operating Frequency (kHz)	Source Level SPL_{rms} (dB)	Source Level 0-pk (dB)	Pulse Duration (ms)	Repetition Rate (Hz)	Beamwidth (degrees)	Information Source
Sub-bottom Profiler	EdgeTech 216	2 – 16	195	-	20	6	24	MAN
	EdgeTech 424	4 – 24	176	-	3.4	2	71	CF
	Edgetech 512	0.7 – 12	179	-	9	8	80	CF
	GeoPulse 5430A	2 – 17	196	-	50	10	55	MAN
	Teledyn Benthos Chirp III - TTV 170	2 – 17	197	-	60	15	100	MAN
Sparker	Applied Acoustics Dura-Spark UHD (400 tips, 500 J)	0.3 – 1.2	203	211	1.1	4	Omni	CF
Boomer	Applied Acoustics triple plate S-Boom (700–1,000 J)	0.1 – 5	205	211	0.6	4	80	CF

- = not applicable; CF = Crocker and Fratantonio (2016); MAN = Manufactures Specifications
Source Levels are given in dB re 1 µPa @ 1m

To estimate the potential for Level A take from the HRG survey sources, the SEL_{cum} metric was applied to non-impulsive sources to estimate the range to acoustic thresholds. Because impulsive sources use dual metrics (SEL_{cum} and SPL_{pk}) for Level A exposure criteria, the metric resulting in the largest isopleth distance was used for exposure estimation. Weighting factor adjustments (WFAs) for Level A isopleths used to account for differences in marine mammal hearing were determined by examining the frequency range and spectral densities for each source. The selected WFAs were then compared to the Applicable Frequencies Table located in the WFA tab of the NMFS User Spreadsheet Tool (NMFS 2018a). If the determined frequency was lower than the applicable frequency for all hearing groups, it was entered as the WFA. When the frequency of a source exceeded the applicable frequency for a certain hearing group, an additional worksheet was created that applied the "use" frequency of the exceeded hearing group as indicated by NMFS (NMFS 2018a).

The User Spreadsheet does not calculate distances to Level B thresholds; the range to the Level B thresholds was determined by applying spherical spreading loss to the SL for that equipment. The operational depth and directionality can greatly influence how the sound propagates and can influence the resulting isopleth distance, so these parameters were considered for sources that had reported beamwidths. Surface-towed omnidirectional sources (e.g., sparkers, boomers) and equipment with wide (more than 180 degrees) reported beamwidths are expected to propagate farther in the horizontal direction and produce larger ensonified fields. For these sources, the rate of TL was estimated using spherical spreading loss to calculate the distance to the Level B threshold.

Sources that project a narrow beam, often in frequencies above 10 kHz directed at the seabed, are expected to have smaller isopleths and less horizontal propagation due to the directionality of the source and faster attenuation rate of higher frequencies. Narrow beamwidths allow geophysical equipment to be highly directional, focusing its energy on the vertical direction and minimizing horizontal propagation, which greatly reduces the possibility of direct path exposure to receivers (i.e., marine mammals) from sounds emitted by these sources. Therefore, for sources with beamwidths less than 180 degrees, isopleth distances were calculated following NMFS OPR interim guidance (NMFS 2020a) to account for the influence of beamwidth and frequency on the horizontal propagation of these sources. The estimated distances to Level A and Level B HRG survey isopleths calculated for each marine mammal hearing group are given in Table 34.

Table 34. Distances to weighted Level A and unweighted level B threshold for each HRG sound source or comparable sound source category for each marine mammal hearing group.

Equipment Type	Representative Model	Distance to Level A Threshold (m) LF (SEL_{cum})	MF (SEL_{cum})	HF (SEL_{cum})	HF ($SPL_{0\text{-}pk}$)	PW (SEL_{cum})	Level B (m) All (SPL_{rms})
Sub-bottom Profiler	EdgeTech 216	<1	<1	2.9	NA	0	9
	EdgeTech 424	0	0	0	NA	0	4
	Edgetech 512	0	0	<1	NA	0	6
	GeoPulse 5430A	<1	<1	36.5	NA	<1	21
	Teledyn Benthos Chirp III - TTV 170	<1	<1	16.9	NA	<1	48
Sparker	Applied Acoustics Dura-Spark UHD (700 tips, 1,000 J)	<1	0	0	4.7	<1	34
	Applied Acoustics Dura-Spark UHD (400 tips, 500 J)	<1	0	0	2.8	<1	141
	Applied Acoustics Dura-Spark UHD (400 tips, 500 J)	<1	0	0	2.8	<1	141
Boomer	Applied Acoustics triple plate S-Boom (700–1,000 J)	<1	0	0	2.8	<1	141

LF = low-frequency cetaceans; MF = mid-frequency cetaceans; HF = high-frequency cetaceans; PW = phocid pinnipeds in water.
= not applicable; CF = Crocker and Fratantonio (2016); MAN = Manufactures Specifications
Source Levels are given in dB re 1 µPa @ 1m

The largest Level A threshold distances was 36.5 m across all representative instruments and with the implementation of planned monitoring and mitigation measures, no Level A takes are anticipated or requested for HRG surveys.

The largest modeled distance to the Level B threshold from HRG survey equipment was 141 m from a sparker. Although a sparker may not be used at all times during HRG surveys, this distance was used in calculating the area exposed to sounds above 160 dB SPL_{rms} for all HRG survey activity. This was done by assuming an average of 70 km of survey activity would be completed daily by each survey vessel when active. The 70 km of survey line was then buffered on all sides by the 141 m distance to estimate a daily ensonified area of 19.8 km^2.

During construction, it is estimated that 11,600 km of HRG surveys will occur within the Lease Area and 5,748 km will occur along the Export Cable Route. Assuming 70 km is surveyed per day, that results in 165.7 days of survey activity in the Lease Area and 82.1 days of survey activity along the Export Cable Route. Multiplying the daily ensonified area by the number of days of survey activity within each area results in a total ensonified area of 746.9 km^2 in the Lease Area and 464.6 km^2 along the Export Cable Route.

6.5.3 *Estimated Takes from HRG Surveys – Construction Phase*

To calculate potential takes from HRG surveys within the Export Cable Route during construction, the annual average marine mammal densities in Table 22 were multiplied by the total ensonified area expected along the Export Cable Route and the results are shown in the ECR column in Table 35. The same calculation was performed for the Lease Area using marine mammal densities in Table 32 and the results are shown in the Lease Area (LA) column of Table 35. No Level A takes for this activity are anticipated or requested.

Table 35. Estimated Level B take from HRG surveys during construction. LA = Lease Area, ECR = Export Cable Route.

Species	Construction Phase Take by Survey Area		Total Density-based Take Estimate	PSO Data Take Estimate	Mean Group Size	Highest Level B Take
	LA	ECR				
Mysticetes						
Blue Whale*	0.0	0.0	0.0	-	1.0	1
Fin Whale*	4.8	1.4	6.2	60.8	1.8	61
Humpback Whale	4.4	1.3	5.7	182.3	2.0	183
Minke Whale	1.7	0.4	2.1	37.4	1.2	38
North Atlantic Right Whale*	7.1	1.9	9.0	9.4	2.4	10
Sei Whale*	0.1	0.0	0.2	2.3	1.6	3
Odontocetes						
Atlantic Spotted Dolphin	0.4	0.1	0.4	-	29.0	29
Atlantic White-Sided Dolphin	39.0	8.2	47.3	23.6	27.9	48
Bottlenose Dolphin	47.2	36.0	83.3	261.8	7.8	262
Common Dolphin	172.9	44.4	217.3	7,375.2	34.9	7,376
Harbor Porpoise	110.1	47.9	158.0	6.5	2.7	159
Pilot Whales	9.4	1.3	10.6	-	8.4	11
Risso's Dolphin	0.1	0.0	0.1	18.3	5.4	19
Sperm Whale*	0.3	0.1	0.4	-	1.5	2
Pinnipeds						
Gray Seal	37.8	25.2	63.1	17.7	1.4	64
Harbor Seal	85.0	56.7	141.7	21.6	1.4	142

* Denotes species listed under the Endangered Species Act

6.6 HRG Surveys – Operations Phase

HRG surveys will be carried out on a routine basis during the four years of operations expected under the requested incidental take regulations. Potential takes for these HRG surveys during the operations phase were calculated using the same approach as described for the construction phase but assume a reduced level of survey effort on an annual basis as described below.

6.6.1 *Marine Mammal Densities*

The same annual average densities used to calculate potential takes from HRG surveys during the construction phase, shown in Table 22 and Table 32, were used to calculate potential takes from HRG surveys during the operations phase.

6.6.2 *Area Potentially Exposed to Sounds Above Threshold Levels from HRG Surveys – Operations Phase*

On an annual basis during operations, it is estimated that 2,640 km of HRG surveys will occur within the Lease Area and 1,642 km will occur along the Export Cable Route. Assuming 70 km is surveyed per day results in 37.7 days of survey activity in the Lease Area and 23.5 days of survey activity along the Export Cable Route each year. Multiplying the daily ensonified area by the number of days of survey activity within each area results in an annual ensonified area of 746.9 km^2 in the Lease Area and 464.6 km^2 along the Export Cable Route. Over the four years of operations that would occur during the five-year period covered by the requested regulations, the total ensonified area in the Lease Area would be 2,987.8 km^2 and along the Export Cable Route would be 1,858.3 km^2.

6.6.3 *Estimated Takes from HRG Surveys – Operations Phase*

The density-based take estimate for one year during the operations phase was calculated for the Export Cable Route and the Lease Area in the same manner as described in Section 6.5.3. This value was then compared against the PSO data take estimate and the mean group size of each species and the largest value was selected as the annual estimated take during operations (Table 35). The annual estimated take was then multiplied by four to calculate the total take over the four years of operations. No Level A takes for this activity are anticipated or requested.

Table 36. Estimated Level B take from HRG surveys during operations. LA = Lease Area, ECR = Export Cable Route.

	Annual Operations Phase Take by Survey Area						
Species	**LA**	**ECR**	**Annual Total Density-based Take Estimate**	**Annual PSO Data Take Estimate**	**Mean Group Size**	**Highest Annual Level B Take**	**4-year Level B Take**
Mysticetes							
Blue Whale*	0.0	0.0	0.0	-	1.0	1	4
Fin Whale*	1.1	0.4	1.5	15.0	1.8	16	64
Humpback Whale	1.0	0.4	1.4	45.0	2.0	46	184
Minke Whale	0.4	0.1	0.5	9.2	1.2	10	40
North Atlantic Right Whale*	1.6	0.5	2.2	2.3	2.4	3	12
Sei Whale*	0.0	0.0	0.0	0.6	1.6	2	8
Odontocetes		0.0					
Atlantic Spotted Dolphin	0.1	0.0	0.1	-	29.0	29	116
Atlantic White-Sided Dolphin	8.9	2.3	11.2	5.8	27.9	28	112
Bottlenose Dolphin	10.8	10.3	21.0	64.6	7.8	65	260
Common Dolphin	39.4	12.7	52.0	1,820.8	34.9	1,821	7,284
Harbor Porpoise	25.1	13.7	38.7	1.6	2.7	39	156
Pilot Whales	2.1	0.4	2.5	-	8.4	9	36
Risso's Dolphin	0.0	0.0	0.0	4.5	5.4	6	24
Sperm Whale*	0.1	0.0	0.1	-	1.5	2	8
Pinnipeds							
Gray Seal	8.6	7.2	15.8	4.4	1.4	16	64
Harbor Seal	19.3	16.2	35.6	5.3	1.4	36	144

* Denotes species listed under the Endangered Species Act

6.7 In-Situ MEC/UXO Disposal

For MEC/UXOs that are positively identified in proximity to planned activities on the seabed, several alternative strategies will be considered prior to detonating the MEC/UXO in place. These may include relocating the activity away from the MEC/UXO (avoidance), moving the MEC/UXO away from the activity (lift and shift), cutting the MEC/UXO open to apportion large ammunition or deactivate fused munitions, using shaped charges to reduce the net explosive yield of a MEC/UXO (low-order detonation), or using shaped charges to ignite the explosive materials and allow them to burn at a slow rate rather than detonate instantaneously (deflagration). Only after these alternatives are considered would a decision to detonate the MEC/UXO in place be made. To detonate a MEC/UXO, a small charge would be placed on the MEC/UXO and detonated causing the MEC/UXO to then detonate.

The exact number and type of MEC/UXOs in the Project area are not yet know. As a conservative approach, it is currently assumed that up to 7 MEC/UXOs in the RWF and up to 6 MEC/UXOs along the export cable route may have to be detonated in place. If necessary, these detonations would occur on 13 different days. To avoid times when sensitive marine mammal species are more likely to be present, in-situ MEC/UXO disposal is only planned to occur during the months from May through November.

6.7.1 *Marine Mammal Densities*

In-situ MEC/UXO disposal would not occur in federal waters during the months from December through April. As part of the federal consistency review for the Project and work in Rhode Island state waters, it is expected that in-situ MEC/UXO disposal will also be subject to state-specific seasonal restrictions. Restrictions imposed may require detonation during this period in state waters. The maximum average monthly densities from May through November calculated from the export cable route area shown in Figure 8 and the lease area shown in Figure 11 were selected. The export cable route densities and months from which they were calculated are shown in Table 37. The lease area densities and months from which they were calculated are shown in Table 38.

Table 37. Maximum average monthly marine mammal densities along the Export Cable Route from only May through November and the month in which the maximum density occurs.

Species	Maximum Monthly Density (Ind/km^2)	Maximum Density Month
Mysticetes		
Blue Whale*	0.0000	Annual
Fin Whale*	0.0012	August
Humpback Whale	0.0019	September
Minke Whale	0.0006	May
North Atlantic Right Whale*	0.0008	May
Sei Whale*	0.0001	May
Odontocetes		
Atlantic Spotted Dolphin	0.0002	October
Atlantic White-Sided Dolphin	0.0070	May
Bottlenose Dolphin	0.0689	August
Common Dolphin	0.0447	October
Harbor Porpoise	0.0391	November
Pilot Whales	0.0008	Annual
Risso's Dolphin	0.0000	August
Sperm Whale*	0.0002	July
Pinnipeds		
Gray Seal	0.0128	May
Harbor Seal	0.0288	May

* Denotes species listed under the Endangered Species Act

Table 38. Maximum average monthly marine mammal densities in the Lease Area from only May through November and the month in which the maximum density occurs.

Species	**Maximum Monthly Density (Ind./km^2)**	**Maximum Density Month**
Mysticetes		
Blue Whale*	0.0000	Annual
Fin Whale*	0.0020	August
Humpback Whale	0.0048	September
Minke Whale	0.0012	May
North Atlantic Right Whale*	0.0018	May
Sei Whale*	0.0002	May
Odontocetes		
Atlantic Spotted Dolphin	0.0003	October
Atlantic White-Sided Dolphin	0.0184	May
Bottlenose Dolphin	0.0392	September
Common Dolphin	0.0907	October
Harbor Porpoise	0.0354	May
Pilot Whales	0.0029	Annual
Risso's Dolphin	0.0001	August
Sperm Whale*	0.0003	July
Pinnipeds		
Seals (Harbor and Gray)	0.0533	May

* Denotes species listed under the Endangered Species Act

6.7.2 *Area Potentially Exposed to Sounds Above Threshold Levels from MEC/UXO Detonations.*

The type and net explosive weight of MEC/UXOs that may be detonated are not known at this time. To capture a range of potential MEC/UXOs, five categories or "bins" of net explosive weight established by the U.S. Navy (2017a) were selected for acoustic modeling (Table 39). Sound propagation away from detonations is affected by acoustic reflections from the sea surface and seabed. Water depth and seabed properties will influence the sound exposure levels and sound pressure levels at distance from detonations. Their influence is complex but can be predicted accurately by acoustic models. There were four modelling sites (S1 to S4) chosen for this modelling assessment. Two are located along the export cable route (Sites 1 and 2) and two are inside the lease area (Sites 3 and 4). The depths of these sites are as follows: Site 1 = 12 m, Site 2 = 20 m, Site 3 = 30 m, and Site 4 = 40 m. Exact locations for these modeling sites are shown in Figure 1 of Appendix B.

Table 39. Navy “bins” and corresponding maximum charge weights (equivalent TNT) modeled.

Navy Bin Designation	Maximum Equivalent Weight (TNT)	
	kg	lbs
E4	2.3	5
E6	9.1	20
E8	45.5	100
E10	227	500
E12	454	1000

Modeling of acoustic fields generated by MEC/UXO detonations was performed using a combination of semi-empirical and physics-based computational models. The source pressure function used for estimating PK and impulse (Jp) metrics was calculated with an empirical model that approximates the rapid conversion (within approximately 1 μs for high explosive) of solid explosive to gaseous form in a small gas bubble under high pressure, followed by an exponential pressure decay as that bubble expands. The shape and amplitude of the pressure versus time signature of the shock pulse changes with distance from the detonation location due to non-linear propagation effects caused by its high peak pressure. This initial empirical model is only valid close to the source (within tens of meters), so alternative formulae were used beyond those distances to a point where the sound pressure decay with range transitions to the spherical spreading model.

The calculation of SEL and SPL levels is dependent on the entire pressure waveform, including the initial shock pulse (described above) and the subsequent oscillation of the gas bubble. The negative phase pressure troughs and bubble pulse peaks following the shock pulse are responsible for most of the low frequency energy of the overall waveform. The SEL and SPL thresholds for injury and disturbance occur at distances of many water depths in the relatively shallow waters of the Project. As a results, the sound field becomes increasingly influenced by the contributions of sound energy reflected from the sea surface and sea bottom multiples times. To account for this, the modeling was carried out in decidecade frequency bands using the marine operations noise model (MONM, JASCO Applied Sciences). This model applied a parabolic equation approach for frequencies below 4 kHz and a Gaussian beam ray trace model at higher frequencies. In this location, sound speed profiles change little with depth, so these environments do not have strong seasonal dependence. The propagation modeling was performed using a sound speed profile representative of September, which is slightly downward refracting and therefore conservative, and also represents the most likely time of year for UXO removal activities. Additional technical details of the modeling methods, assumptions and environmental parameters used as inputs can be found in Appendix B.

A NAS similar to those described for monopile foundation installations is planned to be used during any MEC/UXO detonations and is expected to achieve at least the same 10 dB of attenuation assumed for monopile installation. This is based on an assessment of MEC/UXO-clearance activity in European waters summarized by Bellmann and Betke (2021). As a contingency in case a NAS cannot be placed properly around a UXO because of the presence of boulders or other obstructions on the seafloor, acoustic modeling was also conducted assuming no use of a NAS (unmitigated).

As described in Section 6.2, potential impacts to marine mammals from underwater explosions are assessed using separate criteria for mortality, non-auditory injury, gastrointestinal injury, auditory injury, and behavioral responses. Since marine mammal densities representative of the Export Cable Route include water depths similar to MEC/UXO acoustic modeling Sites 1 and 2 and there is relatively little difference between the results from those two sites, the largest range to the thresholds from either Site 1 or 2, both with and without 10 dB of mitigation, was selected for each MEC/UXO size class and marine mammal size class or hearing group for use here. The same approach was taken to identify ranges to thresholds for the Lease Area from Sites 3 and 4 in the MEC/UXO acoustic modeling report. In all cases, distances to mortality (Table 40 and Table 41), non-auditory lung injury (Table 42 and Table 43), and gastrointestinal injury (Table 44) thresholds were shorter than to auditory injury thresholds (Table 45 and Table 46). Since the mitigation and monitoring measures described in Section 11 and Appendix C are designed to avoid mortality or non-auditory injuries as well as potential auditory injury for most species, only the auditory injury (PTS) threshold distances are used here for the calculation of potential Level A takes.

The largest range to PTS thresholds from either Site 1 or 2 was selected for each MEC/UXO size class and marine mammal hearing group to represent ranges to Level A PTS thresholds, with and without 10 dB of mitigation, along the Export Cable Route as shown in Table 45. The same approach was taken using modeling sites 3 and 4 to identify Level A PTS threshold ranges, with and without 10 dB of mitigation, in the Lease Area (Table 46).

In the case of MEC/UXO detonations, TTS onset serves as the Level B take threshold. As was done for the Level A PTS threshold above, the largest modeled ranges to the TTS onset threshold with and without 10 dB of mitigation for each MEC/UXO size class was selected from modeling results at Sites 1 and 2 to represent the Level B range along the Export Cable Route (Table 47) and from Sites 3 and 4 for the Lease Area (Table 48).

Table 40. Ranges (in meters) to the onset of mortality thresholds along the Export Cable Route for five MEC/UXO size classes with and without 10 dB mitigation. Thresholds are based on animal mass and submersion depth (see Section 6.2 and Appendix B).

	$R_{95\%}$ Distance (m)									
	E4		E6		E8		E10		E12	
Hearing Group	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**
	Assuming 10 dB reduction from mitigation									
Baleen and Sperm Whales	5	5	7	5	23	6	69	21	105	34
Pilot and Minke Whales	5	5	11	5	37	11	103	36	150	58
Beaked Whales	7	5	19	9	60	29	151	85	206	127
Dolphins, *Kogia*, Pinnipdes	14	6	39	18	105	56	220	144	285	198
Porpoises	17	7	46	21	119	65	239	158	307	215
	Assuming no reduction from mitigation									
Baleen and Sperm Whales	9	5	27	7	81	26	203	76	266	116
Pilot and Minke Whales	15	5	43	13	121	43	275	120	346	173
Beaked Whales	27	12	70	34	186	99	376	238	458	305
Dolphins, *Kogia*, Pinnipdes	52	25	128	65	293	176	534	360	644	441
Porpoises	62	29	147	75	319	197	573	393	702	477

Table 41. Ranges (in meters) to the onset of mortality thresholds in the Lease Area for five MEC/UXO size classes with and without 10 dB mitigation. Thresholds are based on animal mass and submersion depth (see Section 6.2 and Appendix B).

	E4		E6		E8		E10		E12	
Hearing Group	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**
	Assuming 10 dB reduction from mitigation									
Baleen and Sperm Whales	5	5	6	5	20	6	68	19	109	31
Pilot and Minke Whales	5	5	10	5	32	10	106	32	162	57
Beaked Whales	6	5	17	8	58	25	164	86	234	135
Dolphins, *Kogia*, Pinnipdes	12	5	31	16	108	54	247	155	332	224
Porpoises	14	6	40	18	122	63	270	173	353	243
	Assuming no reduction from mitigation									
Baleen and Sperm Whales	8	5	23	7	80	22	227	77	334	121
Pilot and Minke Whales	14	5	37	12	123	38	325	125	453	194
Beaked Whales	23	11	68	30	199	100	455	275	602	392
Dolphins, *Kogia*, Pinnipdes	47	22	130	63	328	186	637	434	814	580
Porpoises	58	25	152	73	361	212	690	477	868	628

Table 42. Ranges (in meters) to the onset of non-auditory lung injury thresholds in the Export Cable Route for five MEC/UXO size classes with and without 10 dB mitigation. Thresholds are based on animal mass and submersion depth (see Section 6.2 and Appendix B).

	$R_{95\%}$ Distance (m)									
	E4		E6		E8		E10		E12	
Hearing Group	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**
	Assuming 10 dB reduction from mitigation									
Baleen and Sperm Whales	6	5	17	5	54	16	147	51	204	80
Pilot and Minke Whales	10	5	28	8	83	28	208	83	272	126
Beaked Whales	17	8	47	22	131	68	290	176	366	237
Dolphins, *Kogia*, Pinnipdes	35	16	88	44	211	123	404	277	508	351
Porpoises	42	19	102	50	235	139	433	303	541	381
	Assuming no reduction from mitigation									
Baleen and Sperm Whales	24	7	62	19	172	60	352	161	431	219
Pilot and Minke Whales	38	12	96	33	249	97	455	234	545	300
Beaked Whales	63	30	152	78	362	208	599	402	707	487
Dolphins, *Kogia*, Pinnipdes	117	58	263	142	541	344	839	576	975	681
Porpoises	137	67	297	162	591	380	913	623	1059	733

Table 43. Ranges (in meters) to the onset of non-auditory lung injury thresholds in the Lease Area for five MEC/UXO size classes with and without 10 dB mitigation. Thresholds are based on animal mass and submersion depth (see Section 6.2 and Appendix B).

	$R_{95\%}$ Distance (m)									
	E4		**E6**		**E8**		**E10**		**E12**	
Hearing Group	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**	**Calf/Pup**	**Adult**
	Assuming 10 dB reduction from mitigation									
Baleen and Sperm Whales	5	5	15	5	51	14	156	49	237	81
Pilot and Minke Whales	9	5	24	7	83	25	230	84	330	132
Beaked Whales	15	7	41	19	135	66	331	192	448	282
Dolphins, *Kogia*, Pinnipdes	29	14	88	38	231	126	471	315	606	429
Porpoises	34	16	103	46	261	145	512	347	648	465
	Assuming no reduction from mitigation									
Baleen and Sperm Whales	21	6	60	17	181	58	463	172	648	262
Pilot and Minke Whales	33	10	96	29	270	98	631	270	843	402
Beaked Whales	59	26	156	77	412	222	846	546	1084	746
Dolphins, *Kogia*, Pinnipdes	118	54	283	145	630	389	1148	815	1421	1052
Porpoises	138	65	324	167	695	435	1228	878	1518	1127

Table 44. Ranges (in meters) to the onset of gastrointestinal injury impulse thresholds in the Export Cable Route and Lease Area for five MEC/UXO size classes with and without 10 dB mitigation. Thresholds are based on animal mass and submersion depth (see Section 6.2 and Appendix B).

Hearing Group	**L_{pk} Threshold (dB re 1 μPa)**	**R_{max} Distance (m)** E4	**E6**	**E8**	**E10**	**E12**
		Assuming 10 dB reduction from mitigation				
Onset Gastrointestinal Injury	237	21	34	58	99	125
		Assuming no reduction from mitigation				
Onset Gastrointestinal Injury	237	61	97	167	285	359

Table 45. Ranges to Level A take SEL PTS-onset thresholds in the Export Cable Route for five MEC/UXO charge sizes with and without 10 dB mitigation and the maximum area exposed above the threshold.

Hearing Group	SELThreshold (dB re 1 μPa^2·s)	$R_{95\%}$ Distance (km)					Single Detonation Maximum Area (km^2)
		E4	E6	E8	E10	E12	
		Assuming 10 dB reduction from mitigation					
Low-frequency	183	0.552	0.982	1.73	2.97	3.78	44.9
Mid-frequency	185	<0.050	0.075	0.156	0.337	0.461	0.7
High-frequency	155	1.82	2.59	3.86	5.39	6.2	120.8
Phocid pinnipeds	185	0.182	0.357	0.69	1.22	1.6	8.0
		Assuming no reduction from mitigation					
Low-frequency	183	1.71	2.81	4.88	7.52	8.8	243.3
Mid-frequency	185	0.214	0.385	0.714	1.22	1.54	7.5
High-frequency	155	4.29	5.75	7.81	10.2	11.3	401.1
Phocid pinnipeds	185	0.804	1.31	2.19	3.66	4.5	63.6

Table 46. Ranges to Level A take SEL PTS-onset thresholds in the Lease Area for five MEC/UXO charge sizes with 10 dB mitigation and the maximum area exposed.

Hearing Group	SELThreshold (dB re 1 μPa^2·s)	$R_{95\%}$ Distance (km)					Single Detonation Maximum Area (km^2)
		E4	E6	E8	E10	E12	
		Assuming 10 dB reduction from mitigation					
Low-frequency	183	0.385	0.757	1.58	2.93	3.61	40.9
Mid-frequency	185	<0.050	<0.050	0.085	0.323	0.412	0.5
High-frequency	155	1.75	2.59	3.9	5.4	6.19	120.4
Phocid pinnipeds	185	0.089	0.204	0.538	1.02	1.48	6.9
		Assuming no reduction from mitigation					
Low-frequency	183	1.54	2.72	4.75	7.28	8.54	229.1
Mid-frequency	185	0.161	0.358	0.684	1.14	1.48	6.9
High-frequency	155	4.3	5.75	7.71	9.89	10.9	373.3
Phocid pinnipeds	185	0.607	1.12	2.17	3.74	4.52	64.2

Table 47. Ranges to Level B take SEL TTS-onset thresholds in the Export Cable Route for five MEC/UXO charge sizes with 10 dB mitigation and the maximum area exposed.

Hearing Group	SELThreshold (dB re 1 μPa² ·s)	$R_{95\%}$ Distance (km) E4	E6	E8	E10	E12	Single Detonation Maximum Area (km²)
		Assuming 10 dB reduction from mitigation					
Low-frequency	183	2.74	4.45	7.21	10.3	11.8	437.4
Mid-frequency	185	0.41	0.707	1.23	2.03	2.48	19.3
High-frequency	155	6.14	7.84	10.1	12.6	13.7	589.6
Phocid pinnipeds	185	1.21	2.18	3.81	5.97	7.02	154.8
		Assuming no reduction from mitigation					
Low-frequency	183	7.0	9.85	13.6	17.4	19.3	1170.2
Mid-frequency	185	1.45	2.21	3.49	5.04	5.84	107.1
High-frequency	155	10.7	13.0	15.8	18.7	20.2	1281.9
Phocid pinnipeds	185	4.07	6.07	8.85	12.0	13.3	555.7

Table 48. Ranges to Level B take SEL TTS-onset thresholds in the Lease Area for five MEC/UXO charge sizes with 10 dB mitigation and the maximum area exposed.

Hearing Group	SELThreshold (dB re 1 μPa² ·s)	$R_{95\%}$ Distance (km) E4	E6	E8	E10	E12	Single Detonation Maximum Area (km²)
		Assuming 10 dB reduction from mitigation					
Low-frequency	183	2.82	4.68	7.49	10.5	11.9	444.9
Mid-frequency	185	0.453	0.773	1.24	2.12	2.55	20.4
High-frequency	155	6.16	8	10.3	12.9	14.1	624.6
Phocid pinnipeds	185	1.47	2.35	3.82	5.98	6.99	153.5
		Assuming no reduction from mitigation					
Low-frequency	183	7.34	10.3	13.9	17.5	19.2	1158.1
Mid-frequency	185	1.52	2.29	3.46	5.02	5.86	107.9
High-frequency	155	11.2	13.4	16.0	19.1	20.2	1281.9
Phocid pinnipeds	185	4.2	6.2	9.06	11.9	13.3	555.7

Since the size and type of MEC/UXOs that may be detonated is currently unknown, all area calculations were made using the largest MEC/UXO size class (E12). The E12 ranges to Level A and Level B thresholds within the Export Cable Route, Table 45 and Table 47, respectively, were used as radii to calculate the area of a circle (pi × r^2 where r is the range to the threshold level) for each marine mammal hearing group. The results represent the largest area potentially ensonified above threshold levels from a single detonation within the Export Cable Route and are shown in the final column of Table 45 and Table 47. The same method was used to calculate the maximum area potentially ensonified above threshold levels from a single detonation in the Lease Area as shown in the final column of Table 46 and Table 48.

6.7.3 *Estimated Takes from MEC/UXO Detonations*

Based on the available information, up to six (6) MEC/UXO detonations may be necessary within the Export Cable Route and up to seven (7) MEC/UXO detonations within the Lease Area. The maximum areas to Level A and Level B thresholds from a single detonation in the Export Cable Route shown in Table 45 and Table 47, respectively, were therefore multiplied by 6 and then multiplied by the marine mammal densities shown in Table 37 to calculate the potential take from MEC/UXO detonations in the Export Cable Route shown in the ECR columns of Table 49. In the Lease Area, the same method was applied using the maximum single detonation areas shown in Table 46 and Table 48 to calculate the potential take from MEC/UXO detonations in the Lease area shown in the LA columns of Table 49. In the unlikely event that a NAS cannot be used during a UXO detonation, takes were also calculated using the unmitigated threshold distances in Table 45 through Table 48 and the results are shown in Table 50.

Monitoring and mitigation measures described in Section 11.5 are designed to prevent Level A take of most species. However, given the relatively large distances to the high-frequency cetacean SEL PTS threshold applicable to harbor porpoise and the difficulty with detecting this species, Level A take of 59 harbor porpoise is requested. Similarly, seals are difficult to detect at longer ranges and although the distances to the phocid hearing group SEL PTS threshold is not as large as those for high-frequency cetaceans, it may not be possible with the planned monitoring and mitigation measures to detect all seals within the threshold distances so Level A take of 2 gray seals and 4 harbor seals is requested.

Table 49. Estimated Level A and Level B take from potential MEC/UXO detonations assuming 10 dB of mitigation of the sound levels produced. LA = Lease Area, ECR = Export Cable Route.

	Level A Take		Total Level A Density-based Take Estimate	Level B Take		Total Level B Density-based Take Estimate	PSO Data Take Estimate	Mean Group Size	Highest Level B Take
Species	**LA**	**ECR**		**LA**	**ECR**				
Mysticetes									
Blue Whale*	0.0	0.0	0.0	0.0	0.0	0.1	-	1.0	1
Fin Whale*	0.6	0.3	0.9	6.2	5.4	11.5	3.2	1.8	12
Humpback Whale	1.4	0.5	1.9	14.6	12.7	27.4	9.6	2.0	28
Minke Whale	0.4	0.2	0.5	3.8	3.3	7.1	2.0	1.2	8
North Atlantic Right Whale*	0.5	0.2	0.7	5.4	4.7	10.1	0.5	2.4	11
Sei Whale*	0.0	0.0	0.1	0.5	0.4	0.9	0.1	1.6	2
Odontocetes									
Atlantic Spotted Dolphin	0.0	0.0	0.0	0.0	0.0	0.1	-	29.0	29
Atlantic White-Sided Dolphin	0.1	0.0	0.1	2.5	2.3	4.7	1.2	27.9	28
Bottlenose Dolphin	0.1	0.3	0.4	5.3	4.8	10.1	13.7	7.8	14
Common Dolphin	0.3	0.2	0.5	12.3	11.1	23.4	386.9	34.9	387
Harbor Porpoise	29.8	28.3	58.2	146.2	132.7	278.9	0.3	2.7	279
Pilot Whales	0.0	0.0	0.0	0.4	0.3	0.7	-	8.4	9
Risso's Dolphin	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.4	6
Sperm Whale*	0.0	0.0	0.0	0.0	0.0	0.1	-	1.5	2
Pinnipeds									
Gray Seal	0.8	0.6	0.4	17.8	15.1	32.9	0.9	0.4	33
Harbor Seal	1.8	1.4	1.0	40.0	34.0	73.9	1.1	1.0	74

* Denotes species listed under the Endangered Species Act

Table 50. Estimated Level A and Level B take from potential MEC/UXO detonations assuming no mitigation of the sound levels produced. LA = Lease Area, ECR = Export Cable Route.

Species	Level A Take		Total Level A Density-based Take Estimate	Level B Take		Total Level B Density-based Take Estimate	PSO Data Take Estimate	Mean Group Size	Highest Level B Take
	LA	ECR		LA	ECR				
Mysticetes									
Blue Whale*	0.0	0.0	0.0	0.1	0.1	0.1	-	1.0	1
Fin Whale*	3.2	1.7	5.0	16.5	8.3	24.7	3.2	1.8	25
Humpback Whale	7.7	2.8	10.4	39.1	13.1	52.3	9.6	2.0	53
Minke Whale	2.0	0.8	2.8	10.1	4.0	14.1	2.0	1.2	15
North Atlantic Right Whale*	2.8	1.2	4.0	14.4	5.8	20.1	0.5	2.4	21
Sei Whale*	0.3	0.2	0.4	1.3	0.7	2.0	0.1	1.6	3
Odontocetes									
Atlantic Spotted Dolphin	0.0	0.0	0.0	0.2	0.1	0.3	-	29.0	29
Atlantic White-Sided Dolphin	0.9	0.3	1.2	13.8	4.6	18.3	1.2	27.9	28
Bottlenose Dolphin	1.9	3.1	5.0	29.4	44.6	74.0	13.7	7.8	74
Common Dolphin	4.4	2.0	6.4	68.0	29.0	97.0	386.9	34.9	387
Harbor Porpoise	92.5	94.1	186.7	317.8	300.9	618.6	0.3	2.7	619
Pilot Whales	0.1	0.0	0.2	2.1	0.5	2.6	-	8.4	9
Risso's Dolphin	0.0	0.0	0.0	0.0	0.0	0.1	1.0	5.4	6
Sperm Whale*	0.0	0.0	0.0	0.2	0.1	0.4	-	1.5	2
Pinnipeds									
Gray Seal	7.4	4.9	3.8	63.9	42.7	106.6	0.9	0.4	107
Harbor Seal	16.6	11.0	8.5	143.5	96.0	239.5	1.1	1.0	240

* Denotes species listed under the Endangered Species Act

6.8 Total Requested Take

The estimated Level B take from each activity is summarized in Table 52 and the total requested take for the project was calculated by summing the estimated takes across all activities. The requested Level B take was divided by the most recent abundance estimate in the Draft 2021 NMFS Stock Assessment Report (Hayes et al. 2021) to calculate the percent of each stock for which take is requested. A small number of Level A takes is requested for humpback whales from monopile installations and for harbor porpoise, gray seals, and harbor seals from potential MEC/UXO detonations (Table 51).

Construction activities are planned to occur in the first 1-2 years of the requested regulations, depending on the timing of issuance and logistical considerations. The same amount of construction activity would occur whether it occurs within a single year or extends partially into a second year. HRG surveys during operations will occur annually for the duration of the requested regulations.

Table 51. Summary of the requested Level A take from all activities.

	Requested Level A Take	
Species	**WTG & OSS Monopile Installation**	**UXO Detonations**
Mysticetes		
Humpback Whale	8	-
Odontocetes		
Harbor Porpoise	-	59
Pinnipeds		
Gray Seal	-	2
Harbor Seal	-	4

Table 52. Summary of the estimated Level B take from all activities and the total requested Level B take for the project.

	Construction Phase (Years 1-2)				Operations Phase (Years 2-4)					
Species	**WTG & OSS Monopile Installation**	**Landfall Construction**	**HRG Surveys - Construction**	**UXO Detonoation**	**Annual HRG Surveys**	**4-Years HRG Surveys**	**Requested Level B Take**	**Abundance Roberts[c]**	**NMFS Stock Abundance[a]**	**Percent of NMFS Stock Abundace[a]**
Mysticetes										
Blue Whale*	1	NA	1	1	1	4	7		402	1.7
Fin Whale*	23	NA	61	12	16	64	160		6,802	2.4
Humpback Whale	68	NA	183	28	46	184	463		1,396	33.2
Minke Whale	22	NA	38	8	10	40	108		21,968	0.5
North Atlantic Right Whale*	17	NA	10	11	3	12	50		368	13.6
Sei Whale*	2	NA	3	2	2	8	15		6,292	0.2
Odontocetes										
Atlantic Spotted Dolphin	29	0	29	29	29	116	204		39,921	0.5
Atlantic White-Sided Dolphin	599	10	48	28	28	112	798		93,233	0.9
Bottlenose Dolphin	899	406	262	14	65	260	1,841		62,851	2.9
Common Dolphin	3,402	133	7,376	387	1,821	7,284	18,583		172,974	10.7
Harbor Porpoise	508	137	159	279	39	156	1,240		95,543	1.3
Pilot Whales	50	0	11	9	9	36	107		68,139	0.2
Risso's Dolphin	7	0	19	6	6	24	57		35,215	0.2
Sperm Whale*	3	0	2	2	2	8	16		4,349	0.4
Pinnipeds										
Gray Seal	1,037	301	64	11	16	64	1,168		27,300	4.3
Harbor Seal	1,330	676	142	23	36	144	2,623		61,336	4.3

NA – Incidental take of mysticete whales from landfall construction in Narragansett Bay is not being requested as these species are very unlikely to occur in the area.
* Denotes species listed under the Endangered Species Act

[a] NMFS Stock Assessment Report (Hayes et al. 2021)

7 Anticipated Impact of the Activity

The ability to hear and transmit sound (echolocation and vocalization) is vital for marine mammals to perform basic life functions. Marine mammals use sound to gather and understand information about their current environment, including detection of prey and predators. They also use sound to communicate with one another. The distances to which a sound travels through the water and remains audible depends on existing environmental conditions and propagation characteristics (e.g., sea floor topography, stratification, and ambient noise levels) and characteristics of the sound (SLs and frequency; (Richardson et al. 1995)). Impacts on marine mammals can vary among species based on their sensitivity to sound, life stage, orientation to the sound and depth in the water column, and their ability to hear different frequencies. The Project may impact marine mammals behaviorally and physiologically from temporary increases in underwater and airborne noises during construction, HRG surveys, or MEC/UXO detonation. The level of impact on marine mammals will vary depending on the species, the distance between the marine mammal and the activity, the intensity and duration of the activity, and environmental conditions affecting sound propagation.

7.1 Characteristics of Pile Driving Sounds

Pile driving generates sounds that are relatively broadband (Madsen et al. 2006). Measurements have shown that most energy occurs from 10–2,000 Hz, with some energy up to 10 kHz near the source (Blackwell 2005; Bailey et al. 2010). The dominant frequency range of pile driving is most likely related to differences in the size, shape, and thickness of the piles. Impact pile driving produces impulsive sounds with peak levels typically above L_{pk} 200 dB re 1 µPa near the source (Tougaard et al. 2008). These pulsed sounds are typically high energy with fast rise times and sharp peaks, which can result in both Level B and Level A sound exposures, depending on proximity to the sound source and a variety of environmental and biological conditions (Nedwell et al. 2007; Dahl et al. 2015). Vibratory pile driving produces non-impulsive sounds with lower peak sound pressure levels (SPLs) of around 180 dB re 1 µPa or greater, generally 10 to 20 dB lower than those generated during impact pile driving (Buehler et al. 2015). Appendix A provides a detailed description of the pile driving sounds expected to be produced during the Project and used as a basis for modeling potential impacts.

7.2 Potential Effects of Impact Pile Driving on Marine Mammals

All marine mammals use sound as a primary input to carry out life-sustaining functions, such as foraging, navigating, communicating, and avoiding predators. Marine mammals also use sound to learn about their environment by gathering information from other marine mammals, prey species, phenomena such as wind, waves, and rain, or from seismic activity (Richardson et al. 1995). The effects of sounds from impact pile driving could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, temporary or permanent hearing impairment (TTS or PTS), or non-auditory physical or physiological effects (Richardson et al. 1995; Nowacek et al. 2007; Southall et al. 2007a).

7.2.1 *Masking*

Masking is the obscuring of sounds of interest by interfering sounds, generally at similar frequencies. Introduced underwater sound will, through masking, reduce the effective listening area and/or communication distance of a marine mammal species if the frequency of the source is close to that used as a signal by the marine mammal, and if the anthropogenic sound is present for a significant fraction of the time (Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014a; Erbe et al. 2016; Tennessen and Parks 2016; Guan and Miner 2020). If little or no overlap occurs between the introduced sound and the frequencies used by the species, listening and communication are not expected to be disrupted. Similarly, if the introduced sound is present only infrequently, very little to no masking would occur. In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Madsen et al. 2002; Branstetter et al. 2013a; Branstetter et al. 2013b; Branstetter et al. 2016; Erbe et al. 2016; Sills et al. 2017). The biological repercussions of a loss of listening area or communication space, to the extent that this occurs, are unknown.

Although masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, there are few specific studies on this related to impact pile driving. Low-frequency cetaceans such as baleen whales are likely to be more susceptible to masking by the low-frequency noise produced by pile driving (Richardson et al. 1995); however, to date, most studies have considered impacts from a different impulsive source, seismic airguns. Being low-frequency cetaceans, baleen whales are assumed to be more vulnerable to disturbance from seismic airgun noise due to a greater overlap with the frequency ranges of their communication signals and hearing sensitivities than other whale species (Kavanagh et al. 2019). Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between the seismic pulses (Greene and Richardson 1988; McDonald et al. 1995; Smultea et al. 2004; Holst et al. 2005b; Holst et al. 2006; Dunn and Hernandez 2009; Holst et al. 2011; Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Cerchio et al. 2014; Sciacca et al. 2016). However, some of these studies found evidence of reduced calling (or at least reduced call detection rates) in the presence of seismic pulses. One report indicates that calling fin whales distributed in a part of the North Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that paper whether the whales ceased calling because of masking, or whether this was a behavioral response not directly involving masking. Also, bowhead whales (*Balaena mysticetus*) in the Beaufort Sea apparently decrease their calling rates in response to seismic operations, although movement out of the area may have also contributed to the lower call detection rate (Blackwell et al. 2013; Blackwell et al. 2015). In contrast, Di Iorio and Clark (2010) found that blue whales in the St. Lawrence Estuary increased their call rates during operations by a lower-energy seismic source. The sparker used during the study emitted frequencies of 30–450 Hz with a relatively low source level of 193 $\text{dB}_{\text{pk-pk}}$ re 1 µPa. There is some evidence that fin whale song notes recorded in the Mediterranean had lower bandwidths during periods with, versus without, airgun sounds (Castellote et al. 2012).

Among the odontocetes, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies of sperm whales found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2008; Holst et al. 2011; Nieukirk et al. 2012). Madsen et al. (2006) noted that airgun sounds would not be expected to cause significant masking of sperm whale calls given the intermittent nature of airgun pulses. Dolphins and porpoises are also commonly heard calling while airguns are operating (Gordon et al. 2003; Smultea et al. 2004; Holst et al. 2005a; Holst et al. 2005b; Potter et al. 2007; Holst et al. 2011). Masking effects of impact pile driving are expected to be negligible in the case of the smaller odontocetes, given the intermittent nature of the pulses plus the fact that sounds important to them occur predominantly at much higher frequencies than the dominant components of pile driving sounds. For example, the harbor porpoise produces echolocation clicks of 110–150 kHz (Møhl and Andersen 1973; Teilmann et al. 2002) with source levels of 135–177 dB re 1 µPa at 1 m and the common bottlenose dolphin produces echolocation clicks of 110–130 kHz with source levels of 218–228 dB re 1 µPa (Richardson et al. 1995).

Some cetaceans are known to increase the source levels of their calls, shift their peak frequencies, or otherwise modify their vocal behavior in response to increased noise (Dahlheim 1987; Au 1993; Richardson et al. 1995; Lesage et al. 1999; Terhune 1999; Nieukirk et al. 2005; Scheifele et al. 2005; Parks et al. 2007; Di Iorio and Clark 2009; Hanser et al. 2009; Holst et al. 2009; Parks et al. 2009; Parks et al. 2010; McKenna 2011; Castellote et al. 2012; Melcón et al. 2012; Parks et al. 2012; Risch et al. 2012; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Parks et al. 2016; Bittencourt et al. 2017). Harbor porpoises have been observed to reduce their acoustic activity when exposed to impact pile driving or reduce their buzzing activity when exposed to impulsive sound from seismic surveys (Wang et al. 2015). Holt, (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. It is not known how often these types of vocal responses occur upon exposure to impulsive sounds. If cetaceans exposed to airgun sounds sometimes respond by changing their vocal behavior, this adaptation, along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the importance of masking by impulsive sounds.

Given the higher duty cycle of impact pile driving (one strike every ~two seconds) compared to most airgun surveys (one pulse every ~10 seconds), there may be a somewhat greater potential for masking to occur during pile driving. In this project, impact pile driving is not expected to occur for more than approximately four hours at one time (12 hours maximum). Compared to the 24 hour per day operation of airguns during most seismic surveys, the total time during which masking from impact pile driving might occur would be much lower. Madsen et al. (2006) argued that significant masking effects would be unlikely during impact pile driving given the intermittent nature of these sounds and short signal duration.

7.2.2 *Behavioral Disturbance*

Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. In some cases, behavioral responses to sound may in turn reduce the overall exposure to that sound (Finneran 2015; Wensveen et al. 2015).

Detailed data on reactions of marine mammals to anthropogenic sounds are limited to relatively few species and situations (Richardson et al. 1995; Gordon et al. 2003; Nowacek et al. 2007; Southall et al. 2007a). Marine mammals' behavioral responses to noise range from no response to mild aversion, to panic and flight (Southall et al. 2007). Behavioral reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Southall et al. 2007a; Ellison et al. 2012). If a marine mammal reacts to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (New et al. 2013a).

Similar to masking studies, there is little information available on behavioral responses of baleen whales to impact pile driving sounds. However, a number of studies have considered impacts from seismic airguns that produce a similar impulsive sound. Baleen whales generally tend to avoid impulsive sounds from operating airguns, but avoidance radii vary greatly among species, locations, whale activities, oceanographic conditions affecting sound propagation, etc. (Richardson et al. 1995; Gordon et al. 2003). Whales are often reported to show no overt reactions to impulsive sounds from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. Baleen whales exposed to strong sound pulses from airguns often react by moving away from and/or around the sound source. Some of the major studies and reviews on this topic are Gordon et al. (2003); Johnson et al. (2007); Ljungblad et al. (1988); Malme et al. (1984); Malme et al. (1985); Malme et al. (1988); McCauley et al. (1998); McCauley et al. (2000); Miller et al. (1999); Miller et al. (2005); Moulton and Holst (2010); Nowacek et al. (2007); Richardson et al. (1986); Richardson et al. (1995); Richardson et al. (1999; 2010); Richardson and Malme (1993); Stone (2015); Stone and Tasker (2006); and Weir (2008). Studies of bowhead, humpback, and gray whales have shown that impulsive sounds from seismic airguns with received levels of 160–170 dB re 1 µPa SPL seem to cause obvious avoidance behavior in a substantial portion of the animals exposed (Richardson et al. 1995; 2015). A study conducted across 880,000 km^2 of the East Atlantic Ocean saw an 88% (82-92%) reduction in sightings of baleen whales and a 53% (41-63%) reduction in toothed whale sightings during active seismic surveys when compared to control surveys (Kavanagh et al. 2019). However, this reflected a redistribution of the animals within the entire study area where overall sighting densities remained unaffected (Kavanagh et al. 2019). Studies near the United Kingdom, Newfoundland and Angola, in the Gulf of Mexico, off Central America, and Alaska have shown localized avoidance of seismic surveys by these species (whales), although, dolphins, porpoises and seals are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding).

While baleen whales often show only slight overt responses to operating airgun arrays (Stone and Tasker 2006; Weir 2008; Stone 2015; Kavanagh et al. 2019), strong avoidance reactions by several species of baleen whales have been observed. Experiments with a single airgun (327.7–1,638 cubic centimeters [20–100 cubic inches] in size) showed that bowhead, humpback, and gray whales (Eschrichtius robustus) all showed localized avoidance (Malme et al. 1984; Malme and Miles 1985; Malme et al. 1986; Richardson et al. 1986; Malme et al. 1988; McCauley et al. 1998; McCauley et al. 2000; Kavanagh et al. 2019). More recent studies have shown that some species of baleen whale (bowhead and humpback whales in particular) at times show strong avoidance at received levels lower than 160–170 dB re 1 µPa SPL.

When observing migrating bowhead, humpback, and gray whales, the changes in behavior appeared to be of little or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995; Dunlop et al. 2017). The largest documented avoidance radii involved migrating bowhead whales, which avoided an operating seismic vessel by 20–30 km (65.6–98.4 mi) (Miller et al. 1999; Richardson et al. 1999). Groups of humpback whales migrating towards feeding grounds have been observed responding to seismic activity by changing the magnitude and rates of typical behaviors (singing, socializing with conspecifics, using social signals, and migratory travel), specifically through change in movement patterns, dive/respiratory parameters and rates of breaching (Dunlop et al. 2017). Groups of both humpbacks and female-calf groups exposed to the active seismic array made a 1 km per hour slower progression during southern migration compared to most unexposed baseline groups (largely due to divergence off their normal course rather than a slowing down of travel speed) (Dunlop et al. 2017). Similarly, in response to the seismic airgun array, adult pairs reduced their migration speed by 2.5 km per hour, which resulted in traveling at a speed of approximately half of their initial travel time (Dunlop et al. 2017). Resting female-calf pairs have been found to show avoidance responses at received levels as low as 129 dB re 1μPa2 s while migrating humpback whales demonstrated changes in migration at received levels of 144-151 dB re 1μPa2 s (McCauley 2003; Dunlop et al. 2017).

In contrast to migrating whales, feeding bowhead whales show much smaller avoidance distances (Miller et al. 2005; Harris et al. 2007), presumably because moving away from a food concentration has greater cost to the whales than does a course deviation during migration. Since the Project area is not located in an important feeding area, most responses to the planned impact pile driving are expected to be more similar to those observed for migrating animals, where they simply avoided the area around the activity and continued on their migratory path resulting in little overall impact to individual animals.

Studies specific to behavioral response of marine mammals to offshore wind developments have been conducted on harbor porpoise (Tougaard et al. 2009a; Tougaard et al. 2009b; Bailey et al. 2010; Brandt et al. 2011; Dähne et al. 2013a; Thompson et al. 2013a; Thompson et al. 2013b; Dähne et al. 2017) and harbor and gray seals (Edrén et al. 2010; Russell et al. 2016). These studies showed some avoidance during periods of construction activity, followed by continued use of the area after construction activities were completed. Harbor porpoises have been observed to be displaced at distances greater than 20 km during wind farm installations (Tougaard et al. 2009a). Similarly, displacement of harbor seals during piling was seen starting from predicted received levels of between 166 and 178 re 1μPa(p-p) (Russell et al. 2016). Although displaced during active impact pile driving, harbor seals were then observed to return to a normal distribution (measured during non-piling periods) within 2 hours of cessation of pile driving (Russell et al. 2016). Likewise, one study saw displacement of harbor porpoises within 10 km of the survey vessels at similar received sound levels to the harbor seal study when exposed to seismic air pulses (Thompson et al. 2013b). Harbor porpoises were then observed to take 2-3 days before returning to impacted areas once the sound source has ceased (Brandt et al. 2011; Thompson et al. 2013b).

Overall, odontocete and pinniped reactions to strong impulsive sounds are variable and, at least for delphinids and some porpoises, seem to be confined to a smaller radius than has been observed for some mysticetes. Thus, avoidance responses by these species are expected to be relatively minor and temporary, resulting in minimal overall impacts.

7.2.3 *Hearing Impairment*

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (Southall et al. 2007a; Finneran 2015; Hastie et al. 2015; Kastelein et al. 2016). However, there has been no specific documentation of TTS, nor permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to anthropogenic sounds during realistic field conditions.

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises, and a sound must be stronger in order to be heard. It is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or “injury” (Southall et al. 2007a; Le Prell et al. 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. However, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman 2014). These findings have raised some questions as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015; Tougaard et al. 2016).

TTS was measured in two captive harbor porpoises after being exposed to recorded impact pile driving sounds with an average received single-strike sound exposure level (SELss) of 145 dB re 1 µPa2s, with exposure duration ranging from 15 minutes to 6 hours (SELcum ranged from 173 to 187 dB re 1 µPa2s). A similar study focused on measuring impact pile driving sounds during the construction of a wind farm in Scotland while also predicting the expected peak broadband sound levels associated with TTS (Bailey et al. 2010). Based on regulatory criteria, the peak broadband pressure levels estimated to cause TTS onset in mid-frequency cetaceans (at 224 dB0-pk re 1 µPa) and pinnipeds (212 dB0-pk re 1 µPa) would occur within 10 m of pile driving and 40 m, respectively (Bailey et al. 2010). Additionally, it has been predicted that harbor porpoises and harbor seals could be exposed to TTS without the use of noise mitigation systems (Dähne et al. 2013b; Stöber and Thomsen 2019).

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times. Rise time is the time interval required for sound pressure to increase from the baseline pressure to peak pressure. Permanent damage can also occur from the accumulation of sound energy over time. Through extrapolation of research focused on TTS onset in marine mammals, Bailey et al. (2010) showed that impact pile driving sounds may cause permanent threshold shift (PTS). Based on regulatory criteria, the peak broadband pressure levels estimated to cause PTS onset in mid-frequency cetaceans (230 dB0-pk re 1 µPa) and pinnipeds (218 dB0-pk re 1 µPa) would occur within 5 m and 20 m, respectively (Bailey et al. 2010). Based on the closest measurement of pile-driving noise recorded at 100 m, Bailey et al (2010) indicates that no form of injury or hearing impairment should have occurred at distances greater than 100 m from piling activity.

The criteria used in the exposure modeling (Section 6.2) (NMFS 2018a) reflect the most recent scientific review and conclusions of NMFS regarding sound levels that could cause PTS. Based on the exposure modeling results (Table 12 and Table 15), the number of marine mammals that may experience hearing impairment is quite small, even when planned mitigation measures are not considered. Taking into account that extensive monitoring and mitigation measures will be applied, the likelihood of the Project causing PTS in a marine mammal is negligible.

7.3 Potential Effects of Vibratory Pile Driving on Marine Mammals

Vibratory pile driving uses pairs of rapidly rotating eccentric weights to apply downward force on a pile (Graham et al. 2017). Piling using a vibratory hammer creates non-impulsive sounds with lower peak pressures than impact pile driving (Guan and Miner 2020). Non-impulsive sounds may result in greater temporal potential for behavioral disturbance through mechanisms such as masking (Matthews et al. 2018). Distances to injury thresholds for marine mammals are shorter for non-impulsive sounds when compared to impulsive sounds (Matthews et al. 2018). However, uncertainty remains over the extent to which marine mammals may respond differently to impact pile driving than to vibratory pile driving (Graham et al. 2017).

7.3.1 *Masking*

Similar to impact pile driving, there are limited studies specific to effects of vibratory pile driving on marine mammals. In a study assessing the effects of vibratory pile driver noise on the echolocation and vigilance in bottlenose dolphins, five (5) dolphins were required to scan their enclosure and indicate the occurrences of phantom echoes during 5 different source levels of vibratory pile driver playback sound (no-playback control, 100, 120, 130, and 140 dB re 1 µPa (Branstetter et al. 2018). The initial cessation of echolocation activity during the first 140 dB re 1 µPa exposure suggests a shift of attention from the task to the noise source and/or a decrease in motivation to perform a task. The continued performance decrement for the post-exposure condition, in which there was no noise exposure suggests the animals' motivation state was a major, if not primary factor, influencing target detection performance and vigilant behavior. Rapid acclimation to the noise exposure was demonstrated by all animals within the study (Branstetter et al. 2018).

Similar observation of habituation to vibratory piling was seen in a laboratory study on a harbor porpoise exposed to pile driving sounds. The harbor porpoise displayed an increase in respiration rates and jumps however this animal demonstrated rapid habituation to the sound (i.e., respiration rates decreasing towards baseline levels), just after 10 minutes (Kastelein et al. 2013). By the fourth and fifth replication, the harbor porpoise produced more clicks in response to the 140 dB re 1 µPa playback noise (Kastelein et al. 2013). An increase in click number suggests the harbor porpoises were compensating for the increased noise level. Thus, the harbor porpoises in this study did not habituate to the vibratory pile driver exposures, but rather, acclimated to it by increasing the number of clicks. The results of this study led to the conclusion that auditory masking was not a likely explanation because the pile driving noise peak frequency was below 10 kHz and any energy above 60 kHz was below ambient levels (Kastelein et al. 2013).

A recent study compared potential impacts to marine mammals from two different geophysical survey sources, a non-impulsive source, the marine vibrator (MV), to a strong impulsive source, an airgun array. Potential impacts were assessed by comparing signal level, duration, and bandwidth, which are all parameters known to contribute to masking. The MV array was found to ensonify the marine environment for periods 36-67% longer than the airgun array (Matthews et al. 2018). The longer duration of MV sounds, relative to airgun pulses, increases the potential for MV sound to mask signals of interest to marine mammals. However, despite longer signal durations, MV arrays were found to be less likely than airgun arrays to result in masking for most species because the distances within which MV sounds may be perceived were smaller, and the main frequencies produced by the MV source did not overlap with the hearing ranges of most marine mammals (Matthews et al. 2018). The higher the peak pressure level (SPL_{pk}), cumulative sound exposure level (SEL_{cum}), and sound pressure level (SPL_{rms}) of airgun sounds means that the distances within which masking might occur were 2 to more than 5 times greater for the airgun arrays than the MV arrays (Matthews et al. 2018). Thus, the lower amplitude of non-impulsive MV sounds resulted in smaller ranges of potential masking than those predicted for airgun arrays (Matthews et al. 2018). Due to similarities in the sounds produced, a similar relationship between potential masking from vibratory pile driving and impact pile driving as was found for MV and airgun sounds is anticipated.

7.3.2 *Behavioral Disturbance*

The longer duration of non-impulsive sounds produced by vibratory pile driving may result in greater temporal potential for behavioral disturbance; however, responses are expected to be short-term. During pile driving activities (using both vibratory and impact techniques) at the Nysted offshore wind farm off the coast of Denmark, a significant decrease in harbor porpoise echolocation activities and presumably abundance was reported within the construction area and in a reference area 10–15 km from the wind farm (Carstensen et al. 2006; Teilmann et al. 2008). Similarly, Carstensen et al. (2006) reported a medium-term porpoise response to construction activities in general and a short-term response to ramming/vibration activities.

When comparing the potential for behavioral response to non-impulsive sounds from an MV source versus impulsive sounds from an airgun array using the current NMFS criteria of 120 dB SPL_{rms} for non-impulsive sounds and 160 dB SPL_{rms} for impulsive sounds (NOAA 2005), models predicted longer distances to the behavioural thresholds for the non-impulsive MV source than the airgun source (Matthews et al. 2018). The difference in source levels between the two source types (29.5 dB on average) is generally less than the difference between the behavioral thresholds (40 dB). Consequently, longer distances to the behavioral thresholds were found for the MV source than the airgun source, and more animals were predicted to be exposed to sound levels above behavioral thresholds for the MV than the airgun. However, these criteria do not incorporate known differences in the frequency-dependent hearing sensitivity of different marine mammal species or individual variation in the likelihood of behavioral response, nor is there agreement that the 120 dB re 1 µPa is an appropriate threshold for MV sources. When the more realistic, frequency-weighted, multiple-step functions proposed by Wood et al. (2012) and DoN (2012) are used for comparative purposes, the result is reversed and fewer animals (by about an order of magnitude) are predicted to be exposed to sound levels above behavioral thresholds for the MV than for airgun arrays. This is primarily caused by the higher source levels (i.e., sound pressure amplitude) of airgun arrays resulting in longer distances to behavioral response thresholds that are nearly equivalent for the two source types using these criteria. However, these results do not directly incorporate context-dependent factors that may affect the likelihood of behavioral response, such as feeding, breeding, or migrating behaviors or the previous exposure history of individuals.

7.3.3 *Hearing Impairment*

Based on empirical measurements of pile driving sounds, there appears to be little risk for hearing impairment to marine mammals from vibratory pile driving, given the sound levels from vibratory pile driving are not expected to exceed 165 dB re 1 $\mu\text{Pa}_{\text{rms}}$ beyond 10 m (Illingworth and Rodkin 2007, 2017). It is unlikely that marine mammals would be exposed to vibratory pile driving at a sufficiently high level for a sufficiently long period to cause more than mild TTS. For non-impulsive sounds (such as vibratory pile driving), Southall et al. (2019) estimated that the received levels would have to exceed the TTS threshold by 20 dB, on an SEL basis, for there to be risk of PTS.

Although it is unlikely that pile driving activities would cause PTS in many marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, the lack of knowledge about TTS and PTS thresholds in many species, and the seemingly greater susceptibility of certain species (e.g., harbor porpoise and harbor seal) to TTS and presumably also PTS. The avoidance reactions of some marine mammals, along with commonly applied monitoring and mitigation measures (visual monitoring, ramp ups, and shutdowns when marine mammals are detected within or approaching the "safety radii"), would reduce the probability of exposure of marine mammals to sounds strong enough to induce PTS.

7.4 Potential Effects of High Resolution Geophysical (HRG) Surveys on Marine Mammals

The effects of sounds from HRG surveys could include either masking of natural sounds or behavioral disturbance (Richardson et al. 1995; Nowacek et al. 2007; Southall et al. 2007a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Most types of HRG survey equipment produce impulsive sounds that could have similar effects on marine mammals as described previously for impact pile driving; however, the sounds produced by HRG survey equipment are typically at much higher frequencies, lower source levels, and have a much higher repetition rate than impact pile driving. This means that injurious takes are very unlikely, but at close ranges masking may be more likely.

7.4.1 *Masking*

Some of the HRG survey equipment produce sounds within the frequency range of marine mammal hearing and vocalizations and thus could result in masking of some biologically important sounds. The impulsive nature of these sounds, short distances over which they would be audible, and continuous movement of the survey vessel suggest that any masking experience by marine mammals would be localized and short term. The biological repercussions of these potential outcomes are largely unknown but given the operating frequencies and source levels of the HRG equipment, significant impacts from masking are not expected.

7.4.2 *Behavioral Disturbance*

The most likely behavioral change exhibited by marine mammals as a result of HRG survey activities would be displacement or moving away from the sound. It is presumed that displacement, if it were to occur, would be limited to the area surrounding the sound source that is ensonified to above the Level B threshold of 160 dB SPL_{rms} for impulsive sounds, and would only last for the duration that the sound source is active in that location, with animals resuming regular behavior once the sound source passes.

7.4.3 *Hearing Impairment*

To experience any potential hearing impairment from HRG sources, marine mammals would have to occur in very close proximity (36.5 m) to the survey equipment (Appendix A). This is because the relatively high frequency sounds produced by the survey equipment attenuate rapidly in water. With the implementation of planned monitoring and mitigation measures like pre-start watches and exclusion zones (Appendix B), hearing impairment caused by HRG sources is extremely unlikely to occur.

7.5 Potential Effects from Unexploded Ordnance (MEC/UXO) on Marine Mammals

Underwater noise from MEC/UXO detonation can impact marine animals through mortality, physical injury, auditory damage, physiological stress, acoustic masking, and behavioral responses

(Merchant et al. 2020). The behavior of the pressure wave in the water column depends on water depth, sediment, sea state, stratification of the water column, temperature, salinity and other variables (Koschinski and Kock 2009; Salomons et al. 2021). Therefore, the specific effects on a given marine mammal will depend on all of these factors, as well as species, body size, the distance of the animal from the blast site, and the charge weight of the MEC/UXO in question (Hannay 2021).

7.5.1 *Masking*

Underwater explosions can result in masking, a phenomenon which occurs when the perception of a biologically important signal is interfered with by another signal in the environment (i.e., noise) (DoN (U.S. Department of the Navy) 2017b). For marine mammals, masking could result in a reduced ability to communicate with conspecifics, find food, and navigate in their environment. However, masking only occurs when the sound source is operating and direct masking effects stop immediately upon cessation of the sound-producing activity (DoN (U.S. Department of the Navy) 2018).

7.5.2 *Behavioral Disturbance*

Underwater explosions can also result in behavioral changes such as disturbance to regular migration and movement patterns, feeding, mating, calving/pupping, and resting (von Benda-Beckmann et al. 2015). Behavioral responses consist of reactions ranging from very minor and brief changes in attentional focus, changes in biologically important behaviors, and avoidance of a sound source or area, to aggression or prolonged flight (DoN (U.S. Department of the Navy) 2018).

7.5.3 *Hearing Impairment*

Marine vertebrates, including marine mammals, can suffer lethal and sub-lethal effects from the shock waves generated by underwater explosions (Koschinski 2011). Acoustic trauma via damage to the cochlear structures can either be temporary (temporary threshold shift, TTS) due to sensory cells being overwhelmed by intense acoustic energy, or permanent (permanent threshold shift, PTS) due to neural cell damage and loss of hair cell bodies (Koschinski 2011). The rapid changes in pressure and short signal rise time involved in explosions may lead to PTS (Ketten 1995).

Marine mammals that communicate in the high-frequency range, such as harbor porpoise, are particularly sensitive to the effects of underwater explosions. Studies also indicate that smaller cetacean species are at greatest risk for shock wave or blast injuries (Ketten 2004). A number of mitigation measures will be employed (Section 11.5) including the use of bubble curtains, which have been shown to effectively reduce the sound pressure and the shock wave from detonations (Schmidtke et al. 2009).

Impacts associated with MEC/UXO detonation for the proposed Project are likewise expected to be negligible given the fact that any required detonations will be timed to occur no more than once per day, and noise from these activities will not exceed the 160 dB Level B impulsive threshold for marine mammals; the relatively low number of MEC/UXOs identified in the Project area, and the adoption of extensive mitigation measures (Section 11.5) which will reduce or eliminate Level A and Level B harassment. Adverse effects are therefore not anticipated on marine mammal stocks or populations.

7.6 Population Level Effects

NMFS provides best available estimates of abundance (N_{best}) for all marine mammal stocks under their jurisdiction in their annual Stock Assessment Reports (Hayes et al. 2020). In most cases, NMFS considers these to be underestimates because the full known range of the stock was not surveyed, the estimate did not include availability-bias correction for submerged animals, or there may be uncertainty regarding population structure (Hayes et al. 2017). Marine mammal abundance estimates are also available from Duke University Marine Geospatial Ecological Laboratory habitat-based models Roberts et al. (2016; 2017; 2018; 2021). Since the modeling included availability-bias corrections the abundance estimates can be larger than the SAR N_{best} abundance estimates. However, the Roberts et al. (2016; 2017; 2018; 2021) models only provide estimates of abundance for the U.S. Atlantic EEZ which is a smaller area than occupied by the stocks defined by NMFS. By defining most stocks as inclusive of animals in the larger northwest Atlantic Ocean, including areas outside of the U.S. Atlantic EEZ, the SAR N_{best} abundance estimates are larger for nearly all species. Thus, the SAR N_{best} abundance estimates were used to calculate the percentage of each population or stock that could potentially receive Level A or Level B sound exposures during the Project construction activity (Table 22).

8 Anticipated Impacts on Subsistence Uses

NOAA Office of Protected Resources defines “subsistence” as the use of marine mammals taken by Alaskan Natives for food, clothing, shelter, heating, transportation, and other uses necessary to maintain the life of the taker or those who depend upon the taker to provide them with such subsistence. There are no traditional subsistence hunting areas in the vicinity of the proposed Project Area and there are no activities related to the Project that may impact species or stocks of marine mammals that are used for subsistence purposes elsewhere. Therefore, there will be no effect on the availability of marine mammals for subsistence uses.

9 Anticipated Impacts on Habitat

This section addresses the potential loss or modification of marine mammal habitat resulting from the construction activities and the likelihood of restoration of that habitat. For clarity, potential impacts have been categorized as short-term or long-term in the following subsections. Short-term impacts are those that might occur from the actual construction activities but largely resolve once construction is completed. Long-term impacts are those that might persist after construction is completed including during the operations phase of the RWF.

9.1 Short-Term Impacts

A variety of impact producing factors (i.e., seafloor disturbance, turbidity, physical presence of vessels and equipment, vessel discharges, and noise) with the potential to temporarily affect marine mammal habitat, including prey availability, may be expected as a result of the proposed activities. The marine mammal species found within the Project Area feed on various pelagic and benthic fish species, cephalopods, and crustaceans. Elevated noise levels, installation of structures that disturb the seafloor, and other factors associated with project vessels and equipment may cause some prey species to leave the immediate area of operations, temporarily reducing the availability of prey within the area and thus disrupting feeding behavior and efficiency. Displaced prey species are expected to return shortly after construction is completed.

Increased sound levels from the construction activities and during underwater explosions have the potential to affect local prey populations, which might indirectly affect marine mammals by altering prey abundance, behavior, and distribution (McCauley 2003; Popper and Hastings 2009; Slabbekoom et al. 2010; Danil and St. Leger 2011; von Benda-Beckmann et al. 2015). Marine fish are typically sensitive to noise in the 100 to 500 Hz range, which coincides with the primary frequency range of vessels and pile driving activities. Noise generated by both impact and vibratory pile driving has the potential to elicit behavioral responses in fish, and impact pile driving and/or MEC/UXO detonation also have the potential to cause injury as a result of the high peak pressure levels near the source. Laboratory impact pile driving studies demonstrated swim bladder damage in Chinook salmon and documented tissue damage in other species (Halvorsen et al. 2012). A similar study saw ruptured swim bladders and/or kidney hemorrhaging in fish which had been exposed to ~96 pile strikes with a sound exposure level ($\mathrm{SEL}_{\mathrm{ss}}$) of 183 dB (Casper et al. 2017). Casper et al. (2017) found that physical injuries sustained by the fish increased in both severity and number as the cumulative sound exposure level ($\mathrm{SEL}_{\mathrm{cum}}$) increased with higher per-strike energy and total number of strikes. Hart Crowser et al. (2009) and Houghton et al. (2010) exposed caged juvenile coho salmon (*Oncorhynchus kisutch*) to sounds from vibratory pile driving with maximum peak SPLs of 177 to 195 dB re 1 µPa and SELs of 174.8 to 190.6 dB re 1 µPa. They reported no mortalities or behavioral abnormalities; vibratory pile driving did not affect the feeding ability of the juvenile coho salmon.

The most common behavioral responses by fish to anthropogenic noise are avoidance, alteration of swimming speed and direction, and alteration of schooling behavior (Vabø et al. 2002; Handegard and Tjøstheim 2005; Sarà et al. 2007; Becker et al. 2013). Noise from pile driving and vessel activities may cause prey species to temporarily vacate the area. Squid (*Sepioteuthis australis*) are an extremely important food chain component for many higher order marine predators, and while limited information is available for noise impacts on invertebrate species, squid are known to be able to detect particle motion. McCauley et al. (2000) recorded caged squid responding to airgun signals, suggesting behavioral responses are probable from other anthropogenic sources like pile driving. Crustaceans have also shown behavioral responses to pile driving (Tidau and Briffa 2016). Disturbances associated with noise produced by construction activities are expected to be short-term and temporary with minor impacts to marine mammal prey species.

Seafloor disturbance is expected during seafloor preparation, pile driving, placement of scour protection, installation of the inter-array cables, RWEC installation, and MEC/UXO detonation. The disturbance would be limited to within 200 m of WTG and OSS foundations, and within 40-m wide corridors along cable routes. Vessel anchoring may disturb small areas of seafloor outside of the 40-m wide cable corridor. All seafloor disturbance and associated water turbidity is expected to be short-term and temporary with minimal effects on marine mammal habitat or prey items.

Potential discharges from vessels and other construction equipment will be localized near their source and are not expected to adversely affect prey species or habitat. While the physical presence of vessels and deployed equipment may produce avoidance behavior, night lighting may serve to attract fishes and squid. Neither physical presence nor night lighting are expected to adversely affect prey species.

9.2 Long-Term Impacts

The presence of the RWF monopile foundations, scour protection, and cable protection will result in a conversion of the existing sandy bottom habitat to a hard bottom habitat with areas of vertical structural relief. This could potentially alter the existing habitat by creating an "artificial reef effect" that results in colonization by assemblages of both sessile and mobile animals within the new hard-bottom habitat (Wilhelmsson et al. 2006; Reubens et al. 2013; Bergström et al. 2014; Coates et al. 2014). Artificial structures can create increased habitat heterogeneity important for species diversity and density (Langhamer 2012). The WTG and OSS foundations will extend through the water column, which may serve to increase settlement of meroplankton or planktonic larvae on the structures in both the pelagic and benthic zones (Boehlert and Gill 2010). Fish and invertebrate species are also likely to aggregate around the foundations and scour protection which could provide increased prey availability and structural habitat (Boehlert and Gill 2010; Bonar et al. 2015).

The WTG foundations will have an estimated footprint of 28.3 hectares (70 ac) and the OSS foundations will have an estimated footprint of up to 0.6 hectares (1.4 ac) (COP Table 3.3.4-2) (Revolution-Wind 2021), providing up to 29.1 hectares (72 ac) of heterogeneous habitat throughout the 20–35-year operational life of this Project. Numerous studies have documented significantly higher fish concentrations including species like cod and pouting (*Trisopterus luscus*), flounder (*Platichthys flesus*), eelpout (*Zoarces viviparus*), and eel (*Anguila anguilla*) near the foundations than in surrounding soft bottom habitat (Langhamer and Wilhelmsson 2009; Bergström et al. 2013; Reubens et al. 2013). In the German Bight portion of the North Sea, fish were most densely congregated near the anchorages of jacket foundations, and the structures extending through the water column were thought to make it more likely that juvenile or larval fish encounter and settle on them (RI-CRMC 2010; Krone et al. 2013). In addition, at these structures fish can take advantage of the shelter provided while also being exposed to stronger currents created by the structures, which generate increased feeding opportunities and decreased potential for predation (Wilhelmsson et al. 2006). The presence of the foundations and resulting fish aggregations around the foundations is expected to be a long-term habitat impact, but the increase in prey availability could potentially be beneficial for marine mammals.

10 Anticipated Effects of Habitat Impacts on Marine Mammals

The loss or modification of marine mammal habitat could arise from alteration of benthic habitats, introduced noise, physical presence of vessels and equipment, and vessel discharges as described in the previous section. These impacts could be short- or long-term in nature. The anticipated effects on marine mammals resulting from impacts to their habitat are summarized below.

10.1 Short-Term Impacts

Marine mammals use sound to navigate, communicate, find prey, and avoid predators. Acoustic "space" within their habitat must be available for species to conduct these activities. If noise levels within critical frequency bands preclude animals from accessing or utilizing the acoustic space of that habitat, then availability and quality of that habitat has been diminished. Thus, anthropogenic noise can be viewed as a form of habitat fragmentation resulting in a loss of acoustic space for marine mammals that could otherwise be occupied by vocalizations or other ecologically significant acoustic cues (Rice et al. 2014b).

The sounds that marine mammals produce and hear will vary in terms of dominant frequency, bandwidth, energy, temporal pattern, and directionality. The same variables in ambient noise will, therefore, affect a marine mammal's acoustic resource availability. Acoustic propagation modeling conducted by JASCO (Appendix A) partially accounts for spectral characteristics of the sound received by animals through the application of NMFS marine mammal weighting functions, and it can be assumed animals within the behavior threshold isopleths may encounter a partial loss of acoustic space. Therefore, marine mammals may experience some short-term loss of acoustic habitat, but the nature and duration of this loss due to the temporary nature of the proposed activities is not expected to represent a significant loss of acoustic habitat.

Due to the small and short-term footprint of potential sediment disturbance caused by installation of the WTG and OSS foundations or the IAC and RWEC combined with the availability of similar benthic habitat in and around the Project Area, it is expected that impacts to benthic habitats and associated prey from construction activities would have negligible effects on marine mammals.

Habitat impacts on marine mammals resulting from MEC/UXO detonation may take two forms: 1) the acoustic energy introduced into the water column from the blast itself, which could directly impact marine mammals as described in Section 7 and 2) the mortality or displacement of potential marine mammal prey in the immediate vicinity of the blast. Due to the short duration of any required detonation events, the relatively small number of potential MEC/UXOs identified in the Project area, the comprehensive mitigation and monitoring measures proposed to exclude marine mammals from the immediate vicinity of the blast site, and the fact that marine mammals are highly mobile and able to leave the impacted area during these short-term detonation events, any habitat-related impacts to marine mammals are anticipated to be temporary and negligible.

10.2 Long-Term Impacts

The long-term habitat alteration due to the presence of WTG and OSS foundations and associated scour protection will provide hard-bottom habitat for potential marine mammal prey species and may increase the availability of prey species as discussed in Section 9.2. This could potentially alter marine mammal distribution and behavior patterns by increasing the number of marine mammals using this habitat for foraging. However, the effects of habitat alteration associated with the physical presence of the foundations and scour protection will not be universal across all marine mammal species since only some species are likely to use prey that become associated with those structures.

Pinnipeds and some odontocete species are likely to benefit the most from increases in the availability of prey species that are attracted to the physical structures. Numerous surveys at offshore wind farms, oil and gas platforms, and artificial reef sites have documented increased abundance of smaller odontocete, and pinniped species attracted to the increase in pelagic fish and benthic prey availability (Hammar et al. 2010; Lindeboom et al. 2011; Mikkelsen et al. 2013; Russell et al. 2014; Arnould et al. 2015). Studies examining harbor seal distribution around wind farms have shown seal numbers inside the wind farm to be recovered following construction; however, fewer seals were present on the nearby land sites (Snyder and Kaiser 2009; Vellejo et al. 2017). Harbor porpoise activity around the Danish wind farm "Nysted" showed a significant decline in echolocation activity following construction that gradually increased but did not return to baseline levels (Hammar et al. 2010; Teilmann and Carstensen 2012), while no change in activity was observed around the Danish wind farm "Rodsand II" after construction (Hammar et al. 2010). Projects to restore artificial reefs noted an increase in the presence of harbor porpoises at the new artificial reef site compared to surrounding habitats, and it was hypothesized they were following prey species (Mikkelsen et al. 2013).

Currently there are no quantitative data on how large whale species (i.e., mysticetes) may be impacted by offshore windfarms (Kraus et al. 2019). Navigation through or foraging within the RWF by large whales could be impeded by the presence of the WTG and OSS foundations, which range in diameter from 12 to 15 m with approximately 1.15 mi (1.8 km) spacing between foundations (Section 1). Additionally, wakes in water currents created by the presence of the foundations could alter the distribution of zooplankton within the water column, which would impact prey availability for some marine mammal species (Kraus et al. 2019). However, such wakes are not expected to affect pelagic fish or benthic species, so marine mammals that forage primarily on those species are unlikely to be affected. Given the likely benefits to some marine mammal species from increased prey abundance and the uncertain, but likely minimal negative impacts on large whales from the presence of the widely spaced foundations, overall impacts to marine mammal habitat are anticipated to be negligible.

11 Mitigation Measures

Revolution Wind is committed to minimizing impacts to marine mammal species through a comprehensive monitoring and mitigation program. The mitigation measures to be implemented include, but are not limited to, the following:

1. Noise attenuation through use of a noise mitigation system;
2. Seasonal restrictions;
3. Standard PSO training and equipment requirements;
4. Visual monitoring; including low visibility monitoring tools;
5. Passive acoustic monitoring;
6. Establishment and monitoring of shutdown zones
7. Pre-start clearance;
8. Ramp-up (soft-start) procedures;
9. Operations monitoring;
10. Operational shutdowns and delay;
11. Sound source measurements of at least one foundation installation
12. Survey sighting coordination;
13. Vessel strike avoidance procedures; and
14. Data recording and reporting procedures.

The selection and implementation of appropriate mitigation measures will consider safety, practical application, and effectiveness. While protection of marine mammals is a top priority, environmental and human health and safety is the very highest priority when working in the offshore environment; therefore, revisions or exceptions to monitoring and mitigation measures described in the Protected Species Monitoring and Mitigation Plan (PSMMP) may be made under certain circumstances. Revolution Wind has and will continue to engage with NMFS to further refine specific details of the PSMMP to be implemented during construction of the RWF and RWEC.

All monitoring and mitigation measures to be conducted during the Project will be described in a PSMMP (Appendix C). The materials in this section summarize the main points of the PSMMP. The PSMMP (Appendix C) will include 4 different monitoring plans. These plans include a vessel strike avoidance plan (PSMMP Attachment 6), sound field verification plan (PSMMP Attachment 7), passive acoustic monitoring (PAM) plan, and pile driving and marine mammal monitoring plan. Each plan is to be submitted to NMFS for review and approval at least 90 days prior to commencement of construction activities.

The monitoring and mitigation methods described here are intended to reduce or eliminate exposure of marine mammals to underwater sound levels that could constitute "take" under the MMPA. Many of the monitoring and mitigation measures are applicable across all project activities while others will be specific to the following activities:

- WTG and OSS foundation installation using impact pile driving,
- Cable landfall construction using vibratory pile driving,
- High resolution geophysical (HRG) surveys, and
- In-Situ MEC/UXO disposal.

11.1 Standard Mitigation and Monitoring Requirements for all Activities

11.1.1 *Protected Species Observer (PSO) and Passive Acoustic Monitoring (PAM) Operator training, experience and responsibilities*

- All PSOs and Acoustic PSOs (APSOs / PAM Operators) will have completed a NMFS-approved PSO training course.
- The PSO field team and the PAM team will have a lead observer (Lead PSO and PAM Lead) who will have experience in the northwestern Atlantic Ocean on similar projects.
- Remaining PSOs and PAM operators will have previous experience on similar projects and the ability to work with the relevant software and equipment.
- PSOs and PAM operators will complete a Permits and Environmental Compliance Plan (PECP) training and a two-day training and refresher session with the PSO provider and Project compliance representatives conducted before the anticipated start of Project activities.

11.1.2 *Visual Monitoring*

- No individual PSO will work more than 4 consecutive hours without a 2-hour break, or longer than 12 hours during a 24-hour period.
- Each PSO will be provided with one 8-hour break per 24-hour period to sleep.
- Observations will be conducted from the best available vantage point(s) on the vessels (stable, elevated platform from which PSOs have an unobstructed 360° view of the water).
- PSOs will systematically scan with the naked eye and a 7 x 50 reticle binocular, supplemented with night-vision equipment when needed.
- When monitoring at night or in low visibility conditions, PSOs will monitor for marine mammals and other protected species using night-vision goggles with thermal clip-ons, a hand-held spotlight, and/or a mounted thermal camera system
- Activities with larger monitoring zones will use 25 x 150 mm "big eye" binoculars.
- Vessel personnel will be instructed to report any sightings to the PSO team as soon as they are able and it is safe to do so.
- Members of the monitoring team will consult with NMFS' NARW reporting system for the presence of NARWs in the Project Area

11.1.3 *Acoustic Monitoring (WTG and OSS foundation installation only)*

- Deployment of PAM system will be outside the perimeter of the shutdown zone
- 4-hour PAM operator rotations for 24-hour operation vessels

11.1.4 *Vessel Strike Avoidance*

In addition to the Base Conditions below, Revolution Wind will implement a Standard Plan or an Adaptive Plan as presented below. These three plans are intended to be interchangeable and implemented throughout both the construction and operations phases of the project. Revolution Wind will submit a final NARW Vessel Strike Avoidance Plan at least 90 days prior to commencement of vessel use that further details the Adaptive Plan and specific monitoring equipment to be used. The plan will, at a minimum, describe how PAM, in combination with visual observations, will be conducted to ensure the transit corridor is clear of NARWs. The plan will also provide details on the vessel-based observer protocols on transiting vessels.

11.1.4.1 *Base Conditions- General Measures*

- All personnel working offshore will receive training on marine mammal awareness and vessel strike avoidance measures.
- Vessel personnel will maintain a vigilant watch for marine mammals and slow down or maneuver vessels as appropriate to avoid striking marine mammals.
- Revolution Wind will establish a situational awareness network for marine mammal detections through the integration of sighting communication tools such as Mysticetus, Whale Alert, Whale Map, etc. Sighting information will be made available to all project vessels through the established network. Revolution Wind’s Marine Coordination Center will serve to coordinate and maintain a Common Operating Picture. In addition, systems within the Marine Coordination Center, along with field personnel, will:
    - Monitor the NMFS North Atlantic right whale reporting systems daily;
    - Monitor Coast Guard VHF Channel 16 throughout the day to receive notifications of any sightings; and,
    - Monitor any existing real-time acoustic networks.

11.1.4.2 *Base Conditions- Separation Distances*

- Vessels will maintain, to the extent practicable, separation distances of:
    - > 500 m distance from any sighted NARW or unidentified large marine mammals
    - > 100 m from all other whales
    - > 50 m for dolphins, porpoises and seals

11.1.4.3 *Base Conditions- Speed Restrictions*

- Vessels will comply with NMFS regulations and speed restrictions and state regulations as applicable for NARW.
- All vessels 65 ft (20 m) or longer subject to the jurisdiction of the U.S. will comply with the 10-knot speed restriction when entering or departing a port or place subject to U.S. jurisdiction, and in any SMA during NARW migratory and calving periods from November 1 to April 30.
- Situational Awareness/Common Operating Picture: Revolution Wind will establish a situational awareness network for marine mammal detections through the integration of sighting communication tools such as Mysticetus, Whale Alert, WhaleMap, etc. Sighting information will

be made available to all project vessels through the established network. Revolution Winds Marine Coordination Center will serve to coordinate and maintain a Common Operating Picture. In addition, systems within the Marine Coordination Center, along with field personnel, will:

  - Monitor the NMFS North Atlantic right whale reporting systems daily;
  - Monitor Coast Guard VHF Channel 16 throughout the day to receive
  - notifications of any sighting; and
  - Monitor any existing real-time acoustic networks.

- A complete vessel speed plan will be included in the PSMMP (PSMMP Attachment 7).

11.1.4.4 Standard Plan

- Implement Base Conditions as described above.
- Between November 1st and April 30th: Vessels of all sizes will operate port to port (from ports in NJ, NY, MD, DE, and VA) at 10 knots or less between November 1 and April 30 except for vessels while transiting in Narragansett Bay or Long Island Sound which have not been demonstrated by best available science to provide consistent habitat for North Atlantic right whales. Vessels transiting from other ports outside those described will operate at 10 knots or less when within any active SMA or within the Wind Development Area (WDA), including the lease area and export cable route.
- Year Round: Vessels of all sizes will operate at 10 knots or less in any Dynamic Management Areas (DMAs)
- Between May 1st and September 30th: All underway vessels (transiting or surveying) operating at >10 knots will have a dedicated visual observer (or NMFS approved automated visual detection system) on duty at all times to monitor for marine mammals within a 180° direction of the forward path of the vessel (90° port to 90°starboard). Visual observers must be equipped with alternative monitoring technology for periods of low visibility (e.g., darkness, rain, fog, etc.).
  - The dedicated visual observer must receive prior training on protected species detection and identification, vessel strike minimization procedures, how and when to communicate with the vessel captain, and reporting requirements.
- Visual observers may be third-party observers (i.e., NMFS-approved PSOs) or crew members.

11.1.4.5 Adaptive Plan

The Standard Plan outlined above will be adhered to except in cases where crew safety is at risk, and/or labor restrictions, vessel availability, costs to the project, or other unforeseen circumstance make these measures impracticable. To address these situations, an *Adaptive Plan* will be developed in consultation with NMFS to allow modification of speed restrictions for vessels. Should Revolution Wind choose not to implement this *Adaptive Plan,* or a component of the *Adaptive Plan* is offline (e.g., equipment technical issues), Revolution Wind will default to the *Standard Plan* (described above). The Adaptive Plan will not apply to vessels subject to speed reductions in SMAs as designated by NOAA's Vessel Strike Reduction Rule.

- Year Round: A semi-permanent acoustic network comprising near real-time bottom mounted and/or mobile acoustic monitoring platforms will be installed year-round such that confirmed North Atlantic right whale detections are regularly transmitted to a central information portal and disseminated through the situational awareness network.
  - The transit corridor and WDA will be divided into detection action zones.

    - Localized detections of NARW in an action zone would trigger a slow-down to 10 knots or less in the respective zone for the following 12 hours. Each subsequent detection would trigger a 12-hour reset. A zone slow-down expires when there has been no further visual or acoustic detection in the past 12 hours within the triggered zone.
    - The detection action zone's size will be defined based on efficacy of PAM equipment deployed and subject to NMFS approval as part of the NARW Vessel Strike Avoidance Plan.
  - Year Round: All underway vessels (transiting or surveying) operating > 10 knots will have a dedicated visual observer (or NMFS approved automated visual detection system) on duty at all times to monitor for marine mammals within a 180° direction of the forward path of the vessel (90° port to 90°starboard). Visual observers must be equipped with alternative monitoring technology for periods of low visibility (e.g., darkness, rain, fog, etc.). The dedicated visual observer must receive prior training on protected species detection and identification, vessel strike minimization procedures, how and when to communicate with the vessel captain, and reporting requirements. Visual observers may be third-party observers (i.e., NMFS-approved PSOs) or crew members.
  - Year-round if any DMA is established that overlaps with an area where a project vessel would operate, that vessel, regardless of size when entering the DMA, may transit that area at a speed of 10 knots or less. Any active action zones within the DMA may trigger a slow down as described above.
  - If PAM and/or thermal systems are offline, the Standard Plan measures will apply for the respective zone (where PAM is offline) or vessel (if automated visual systems are offline).

11.1.5 *Data Recording*

- All data will be recorded using industry-standard software.
- Data recorded will include information related to ongoing operations, observation methods and effort, visibility conditions, marine mammal detections, and any mitigation actions requested and enacted.

11.1.6 *Reporting*

- If a stranded, entangled, injured, or dead protected species is observed, the sighting will be reported within 24 hours to NMFS SAS hotline
- If a protected species is injured or killed as a result of Project activities, the vessel captain or PSO on board will report it to the NMFS Office of Protected Resources (OPR) and Greater Atlantic Regional Fisheries Office immediately, no later than within 24 hours.
  - Activity operations will cease until NMFS OPR is able to review the circumstances of the incident and determine what, if any, additional measures are appropriate before continuing operations.
- Any NARW sightings will be reported as soon as feasible and no later than within 24 hours to the NMFS SAS hotline or via the WhaleAlert App.
- Data and Final Reports will be prepared using the following protocols:

- A QA/QC'd database of all sightings and associated details (e.g., distance from vessel, behavior, species, group size/composition) within and outside of the designated shutdown zones, monitoring effort, environmental conditions, and Project-related activity will be provided after field operations and reporting are complete.
- Weekly PSO/PAM reports (during construction activity) will be submitted every Wednesday following a Sunday-Saturday week
- Final reports will follow a standardized format for PSO reporting from activities requiring marine mammal mitigation and monitoring.
- An annual visual and acoustic monitoring report will be provided to NMFS and to BOEM on April 1st of each year of the Rule summarizing the prior year's activities.

11.2 WTG and OSS Monopile Foundation Installation – Impact Pile Driving

11.2.1 *Monitoring Equipment*

Table 53 Equipment used for marine mammal monitoring during impact pile driving.

	Standard Daytime		Monitoring during Nighttime and Low Visibility	
Item	**Number on Construction Vessel**	**Number on Secondary Vessel**	**Number on Construction Vessel**	**Number on Secondary Vessel**
Reticle binoculars	2	2		
Mounted thermal/IR camera system[2]	1	1	1	1
Mounted "big-eye" binocular	1	1		
Monitoring station for real time PAM system[3]	1	1	1	1
Hand-held or wearable NVDs	0	0	2	2
IR spotlights	0	0	2	2
Mysticetus data collection software system	1	1	1	1
PSO-dedicated VHF radios	2	2	2	2
Digital single-lens reflex camera equipped with 300-mm lens	1	1		

[2] The camera systems will be automated with detection alerts that will be checked by a PSO on duty; however, cameras will not be manned by a dedicated observer.

[3] The selected PAM system will transmit real time data to PAM monitoring stations on the vessels and/or a shore side monitoring station.

11.2.2 *Visual Monitoring*

- Six to eight visual and APSOs[3] on the impact pile driving vessel and four to eight visual and APSOs on any secondary marine mammal monitoring vessel.
- Two visual PSOs will be watch on each construction and secondary vessel during pre-start clearance, throughout impact pile driving, and 30 minutes after piling is completed.

11.2.3 *Daytime Visual Monitoring*

- PSOs will monitor for 30 minutes before and after each piling event.
- Two PSOs will monitor the shutdown zone with the naked eye and reticle binoculars while one PSO periodically scans outside the shutdown zone using the mounted big eye binoculars.
- The secondary vessel will be positioned and circling at the outer limit of the Large Whale shutdown zone.

11.2.4 *Daytime Periods of Reduced Visibility*

- If the monitoring zone is obscured, the two PSOs on watch will continue to monitor the shutdown zone using thermal camera systems and handheld NVDs (as able).
- All PSOs on duty will be in contact with the on-duty PAM operator who will monitor the PAM systems for acoustic detections of marine mammals that are vocalizing in the area.

11.2.5 *Nighttime Visual: Construction Piling and Secondary Vessel*

During nighttime operations, night vision equipment (night vision goggles) and infrared/thermal imaging technology will be used. Recent studies have concluded that the use of infrared/thermal imaging technology allow for the detection of marine mammals at night (Verfuss et al. 2018). Guazzo et al (2019) showed that probability of detecting a large whale blow by a commercially available infrared camera was similar at night as during the day; camera monitoring distance was 2.1 km from an elevated vantage point at night versus 3 km for daylight visual monitoring from the same location. The following nighttime piling monitoring and mitigation methods use the best current available technology to mitigate potential impacts and result in the least practicable adverse impact.

- Visual PSOs will rotate in pairs: one observing with an NVD and one monitoring the IR thermal imaging camera system[4].
- Deck lights will be extinguished or dimmed during night observations when using NVDs; however, if the deck lights must remain on for safety reasons, the PSO will attempt to use the NVDs in areas away from potential interference by these lights. If a PSO is still unable to observe the required visual zones, piling would not occur.
- The use of thermal camera systems for mitigation purposes warrants additional application in the field as both a standalone tool and in conjunction with other alternative monitoring methods (e.g., night vision binoculars).

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[3] Acoustic PSOs maybe located on shore

[4] In support of the request for nighttime piling, Ørsted is assessing the opportunity to conduct a marine mammal monitoring field demonstration project in the spring of 2022. Additional details on the project and further engagement will follow.

11.2.6 *Acoustic Monitoring*

- PAM operator will monitor during all pre-start clearance periods, piling, and post-piling monitoring periods (daylight, reduced visibility, and nighttime monitoring).
- One PAM operator on duty during both daytime and nighttime/low visibility monitoring.
- Real-time PAM systems require at least one PAM operator to monitor each system by viewing data or data products that are streamed in real-time or near real-time to a computer workstation and monitor located on a Project vessel or onshore.
- PAM operator will inform the PSOs on duty of animal detections approaching or within applicable ranges of interest to the pile-driving activity.
- The PAM system deployed will be capable of monitoring up to 10 km radii from the pile.
- A Passive Acoustic Monitoring (PAM) Plan must be submitted to NMFS and BOEM for review and approval at least 90 days prior to the planned start of pile driving.

11.2.7 *Shutdown Zones*

Summer distances were determined from the modeling conducted assuming a summer sound speed profile. These distances will be used to implement shutdown zones during the months identified in the acoustic modeling report as being represented by the summer sound speed profile (April – November). Winter distances were determined from the modeling conducted assuming a winter sound speed profile. These distances will be used to implement shutdown zones during the months identified in the acoustic modeling report as being represented by the winter sound speed profile (December – March).

11.2.7.1 WTG Summer Distances (May-November):

- Mysticete whales (low-frequency cetaceans): 2,300 m
- North Atlantic Right Whale Visual Detection: any distance
- North Atlantic Right Whale Acoustic Detection: 3,900 m
- Sperm whale (mid-frequency cetacean): 2,300
- Mid-frequency cetaceans (except sperm whales): NAS
- Harbor porpoise (high-frequency cetacean): 1,400 m
- Seals: 500 m

11.2.7.2 WTG Winter Distances (December):

- Mysticete whales (low-frequency cetaceans): 4,400 m
- North Atlantic Right Whale Visual Detection: any distance
- North Atlantic Right Whale Acoustic Detection: 4,400 m
- Sperm whale (mid-frequency cetacean): 4,400 m
- Mid-frequency cetaceans (except sperm whales): NAS
- Harbor porpoise (high-frequency cetacean): 2,400 m
- Seals: 900 m

11.2.7.3 OSS Summer Distances (May- November)

- Mysticete whales (low-frequency cetaceans): 1,600 m
- North Atlantic Right Whale Visual Detection: any distance
- North Atlantic Right Whale Acoustic Detection: 4,100 m
- Sperm whale (mid-frequency cetacean): 1,600

- Mid-frequency cetaceans (except sperm whales): NAS
- Harbor porpoise (high-frequency cetacean): 900 m
- Seals: 400 m

11.2.7.4 OSS Winter Distances (December)

- Mysticete whales (low-frequency cetaceans): 2,700 m
- North Atlantic Right Whale Visual Detection: any distance
- North Atlantic Right Whale Acoustic Detection: 4,700 m
- Sperm whale (mid-frequency cetacean): 2,700
- Mid-frequency cetaceans (except sperm whales): NAS
- Harbor porpoise (high-frequency cetacean): 1,300 m
- Seals: 400 m

11.2.8 *Pre-Start Clearance*

- Piling may be initiated any time with in a 24-hour period
- Prior to the beginning of each pile driving event, PSOs and APSOs will monitor for marine mammals for a minimum of 30 minutes and continue at all times during impact pile driving.
- All clearance zones will be confirmed to be free of marine mammals prior to initiating ramp-up and the large whale clearance zone will be fully visible and the NARW acoustic zone monitored for the least 30-minutes prior to commencing ramp-up
- If a marine mammal is observed entering or within the relevant shutdown zones prior to the initiation of pile driving activity, pile driving activity will be delayed and will not begin until either the marine mammal(s) has voluntarily left the respective shutdown zones and been visually or acoustically confirmed beyond that shutdown zone, or, when the additional time period has elapsed with no further sighting or acoustic detection (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

11.2.9 *Ramp up (Soft Start)*

- Ramp-up is required prior to the initiation of HRG sources (boomers, sparkers, Chirps)
- Each monopile installation will begin with a minimum of 20-minute ramp up (soft-start) procedure as technically feasible
- Soft-start procedure will not begin until the shutdown zone has been cleared by the visual PSO or PAM operators
- If a marine mammal is detected within or about to enter the applicable shutdown zone, prior to or during the soft-start procedure, pile driving will be delayed until the animal has been observed exiting the shutdown zone or until an additional time period has elapsed with no further sighting (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

11.2.10 *Shutdowns*

- If a marine mammal is detected entering or within the respective shutdown zones after pile driving has commenced, an immediate shutdown of pile driving will be implemented unless RW determines shutdown is not feasible due to an imminent risk of injury or loss of life to an individual.

- If shutdown is called for but it is determined that shutdown is not feasible due to risk of injury or loss of life, there will be a reduction of hammer energy.
- Following shutdown, pile driving will only be initiated once all shutdown zones are confirmed by PSOs to be clear of marine mammals for the minimum species-specific time periods.
- The shutdown zone will be continually monitored by PSOs and PAM during any pauses in pile driving.
- If a marine mammal is sighted within the shutdown zone during a pause in piling, piling will be delayed until the animal(s) has moved outside the shutdown zone and no marine mammals are sighted for a period of 30 minutes.

11.2.11 *Post-Piling Monitoring*

- PSOs will continue to survey the monitoring zone throughout the duration of pile installation and for a minimum of 30 minutes after piling has been completed.

11.2.12 *Noise Attenuation*

- The Project will use a noise attenuation system (NAS) for all piling events and is committed to achieving ranges associated with 10 dB of noise attenuation. The type and number of NAS to be used during construction have not yet been determined but will consist of a double big bubble curtain or a single bubble curtain paired with an additional sound attenuation device or a double big bubble curtain. Based on prior measurements this combination of NAS is reasonably expected to achieve greater than 10 dB broadband attenuation of impact pile driving sounds (described further in Section 6.3.2)

11.2.13 *Sound Measurements*

- Measurements of the installation of at least three monopile foundations will be made and results used to modify shutdown zones, as appropriate.
- For each monopile measured, Revolution Wind will estimate ranges to Level A and Level B harassment isopleths by extrapolating from in-situ measurements at multiple distances from the monopile including at least one measurement location of 750 m from the monopile.
- A sound field verification plan will be submitted to NMFS for review and approval at least 90 days prior to planned start of pile driving.
- This will include procedures for how measurement results will be used to justify any requested changes to planned monitoring and mitigation distances.

11.3 Construction-Temporary Cofferdam Installation (Vibratory or Impulsive Pile Driving)

11.3.1 *Monitoring Equipment*

- Two sets of reticle binoculars
- Two hand-held or wearable NVDs
- Two IR spotlights
- One data collection software system
- Two PSO-dedicated VHF radios
- One digital single-lens reflex camera equipped with 300-mm lens

11.3.2 *Visual Monitoring*

- All observations will take place from one of the construction vessels stationed at or near the vibratory piling location.
- Two PSOs on duty on the construction vessel.
- PSOs will continue to survey the shutdown zone using visual protocols throughout the installation of each cofferdam sheet pile and for a minimum of 30 minutes after piling has been completed.

11.3.3 *Daytime Visual Monitoring*

- Two PSOs will maintain watch during the pre-start clearance period, throughout vibratory pile driving, and 30 minutes after piling is completed.
- Two PSOs will conduct observations concurrently
- One observer will monitor the shutdown zone with the naked eye and reticle binoculars; one PSO will monitor in the same way but will periodically scan outside the shutdown zone.

11.3.4 *Daytime Visual Monitoring During Periods of Low Visibility*

- One PSO will monitor the shutdown zone with the mounted IR camera while the other maintains visual watch with the naked eye/binoculars.

11.3.5 *Nighttime Visual*

- Construction at the landfall site will not occur at night.

11.3.6 *Acoustic Monitoring*

- No PAM operators will be needed due to the likelihood of masking effects of the vibratory pile driving activities which will result in ineffective acoustic monitoring opportunities.

11.3.7 *Shutdown Zones*

- Mysticete whales (low-frequency cetaceans): 100 m
- Sperm whale (mid-frequency cetacean): 100 m
- Mid-frequency cetaceans except sperm whales: 50 m
- Harbor porpoise (high-frequency cetacean): 100 m
- Seals: 50 m

11.3.8 *Pre-Start Clearance*

- PSOs will monitor the shutdown zone for 30 minutes prior to the start of vibratory pile driving.
- If a marine mammal is observed entering or within the respective EZs piling cannot commence until the animal has exited the shutdown zone or time has elapsed since the last sighting (30 minutes for large whales, 15 minutes for dolphins, porpoises, and pinnipeds).

11.3.9 *Ramp up (Soft Start)*

- Ramp-up will not be initiated if the shutdown zone cannot be adequately monitored (i.e., obscured by fog, inclement weather, poor lighting conditions) for a 30-minute period

11.3.10 *Shutdowns*

- If a marine mammal is observed entering or within the respective shutdown zones after sheet pile installation has commenced, a shutdown will be implemented.
- The shutdown zone must be continually monitored by PSOs during any pauses in vibratory pile driving, activities will be delayed until the animal(s) has moved outside the shutdown zone and no marine mammals are sighted for a period of 30 minutes.

11.3.11 *Sound Measurements*

- Measurements of the installation of sheet piles using a vibratory hammer will be made during landfall construction activities.
- Measurements will provide verification of modeled ranges to the harassment threshold isopleths and provide sound measurement data collected using International Organization for Standardization (ISO)-standard methodology for comparison among projects and to inform future projects.
- A sound field verification plan will be submitted to NMFS for review and approval at least 90 days prior to planned start of pile driving.
- This will include procedures for how measurement results will be used to justify any requested changes to planned monitoring and mitigation distances, if necessary.

11.4 HRG Surveys

The following mitigation and monitoring measures for HRG surveys apply only to sound sources with operating frequencies below 180 kHz. There are no mitigation or monitoring protocols required for sources operating >180 kHz.

Additionally, shutdown, pre-start clearance, and ramp-up procedures will not be conducted during HRG survey operations using only non-impulsive sources (*e.g*., USBL and parametric sub-bottom profilers) other than non-parametric sub-bottom profilers (*e.g*., CHIRPs). Pre-clearance and ramp-up, but not shutdown, will be conducted when using non-impulsive, non-parametric sub-bottom profilers.

11.4.1 *Monitoring Equipment*

- Two pairs of reticle binoculars
- One mounted thermal/ infrared (IR) camera system during nighttime and low visibility conditions
- Two hand-held or wearable night vision devices (NVDs)
- Two IR spotlights
- One data collection software system
- Two PSO-dedicated very high frequency (VHF) radios
- One digital single-lens reflex camera equipped with a 300-mm lens

11.4.2 *Visual Monitoring*

- Four to six PSOs on all 24-hour survey vessels
- Two to three PSOs on all daylight only (~12-hour) survey vessels

- The PSOs will begin observation of the shutdown zones prior to initiation of HRG survey operations and will continue throughout the survey activity and/or while equipment operating below 200 kHz is in use.
- PSOs will monitor the NMFS NARW reporting systems including WhaleAlert and SAS once every 4-hour shift during Project-related activities.

11.4.3 *Daytime Visual Monitoring (period between nautical twilight rise and set for the region)*

- One PSO on watch during all pre-clearance periods and all source operations.
- PSOs will use reticle binoculars and the naked eye to scan the monitoring zone for marine mammals.

11.4.4 *Nighttime and Low Visibility Visual Observations*

- The lead PSO will determine if conditions warrant implementing reduced visibility protocols.
- Two PSOs on watch during all pre-clearance periods and operations.
- Each PSO will use the most appropriate available technology (e.g., IR camera and NVD) and viewing locations to monitor the shutdown zones and maintain vessel separation distances.

11.4.5 *Shutdown Zones*

- North Atlantic right whale: 500 m
- Mysticete whales (low-frequency cetaceans): 100 m
- Sperm whale, Risso's dolphin, long-finned pilot whale, and short finned pilot whale (mid-frequency cetaceans): 100 m
- Atlantic white-sided dolphin, Atlantic spotted dolphin, short beaked common dolphin, coastal bottlenose dolphin, and offshore common bottlenose dolphin (mid-frequency cetaceans): No shutdown zone
- Harbor porpoise (high-frequency cetacean): 100 m
- Seals: 100 m

11.4.6 *Pre-Start Clearance*

- Prior to the initiation of equipment ramp-up, PSOs and APSOs will conduct a 30- minute watch of the shutdown zones to monitor for marine mammals.
- The shutdown zones must be visible using the naked eye or appropriate visual technology during the entire clearance period for operations to start; if the shutdown zones are not visible, source operations <180 kHz will not commence.
- If a marine mammal is observed within its respective shutdown zone during pre-clearance period, ramp-up will not begin until the animal(s) has been observed exiting its respective shutdown zone or until an additional time period has elapsed with no further sighting (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

11.4.7 *Ramp up (Soft Start)*

- Ramp-up will not be initiated during periods of inclement conditions or if the shutdown zones cannot be adequately monitored by the PSOs, using the appropriate visual technology for a 30-minute period.

- Ramp-up will begin by powering up the smallest acoustic HRG equipment at its lowest practical power output appropriate for the survey followed by a gradual increase and addition of other acoustic sources (as able).
- If a marine mammal is detected within or about to enter its respective shutdown zone, ramp-up will be delayed.
- Ramp-up will continue once the animal has been observed exiting its respective shutdown zone or until an additional time period has elapsed with no further sighting (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

11.4.8 *Shutdowns*

- Shutdown of impulsive, non-parametric HRG survey equipment other than CHRIP sub-bottom profilers operating at frequencies <200 kHz is required if a marine mammal is sighted at or within its respective shutdown zone.
- Shutdowns will not be implemented for dolphins that voluntarily approach the survey vessel.
- Subsequent restart of the survey equipment will be initiated using the same procedure described above during pre-start clearance
- If the acoustic source is shutdown for reasons other than mitigation (e.g., mechanical difficulty) for less than 30 minutes, it will be reactivated without ramp-up if PSOs have maintained constant observation and no detections of any marine mammal have occurred within the respective shutdown zones
- If the acoustic source is shutdown for a period longer than 30 minutes or PSOs were unable to maintain constant observation, then ramp-up and pre-start clearance procedures will be initiated

11.5 MEC/UXO Disposal

For MEC/UXOs that are positively identified in proximity to planned activities on the seabed, several alternative strategies will be considered prior to detonating the MEC/UXO in place. These may include relocating the activity away from the MEC/UXO (avoidance), moving the MEC/UXO away from the activity (lift and shift), cutting the MEC/UXO open to apportion large ammunition or deactivate fused munitions, using shaped charges to reduce the net explosive yield of a MEC/UXO (low-order detonation), or using shaped charges to ignite the explosive materials and allow them to burn at a slow rate rather than detonate instantaneously (deflagration). Only after these alternatives are considered would a decision to detonate the MEC/UXO in place be made. If deflagration is conducted, mitigation and a monitoring measure would be implemented as if it was a high order detonation based on MEC/UXO size. Decision on removal method will be made in consultation with a MEC/UXO specialist and in coordination with the agencies with regulatory oversite of MEC/UXO. For detonations that cannot be avoided due to safety considerations, a number of mitigation measures will be employed by Revolution Wind. No more than a single MEC/UXO will be detonated in a 24-hour period.

11.5.1 *Monitoring Equipment*

The equipment to be used during monitoring of MEC/UXO detonations is shown in Table 53.

Table 54. Equipment use for all marine mammal monitoring vessels during pre-start clearance and post-detonation monitoring.

Item	Daytime Number on Each PSO Vessel
Reticle binoculars	2
Mounted “big-eye” binocular	1
Monitoring station for real time PAM system[1]	1
Data collection software system	1
PSO-dedicated VHF radios	2
Digital single-lens reflex camera equipped with 300-mm lens	1

PSO = protected species observer; VHF=very high frequency.

[1] The selected PAM system will transmit real time data to PAM monitoring stations on the vessels and/or a shore side monitoring station.

11.5.2 *Pre-Start Clearance*

All mitigation and monitoring zones assume the use of an NAS resulting in a 10 dB reduction of noise levels. Mitigation and monitoring zones specific to marine mammal hearing groups for the five different charge weight bins are presented in Table 54 as summarized from the propagation modeling report (Appendix B).

Table 55. Mitigation and Monitoring Zones Associated with In-Situ MEC/UXO Detonation of Binned Charge Weights, with a 10 dB Noise Mitigation System.

Marine Mammal Hearing Groups	MEC/UXO Charge Weight[1]				
	E4 (2.3 kg)	E6 (9.1 kg)	E8 (45.4 kg)	E10 (227 kg)	E12 (454 kg)
	Pre-Start Clearance Zone[2] (m)	Pre-Start Clearance Zone (m)	Pre-Start Clearance Zone (m)	Pre-Start Clearance Zone (m)	Pre-Start Clearance Zone (m)
Export Cable Route					
Low-Frequency Cetaceans	600	1,000	1,800	3,000	3,800
Mid-Frequency Cetaceans	50	80	200	400	500
High-Frequency Cetaceans	1,900	2,600	3,900	5,400	6,200
Phocid Pinnipeds	200	400	700	1,200	1,600
Lease Area					
Low-Frequency Cetaceans	400	800	1,600	3,000	3,700
Mid-Frequency Cetaceans	50	50	100	400	500
High-Frequency Cetaceans	1,800	2,600	3,900	5,400	6,200
Phocid Pinnipeds	100	200	600	1,100	1,500

kg = kilograms; m = meters

[1] MEC/UXO charge weights are groups of similar munitions defined by the U.S. Navy and binned into five categories (E4-E12) by weight (equivalent weight in TNT). For this assessment, four project sites (S1-S4) were chosen and modeled (see Hannay and Zykov 2021) for the detonation of each charge weight bin.

[2] Pre-start clearance zones were calculated by selecting the largest Level A threshold (the larger of either the PK or SEL noise metric). The chosen values were the most conservative per charge weight bin across each of the four modeled sites. A 20 percent buffer was then added to the modeled distances and zones were rounded up for PSO clarity.

- A 60-minute pre-start clearance period will be implemented prior to any in-situ MEC/UXO detonation
- The clearance zone (see distances to low-frequency cetacean thresholds in Table 54) must be fully visible for at least 60 minutes prior to commencing detonation
- All marine mammals must be confirmed to be out of the clearance zone prior to initiating detonation
- If a marine mammal is observed entering or within the relevant clearance zones prior to the initiation of detonation, the detonation must be delayed
- The detonation may commence when either the marine mammal(s) has voluntarily left the respective clearance zone and been visually confirmed beyond that clearance zone, or when 60 minutes have elapsed without redetection for whales, including the NARW, or 15 minutes have elapsed without redetection of dolphins, porpoises, and seals.

11.5.3 *Visual Monitoring*

- The number of vessels deployed will depend on monitoring zone size and safety set back distance from detonation. A sufficient number of vessels will be deployed to cover the clearance and shutdown zones 100%.
- PSOs will visually monitor the maximum Low Frequency (Large Whale) Level A zone which constitutes the pre-start clearance zone. This zone encompasses the maximum Level A exposure ranges for all marine mammal species except harbor porpoise, where Level A take has been requested due to the large zone sizes associated with High Frequency cetaceans.

11.5.3.1 Primary Vessel Measures

- Two PSOs on duty on the primary vessel
- Visual PSOs will survey the monitoring zones at least 60 minutes prior to a detonation event
- Two PSOs will maintain watch at all times during the pre-start clearance period and 60-minutes after the detonation event
- There will be a PAM operator on duty conducting acoustic monitoring in coordination with the visual PSOs during all pre-start clearance periods and post-detonation monitoring periods

11.5.3.2 Secondary Vessel Measures

- Visual monitoring will be conducted on a secondary vessel following the same methods as stated for the primary vessel in addition to the following measures when monitoring zones have radii greater than 2,000 m.
- Two PSOs on duty on the secondary vessel

- Based on the pre-start clearance zones for low-frequency cetaceans shown in Table 54, a secondary vessel will be used in the specified locations for the following MEC/UXO charge weight bins:
    - Export Cable Route:
        - Bins E10 and E12
    - Lease Area
        - Bins E10 and E12

11.5.4 *Acoustic Monitoring*

- Only 1 PAM team for all deployed PSO vessels
- PAM will be conducted in the daylight only as no MEC/UXO will be detonated during nighttime hours
- There will be a PAM operator stationed on at least one of the dedicated monitoring vessels (primary or secondary) in addition to the PSO; or located remotely/onshore
- PAM will begin 60 minutes prior to a detonation event
- PAM operator will be on duty during all pre-start clearance periods and post-detonation monitoring periods
- Acoustic monitoring will extend beyond the Large Whale Pre-Start Clearance Zone (Section 11.5.2)
- For real-time PAM systems, at least one PAM operator will be designated to monitor each system by viewing data or data products that are streamed in real-time or near real-time to a computer workstation and monitor located on a Project vessel or onshore
- PAM operator will inform the Lead PSO on duty of animal detections approaching or within applicable ranges of interest to the detonation activity via the data collection software system
- PAM devices used will include independent (e.g., autonomous or moored remote) systems

11.5.5 *Noise Attenuation*

- Revolution Wind will use an NAS for all detonation events as feasible and is committed to achieving the modeled ranges associated with 10 dB of noise attenuation (see Section 6.3.2). Zones without 10 dB attenuation would be implemented if use of a big bubble curtain was not feasible due to location, depth, or safety related constraints (unmitigated distances to thresholds are available in Appendix B). If a NAS system is not feasible, Revolution Wind will implement mitigation measures for the larger unmitigated zone sizes with deployment of vessels adequate to cover the entire clearance and exclusion zones.

11.5.6 *Seasonal Restrictions*

- No in-situ MEC/UXO detonations are planned between January and April. As part of the federal consistency review for the Project and work in Rhode Island state waters, it is expected that in-situ MEC/UXO disposal will also be subject to state specific seasonal restrictions.

11.5.7 *Post MEC/UXO Detonation Monitoring*

- Post-detonation monitoring will occur for 30 minutes

11.5.8 *Sound Measurements*

- Acoustic measurements will be made during any MEC/UXO detonations.
- Measurements will provide verification of modeled ranges to the modeled harassment threshold isopleths and provide acoustic measurement data collected using International Organization for Standardization (ISO)-standard methodology for comparison among projects and to inform future projects.
- A sound field verification plan for MEX/UXO detonation will be submitted to NMFS for review and approval at least 90 days prior to planned start of pile driving.

12 Arctic Plan of Coordination

This section of the application must be completed only for activities that occur offshore of Alaska and north of 60° N latitude. The proposed activities will take place off the US northeast coast in the Atlantic Ocean and, therefore, will not have an adverse effect on the availability of marine mammals for subsistence uses.

13 Monitoring and Reporting

Marine mammal monitoring efforts around Project activities are currently summarized in Section 11 and will be updated in the PSMMP (Appendix C).

As required in Lease OCS-A-0486, Revolution Wind will comply with the marine mammal reporting requirements for construction activities summarized below.

Reporting Injured or Dead Marine Mammals. Revolution Wind will ensure that sightings of any injured or dead protected species are reported to the Greater Atlantic (Northeast) Region Marine Mammal and Sea Turtle Stranding and Entanglement Hotline (866-755-NOAA [6622] or current) within 24 hours of sighting, regardless of whether the injury or death is caused by a Project vessel. In addition, if the injury or death was caused by a collision with a Project vessel, Revolution Wind will ensure that NMFS is notified of the strike within 24-hours. The notification of such strike will include the date and location (latitude/longitude) of the strike, the name of the vessel involved, and the species identification or a description of the animal, if possible. If a Project activity is responsible for the injury or death, Revolution Wind will supply a vessel to assist in any salvage effort as requested by NMFS.

Report of Activities and Observations. Revolution Wind will provide NMFS with a report within 90 calendar days following the completion of construction activities, including a summary of the construction activities and an estimate of the number of marine mammals taken during these activities.

Report Information. Data on all protected-species observations will be recorded using accepted standards of marine mammal data collection by PSOs. The information will include dates, times, and locations of survey operations; time of operation; location and weather; details of marine mammal sightings (e.g., species, numbers, behavior); and details of any observed take (e.g., behavioral disturbances or injury/mortality).

14 Suggested Means of Coordination

To minimize the likelihood that impacts will occur to species, stocks, and subsistence use of marine mammals, all Project activities will be conducted in accordance with federal, state, and local regulations. To further minimize potential impacts from the planned Project, Orsted will continue to cooperate with NMFS and other appropriate federal agencies (e.g., BOEM, USFWS), and the State of Rhode Island.

While no direct research on marine mammals or marine mammal stocks is expected from the Project, there is the opportunity for the proposed activity to contribute greatly to the noise characterization in the region and to specific sound source measurements.

Data acquired during the Visual and Acoustic Monitoring Program may provide valuable information to direct or refine future research on marine mammal species present in the area. Sighting data (e.g., date, time, weather conditions, species identification, approximate sighting distance, direction, heading in relation to sound sources, behavioral observations) may be useful in designing the location and scope of future marine mammal survey and monitoring programs.

All marine mammal data collected by Revolution Wind during marine construction activities will be provided to NMFS, BOEM, and other interested government agencies. In addition, the data, upon request, will be made available to educational institutions and environmental groups.

The PSMMP also provides a framework for long-term ecological monitoring as part of Revolution Wind development and operations.

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NMFS. 2021g. Gray seal (*Halichoerus grypus atlantica*) overview.

NMFS. 2021h. Harbor seal (*Phoca vitulina*) overview.

NMFS. 2021i. Humpback whale (*Megaptera novaeangliae*) overview.

NMFS. 2021j. Long-finned pilot whale (*Globicephala melas*) overview.

NMFS. 2021k. Minke whale (*Balaenoptera acutorostrata*) overview.

NMFS. 2021l. North Atlantic right whale (*Eubalaena glacialis*) overview.

NMFS. 2021m. Risso's dolphin (*Grampus griseus*) overview.

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Appendix A – WTG and OSS Monopile Foundation Installation Sound Exposure Modeling Report

Appendix B – Underwater Acoustic Modeling of Detonations of Unexploded Ordnance (UXO)

Appendix C – Protected Species Monitoring and Mitigation Plan

Underwater Acoustic Analysis and Exposure Modeling

Revolution Wind: Impact Pile Driving during Foundation Installation

JASCO Applied Sciences (USA) Inc.

12 November 2021

Submitted to:

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The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Executive Summary

Revolution Wind, LLC (Revolution Wind), a 50/50 joint venture between Ørsted North America Inc. (Ørsted NA) and Eversource Investment LLC (Eversource), proposes to construct, own, and operate the Revolution Wind Farm (RWF) in the designated Bureau of Ocean Energy Management (BOEM) Renewable Energy Lease Area OCS-A 0486. RWF includes up to 100 foundations consisting of wind turbine generators (WTG) and two offshore substations (OSS), as well as inter-array cables (IAC) connecting the WTG and OSS. The WTG will each be supported by a tapered monopile foundation that is 7 m on top and 12 m diameter at the mudline, while the OSS will be supported by a tapered 7 m (top) to 15 m (mudline) monopile foundation.

Underwater noise associated with the construction of the RWF will predominantly result from the impact pile driving of the monopile foundations. A quantitative assessment of the sounds produced by the impact pile driving of the monopile foundations was undertaken in this study. Other sources of sound, such as dynamic positioning (DP) vessel thrusters used during cable installation and vessel propulsion during transit, were considered here as a qualitative assessment.

WTG monopile foundations consisting of a single pile, tapered from 7 to 12 m in diameter, were modeled at two representative locations in the lease area. Forcing functions for impact pile driving were computed for each pile type using GRLWEAP (GRLWEAP, Pile Dynamics 2010). The resulting forcing functions were used as inputs to JASCO's impact pile driving source model to characterize the sounds generated by the piles. Acoustic sound fields were estimated using JASCO's Marine Operations Noise model (MONM) and Full Wave Range Dependent Acoustic Model (FWRAM). To account for the likely minimum sound reduction resulting from noise abatement systems (NAS) such as bubble curtains, the modeling study included hypothetical broadband attenuation levels of 0, 6, 10, and 15 dB for all impact pile driving acoustic modeling results. Based on a recent analysis of NAS (Bellmann et al. 2020b), the 10 dB level was conservatively chosen as an achievable sound reduction level when one NAS is in use during pile driving, and is highlighted in this analysis.

The goal of the study was to determine the number of individual animals that may be impacted and the associated monitoring distances (exposure and acoustic ranges) for mitigation purposes. JASCO's animal movement modeling software, JASMINE, was used to integrate the computed sound fields with species-typical movement (e.g., dive patterns) to estimate received sound levels for the modeled marine mammals and sea turtles that may occur near the construction area. Using the time history of the received levels, exposure estimates and exposure ranges accounting for 95% of exposures above regulatory-defined injury and behavioral disruption thresholds (NMFS 2018, McCauley et al. 2000b, Finneran et al. 2017) were calculated. Fish were considered static receivers, so the acoustic distance to their regulatory thresholds (FHWG Andersson et al. 2007, Wysocki et al. 2007, 2008, Stadler and Woodbury 2009, Mueller-Blenkle et al. 2010, Purser and Radford 2011) were calculated. Exposure ranges (marine mammals) and acoustic ranges (fish) are reported for various levels (0, 6, 10, and 15) of broadband attenuation that could be expected from the use of mitigation systems such as a bubble curtain.

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1. Introduction

1.1. Project Background and Overview of Assessed Activity

Revolution Wind, LLC (Revolution Wind), a 50/50 joint venture between Ørsted North America Inc. (Ørsted NA) and Eversource Investment LLC (Eversource), proposes to construct, own, and operate the Revolution Wind Farm in the designated Bureau of Ocean Energy Management (BOEM) Renewable Energy Lease Area OCS-A 0486 (Lease Area, Figure 1). The Revolution Wind Offshore Windfarm Project (RWF) consists of wind turbine generators (WTGs), offshore substations (OSSs), inter-array cables (IAC), and export cables (ECs). The ECs will connect from the OSSs to landfall in Connecticut and Rhode Island.

Underwater noise may be generated by several activities associated with the Project. Impacts of noise on marine fauna for most of these anthropogenic sound sources is expected to be low or very low. Only pile driving for the installation of WTGs and OSS foundations could be expected to have greater impacts. A quantitative assessment of pile driving activities is undertaken here as the primary source of noise associated with the Project. A qualitative assessment of secondary sound sources associated with other construction and operational activities that contribute non-impulsive (aircraft, dredging, drilling, dynamic positioning [DP] thrusters) and continuous (vessel propulsion, turbine operation) sound to the environment can be found in Appendix C.

For the quantitative acoustic analysis, the potential underwater acoustic impacts resulting from the installation of tapered monopile foundations were modeled. The WTGs will be supported by tapered monopiles which have a diameter of 7 meters (m) (23 feet (ft)) at the waterline and 12 m (39 ft) at the mudline. OSSs will be supported by a monopile foundation. OSS monopiles are tapered, with diameter ranging from 7 m at the waterline to 15 m at the mudline. This underwater noise assessment considers that the currently available information; the precise locations, noise sources, and schedule of the construction and operation scenarios is subject to change as the engineering design progresses.

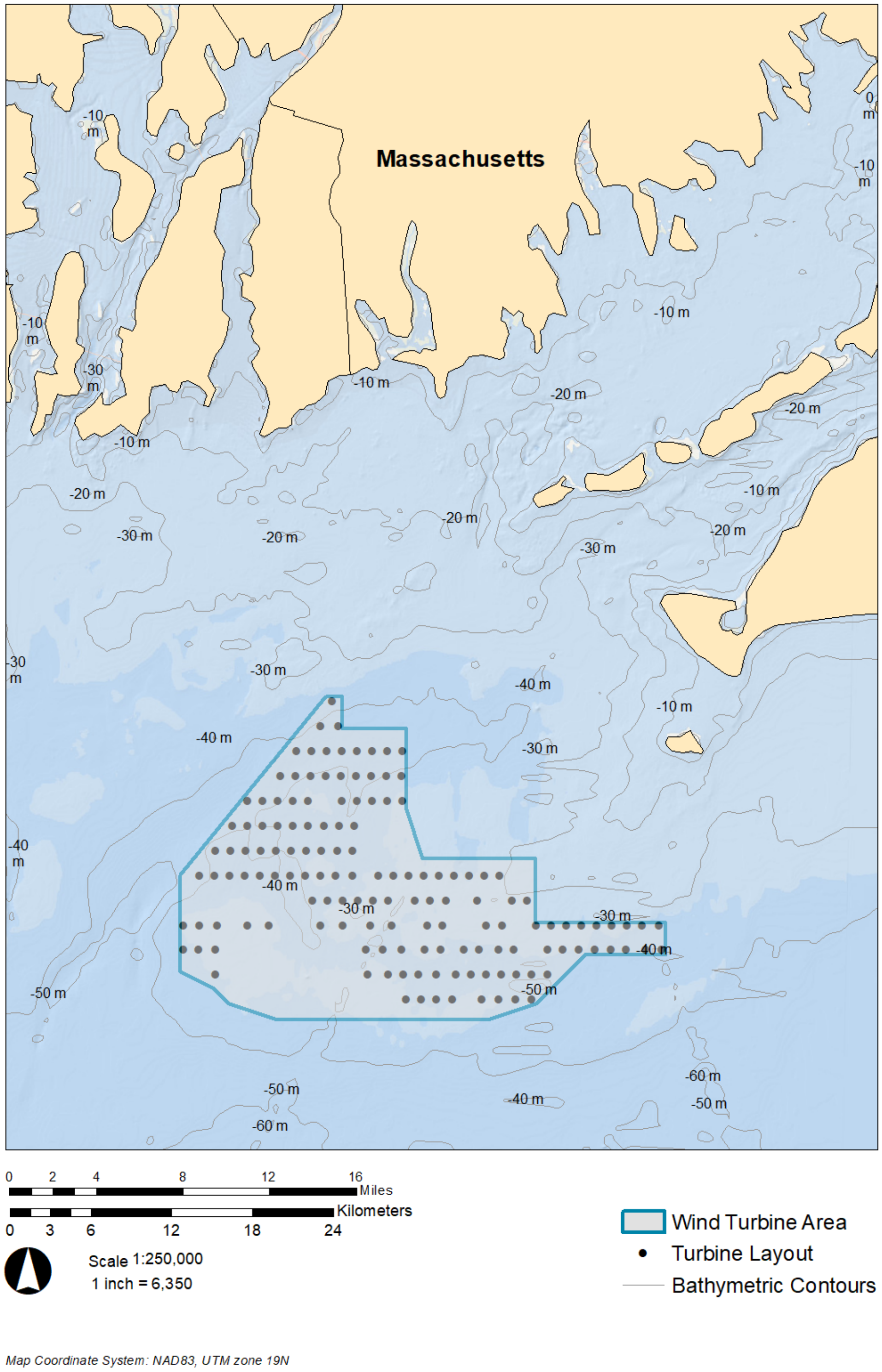

Figure 1. Revolution Wind Offshore Wind Farm Project (RWF).

1.2. Modeling Scope and Assumptions

The objective of the quantitative underwater noise assessment was to determine exposure estimates and exposure ranges from impact pile driving for marine mammals and sea turtle species that occur near the RWF. Exposure ranges and exposure estimates for animals exceeding regulatory acoustic thresholds for injury and behavioral disruption are predicted using animal movement modeling. For fish, acoustic ranges to their regulatory thresholds predicting injury and behavioral disturbance were calculated.

1.2.1. Foundations

A monopile used as a foundation in a wind farm is a single hollow cylinder fabricated from steel that is installed by driving (hammering) it into the seabed. Tapered 7/12 m monopiles (7 m top diameter, 12 m bottom diameter, with a tapered section near the water line) are proposed as the WTG foundations within the project development envelope (PDE). The proposed OSS monopile foundations are single, 7/15 m diameter tapered piles (7 m top diameter, 15 m bottom diameter, and a tapered section near the waterline). Nominal dimensions of the monopiles are shown in Appendix B.

The amount of sound generated during pile driving varies with the energy required to drive piles to the desired depth and depends on the sediment resistance encountered. Sediment types with greater resistance require hammers that deliver higher energy strikes and/or an increased number of strikes relative to installations in softer sediment. Maximum sound levels usually occur during the last stage of impact pile driving, where the greatest resistance is encountered (Betke 2008). The make and model of impact hammer (IHC S-4000 and IHC S-2300) and the representative hammering schedule used in the acoustic modeling effort were provided by Revolution Wind in coordination with potential hammer suppliers. The number of strikes at each hammer energy level needed to drive piles for the foundations can be found in Tables 1 and 2.

Sound fields from 7/12 m WTG monopiles were modeled at two locations: L024-002 in the northwest section of the RWF area and L024-114 in the southeast (L024_002 and L024_114 in Table 3 and Figure 2). The OSS monopile foundations were modeled at three proposed installation locations within the RWF area (OSS1, OSS2, and OSS3 in Table 3 and Figure 2). All piles were assumed to be vertical and driven to a maximum expected penetration depth of 50 m (130 ft) for the 7/12 WTGs monopiles the OSS monopiles. For exposure analysis, it was assumed that 1, 2, or 3 WTG monopiles may be driven in a day, and 1 or 2 OSS monopiles may be driven per day.

Key modeling assumptions for WTG and OSS foundation types are listed in Table 4. Additional modeling details and input parameters are provided in Appendix B.

Table 1. Hammer energy schedule for 7 to 12 m WTG monopile installation. Total strike count is 10,740 and total penetration depth is 50 m.

Energy level (kilojoule [kJ])	Strike count	Pile penetration (m)	Modeled strike rate (min^{-1})
1,000	1,705	0-6	50
2,000	3,590	6-24	
3,000	2,384	24-36	
4,000	3,061	36-50	

Table 2. Hammer energy schedule for 7 to 15 m OSS monopile installation. Total strike count is 11,564 and total penetration depth is 50 m.

Energy level (kilojoule [kJ])	Strike count	Pile penetration (m)	Modeled strike rate (min^{-1})
1,000	954	0-5	50
2,000	2,944	5-17	
3,000	4,899	17-36	
4,000	2,766	36-50	

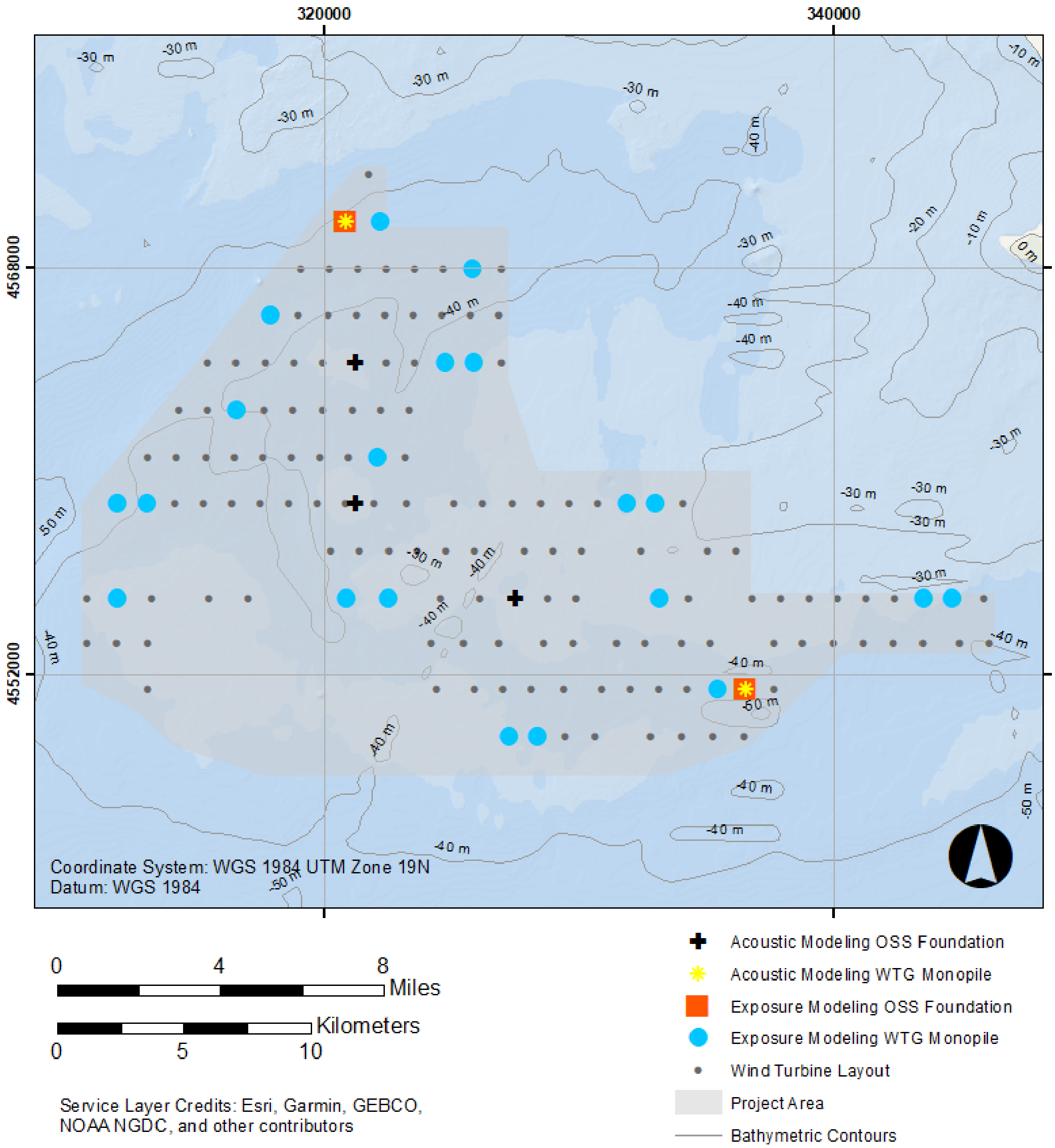

Figure 2. RWF monopile foundation locations with acoustic propagation and animal movement modeling locations.

Table 3. Locations for acoustic modeling of WTG and OSS foundations.

Model site	Location (UTM Zone 19N)		Water depth (m)	Sources	Source type
	Easting	Northing			
L024-002	320793.48	4569669.5	41.3	Monopile	Impulsive
L024-114	336403.93	4551413.2	36.8		
OSS 1	327480.00	4554999.69	34.2	Monopile Foundations	Impulsive
OSS 2	321190.00	4564259.69	34.4		
OSS 3	321190.00	4558703.00	33.7		

Table 4. Key piling assumptions used in underwater acoustic modeling.

Foundation type	Modeled maximum impact hammer energy (kJ)	Pile length	Pile diameter	Pile wall thickness (mm)	Seabed penetration (m)	Number of piles per day
WTG Monopile	4000	110 m	7/12 m	160	40	1, 2, 3
OSS Monopile	4000	120 m	7/15 m	200	50	1, 2

1.2.2. Modeling Scenario and Pile Construction Schedules

Construction schedules cannot be fully predicted because of environmental factors like weather and because of installation variation such as drivability. To estimate the number of animals likely to be exposed above the regulatory thresholds a conservative construction schedule that maximizes activity during the highest density months for each species was assumed – 90 WTG monopiles (3 per day for 30 days) are assumed installed in the highest density month of each species (see Sections 3.1 and 3.2 for details on animal density estimates) and 10 WTG monopiles (3 per day for 3 days and 1 per day for 1 day) are assumed installed during the month with the second highest density. The two OSS monopile foundations (1 per day for 2 days) are assumed installed during the second highest density month. Construction schedule assumptions are summarized in Table 5.

Table 5. Construction schedule assumptions for WTG and OSS foundations. Dashes indicate no piling days.

Foundation type	Configuration	Days of piling	
		Highest density month	2nd highest density month
WTG	Monopile, 3 per day	30	3
WTG	Monopile, 1 per day	-	1
OSS	Monopile, 1 per day		2

2. Methods

The basic modeling approach is to characterize the sound produced by the source, determine how the sound propagates within the surrounding water column, and then estimate species-specific exposure probabilities by combing the computed sound fields with animal movement in simulated representative scenarios.

For impact pile driving sounds, time-domain representations of the acoustic pressure waves generated in the water are required for calculating sound pressure level (SPL), sound exposure level (SEL), and peak pressure level (PK). The source signatures associated with the installation of each of the modeled 7/12 m and 7/15 m monopile locations are predicted using a finite-difference model that calculates the physical vibration of the pile caused by the pile driving equipment. The sound field radiating from the pile is computed using a vertical array of point sources.

For this study, synthetic pressure waveforms were computed using a Full-Waveform Range-dependent Acoustic Model (FWRAM), which is JASCO's acoustic propagation model capable of producing time-domain waveforms. The sound propagation modeling incorporated site-specific environmental data including bathymetry, sound speed in the water column, and seabed geoacoustics in the proposed construction area. Animal movement modeling integrated the estimated sound fields with species-typical behavioral parameters (e.g., dive patterns) to estimate received sound levels for the modeled animals (animats) that may occur in the construction area. Animats that exceed pre-defined acoustic thresholds (e.g., NMFS 2018) are identified and the distance for the exceedances determined. The number of animals expected to exceed the regulatory thresholds is determined by scaling the probability of exposure by the species-specific density of animals in the area.

2.1. Acoustic Environment

The proposed RWF is located in a continental shelf environment characterized by predominantly sandy seabed sediments. Water depths in the construction area vary between 30-45 m. From May through October, the average temperature of the upper (10–15 m) water column is higher than deeper layers, leading to an increased surface layer sound speed. This situation creates a downward-refracting environment in which propagating sound interacts with the seafloor more than in a well-mixed environment. Increased wind mixing, combined with a decrease in solar energy in during winter from December through March, results in a sound speed profile that is more uniform as a function of depth. Separate acoustic propagation model runs were conducted for both average summer and average winter sound speed profiles. See Appendix G.1 for more details on the environmental parameters used in acoustic propagation and exposure modeling.

2.2. Modeling Acoustic Sources

2.2.1. Impact Pile Driving

Piles deform when driven with impact hammers, creating a bulge that travels down the pile and radiates sound into the surrounding air, water, and seabed. This sound may be received as a direct transmission from the sound source to biological receivers (such as marine mammals, sea turtles, and fish) through the water, or as the result of reflected paths from the surface or re-radiated into the water from the seabed (Figure 3). Sound transmission depends on many environmental parameters, such as the sound speeds in water and substrates. It also depends on the sound production parameters of the pile and how it is driven, including the pile material, size (length, diameter, and thickness), and the make and energy of the hammer.

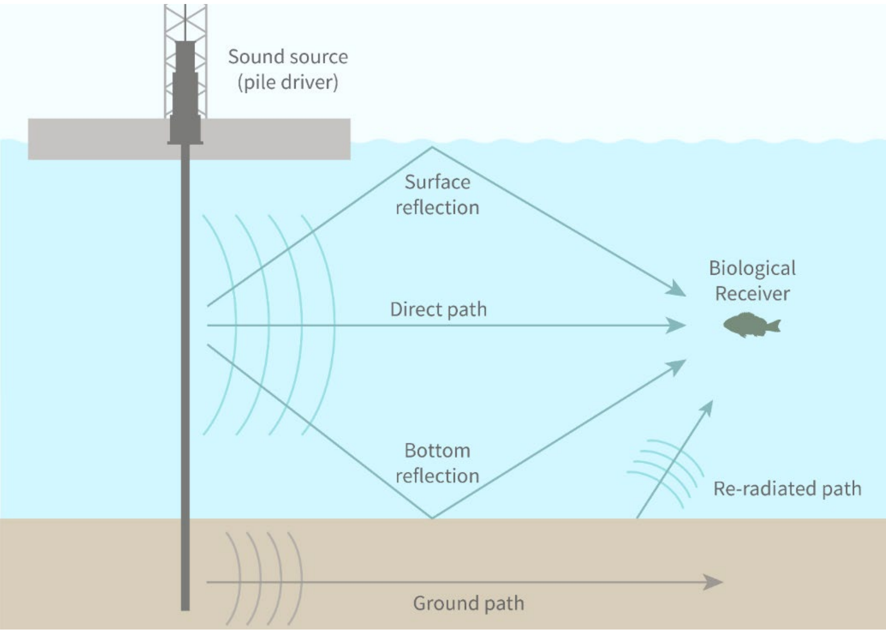

Figure 3. Sound propagation paths associated with impact pile driving (adapted from Buehler et al. 2015).

JASCO’s physical model of pile vibration and near-field sound radiation (MacGillivray 2014) was used in conjunction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010) to predict sound levels associated with impact pile driving activities. Piles are modeled as a vertical installation using a finite-difference structural model of pile vibration based on thin-shell theory. The sound radiating from the pile itself was simulated using a vertical array of discrete point sources. These models account for several parameters that describe the operation—pile type, material, size, and length—, the pile driving equipment, and approximate pile penetration depth. See Appendix F for a more detailed description.

Forcing functions were computed for the 7/12 m and 7/15 m monopile using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010). The model assumed direct contact between the representative hammers, helmets, and piles (i.e., no cushion material). The forcing functions serve as the inputs for the pile driving source model (PDSM) used to estimate equivalent acoustic source characteristics detailed in Appendix F. Decidecade spectral source levels for each pile type, hammer energy, and modeled location, using an average summer sound speed profile provided in Appendix G. Additionally, to ensure a conservative impact estimate for the 7/15 m OSS monopiles, a 2 dB factor was added to their source levels.

Acoustic propagation modeling used JASCO's Marine Operations Noise Model (MONM) and FWRAM that combine the outputs of the source model with the spatial and temporal environmental context (e.g., location, oceanographic conditions, and seabed type) to estimate sound fields. The lower frequency bands were modeled using MONM and FWRAM, which are based on the parabolic equation method of acoustic propagation modeling. For higher frequencies, additional losses resulting from absorption were added to the propagation loss model. See Appendix D for a more detailed description.

2.3. Noise Mitigation

Noise abatement systems (NASs) are often used to decrease the sound levels in the water near a source by inserting a local impedance change that acts as a barrier to sound transmission. A variety of technologies can achieve attenuation by impedance change, including bubble curtains, evacuated sleeve systems (e.g., IHC-Noise Mitigation System (NMS)), encapsulated bubble systems (e.g., HydroSound Dampers (HSD)), and Helmholtz resonators (AdBm NMS). The effectiveness of each system is frequency-dependent and may be influenced by local environmental conditions such as current and depth. For example, the size of the bubbles determines the effective frequency band of an air bubble curtain, with larger bubbles needed for lower frequencies.

Small bubble curtains (bubble curtains positioned within a small radius around the pile) have been measured to reduce sound levels from ~10 dB to more than 20 dB but are highly dependent on water depth, current, and how the curtain is configured and operated (Koschinski and Lüdemann 2013, Bellmann 2014, Austin and Li 2016). Larger bubble curtains tend to perform better and more reliably, particularly when deployed with two rings (Koschinski and Lüdemann 2013, Bellmann 2014, Nehls et al. 2016). A California Department of Transportation (CalTrans) study tested several small, single, bubble-curtain systems and found that the best attenuation systems resulted in 10–15 dB of attenuation. Buehler et al. (2015) concluded that attenuation greater than 10 dB could not be reliably predicted from small, single, bubble curtains because sound transmitted through the seabed and re-radiated into the water column is the dominant source of sound in the water for bubble curtains deployed immediately around (10 m [32 ft]) the pile (Buehler et al. 2015).

A recent analysis by Bellmann et al. (2020a) of NASs performance measured during impact driving for wind farm foundation installation provides expected performance for common NASs configurations. Measurements with a single bubble curtain and an air supply of 0.3 m^3/min resulted in 7 to 11 dB of broadband attenuation for optimized systems in up to 131 ft (40 m) water depth. Increased air flow (0.5 m^3/min) may improve the attenuation levels up to 11 to 13 dB (M. Bellmann, personal communication, 2019). Double bubble curtains add another local impedance change and, for optimized systems, can achieve 15 to 16 dB of broadband attenuation (measured in up to 131.25 ft [40 m] water depth). The IHC-NMS can provide 15 to 17 dB of attenuation but is currently limited to piles <8 m diameter. Other NASs such as the AdBm NMS achieved 6 to 8 dB (M. Bellmann, personal communication, 2019), but HSDs were measured at 10 to 12 dB attenuation and are independent of depth (Bellmann et al. 2020a). Systems may be deployed in series to achieve higher levels of attenuation.

The NAS must be chosen, tailored, and optimized for site-specific conditions. NAS performance of 10 dB broadband attenuation was chosen for this study as an achievable reduction of sound levels produced during pile driving when one NAS is in use, noting that a 10 dB decrease means the sound energy level is reduced by 90%. For exposure modeling, several levels of attenuation were included for comparison purposes.

2.4. Acoustic Criteria for Marine Fauna

The acoustic criteria used for this study were derived from the current US regulatory acoustic criteria and are summarized below (further details on these criteria are in Sections 2.4.1 and 2.4.2):

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24\text{h}}$) were derived from the US National Oceanic and Atmospheric Administration (NOAA) Technical Guidance (NMFS 2018) for marine mammal injury thresholds.
2. Sound pressure level (SPL; L_{p}) for marine mammal behavioral thresholds were based on the unweighted NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria.
3. Injury thresholds (PK and SEL) for fish were derived from the Fisheries Hydroacoustic Working Group (FHWG 2008) and Stadler and Woodbury (2009) for fish that are equal, greater than, or less than 2 g.
4. Injury thresholds (PK and SEL) for fish were obtained from Popper et al. (2014) for fish without swim bladders, fish with swim bladders not involved in hearing, and fish with swim bladders involved in hearing.
5. Behavioral thresholds for fish were developed by the NOAA Fisheries Greater Atlantic Regional Fisheries Office (GARFO) (Andersson et al. 2007, Wysocki et al. 2007, Mueller-Blenkle et al. 2010, Purser and Radford 2011)
6. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24\text{h}}$) from Finneran et al. (2017) were used for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in sea turtles.
7. Behavioral response thresholds for sea turtles were obtained from McCauley et al. (2000b).

2.4.1. Acoustic Criteria-Marine Mammals

The Marine Mammal Protection Act (MMPA) prohibits the take of marine mammals. The term “take” is defined as: to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal. MMPA regulations define harassment in two categories relevant to the Project construction and operations. These are:

- **Level A**: Any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild, and
- **Level B**: Any act of pursuit, torment or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing a disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild (16 U.S.C. 1362).

To assess the potential impacts of the underwater sound in the RWF, it is first necessary to establish the acoustic exposure criteria used by United States regulators to estimate marine mammal takes. In 2016, National Oceanographic and Atmospheric Administration (NOAA) Fisheries issued a Technical Guidance document that provides acoustic thresholds for onset of PTS in marine mammal hearing for most sound sources, which was updated in 2018 (NMFS 2016, 2018). The Technical Guidance document also recognizes two main types of sound sources: impulsive and non-impulsive. Non-impulsive sources are further broken down into continuous or intermittent categories.

NMFS also provided guidance on the use of weighting functions when applying Level A harassment criteria. The Guidance recommends the use of a dual criterion for assessing Level A exposures, including a PK (unweighted/flat) sound level metric and a cumulative SEL metric with frequency weighting. Both acoustic criteria and weighting function application are divided into functional hearing groups (low-, mid-, and high-frequency and phocid pinnipeds) that species are assigned to based on their respective hearing distances. The acoustic analysis applies the most recent sound exposure criteria utilized by NMFS to estimate acoustic harassment (NMFS 2018).

Based on observations of mysticetes (Malme et al. 1983, 1984, Richardson et al. 1986, 1990b), sound levels thought to elicit disruptive behavioral response are described using the SPL metric (NMFS and NOAA 2005). NOAA Fisheries (NMFS) currently uses a behavioral response threshold of 160 dB re 1 µPa for marine mammals exposed to impulsive sounds, with the modification that 120 dB re 1 µPa be used for migrating mysticetes (NOAA 2005). 120 dB re 1 µPa is used for all marine mammals exposed to non-impulsive sounds (NMFS 2018). Alternative thresholds used in acoustic assessments include a graded probability of response approach and take into account the frequency-dependence of animal hearing sensitivity (Wood et al. 2012). The 160 dB threshold is used in this assessment as per NOAA guidance (2019).

The publication of ISO 18405 Underwater Acoustics–Terminology (ISO 2017) provided a dictionary of underwater bioacoustics (the previous standard was [ANSI] American National Standards Institute and [ASA] Acoustical Society of America S1.1-2013). In the remainder of this report, we follow the definitions and conventions of ISO (2017) except where stated otherwise (Table 6).

Table 6. Summary of relevant acoustic terminology used by US regulators and in the modeling report.

Metric	NMFS (2018)	ISO (2017)	
		Main text	Equations/tables
Sound pressure level	n/a	SPL	L_p
Peak pressure level	PK	PK	L_{pk}
Cumulative sound exposure level	SELcum[a]	SEL	L_E

[a] The SEL_{cum} metric used by NOAA Fisheries (NMFS) describes the sound energy received by a receptor over a period of 24 h. Accordingly, following the ISO standard, this will be denoted as SEL in this report, except for in tables and equations where L_E will be used.

2.4.1.1. Marine Mammal Hearing Groups

Current data and predictions show that marine mammal species differ in their hearing capabilities, in absolute hearing sensitivity as well as frequency band (Richardson et al. 1995, Wartzok and Ketten 1999, Southall et al. 2007, Au and Hastings 2008). While hearing measurements are available for a small number of species based on captive animal studies, there are no direct measurements of many odontocetes or any mysticetes. As a result, hearing distances for many odontocetes are grouped with similar species, and predictions for mysticetes are based on other methods including anatomical studies and modeling (Houser et al. 2001, Parks et al. 2007, Tubelli et al. 2012, Cranford and Krysl 2015); vocalizations (see reviews in Richardson et al. 1995, Wartzok and Ketten 1999, Au and Hastings 2008); taxonomy; and behavioral responses to sound (Dahlheim and Ljungblad 1990, see review in Reichmuth et al. 2007). In 2007, Southall et al. proposed that marine mammals be divided into hearing groups. This division was updated in 2016 and 2018 by NOAA Fisheries using more recent best available science (Table 7).

Southall et al. (2019) published an updated set of Level A sound exposure criteria (including the onset of temporary threshold shift [TTS] and permanent threshold shift [PTS] in marine mammals). While the authors propose a new nomenclature and classification for the marine mammal functional hearing groups, the proposed thresholds and weighting functions do not differ in effect from those proposed by NOAA Fisheries (2018). The new hearing groups proposed by Southall et al. (2019) have not yet been adopted by NOAA. The NOAA Fisheries (NMFS 2018) hearing groups presented in Table 7 are used in this analysis.

Table 7. Marine mammal hearing groups (Sills et al. 2014, NMFS 2018).

Faunal group	Generalized hearing range[a]
Low-frequency (LF) cetaceans (mysticetes or baleen whales)	7 Hz to 35 kHz
Mid-frequency (MF) cetaceans (odontocetes: delphinids, beaked whales)	150 Hz to 160 kHz
High-frequency (HF) cetaceans (other odontocetes)	275 Hz to 160 kHz
Phocid pinnipeds in water (PPW)	50 Hz to 86 kHz
Phocid pinnipeds in air (PPA)[b]	50 Hz to 36 kHz

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

[b] Sound from piling will not reach NOAA Fisheries thresholds for behavioral disturbance of seals in air (90 dB [rms] re 20 µPa for harbor seals and 100 dB [rms] re 20 µPa for all other seal species) at the closest land-based sites where seals may spend time out of the water. Thus in-air hearing is not considered further.

2.4.1.2. Marine Mammal Auditory Weighting Functions

The potential for anthropogenic sound to impact marine mammals is largely dependent on whether the sound occurs at frequencies that an animal can hear well, unless the sound pressure level is so high that it can cause physical tissue damage regardless of frequency. Auditory (frequency) weighting functions reflect an animal's ability to hear a sound (Nedwell and Turnpenny 1998, Nedwell et al. 2007). Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS thresholds expressed in metrics that consider what is known about marine mammal hearing (e.g., SEL) (Southall et al. 2007, Erbe et al. 2016a, Finneran 2016). Marine mammal auditory weighting functions for all hearing groups (Table 7) published by Finneran (2016) are included in the NMFS (2018) Technical Guidance for use in conjunction with corresponding permanent threshold shift (PTS [Level A]) onset acoustic criteria (Table 8). (See Appendix E for a detailed description of the weighting functions.)

The application of marine mammal auditory weighting functions emphasizes the importance of taking measurements and characterizing sound sources in terms of their overlap with biologically important frequencies (e.g., frequencies used for environmental awareness, communication, and the detection of predators or prey), and not only the frequencies that are relevant to achieving the objectives of the sound producing activity (i.e., context of sound source; NMFS 2018).

2.4.1.3. Marine Mammal Auditory Injury Exposure Criteria

Injury to the hearing apparatus of a marine mammal may result from a fatiguing stimulus measured in terms of SEL, which considers the sound level and duration of the exposure signal. Intense sounds may also damage hearing independent of duration, so an additional metric of peak pressure (PK) is used to assess acoustic exposure injury risk. A PTS in hearing may be considered injurious, but there are no published data on the sound levels that cause PTS in marine mammals. There are data that indicate the received sound levels at which temporary threshold shift, TTS, occurs, and PTS onset may be extrapolated from TTS onset level and an assumed growth function (Southall et al. 2007). The NMFS (2018) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy accumulated over 24 h (SEL), or very loud, instantaneous peak sound pressure levels. These dual threshold criteria of SEL and PK are used to calculate marine mammal exposures (Table 8). If a non-impulsive sound has the potential to exceed the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

Table 8. Summary of relevant permanent threshold shift (PTS) onset acoustic thresholds for marine mammal hearing groups (NMFS 2018).

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

[a] Dual metric acoustic threshold for impulsive sounds: The largest range of the two criteria is used for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds have also been considered.

2.4.1.4. Marine Mammal Behavioral Response Exposure Criteria

Numerous studies on marine mammal behavioral responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioral reactions. It is recognized that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison et al. 2012). Due to the complexity and variability of marine mammal behavioral responses to acoustic exposure, NOAA has not yet released technical guidance for determining potential behavioral responses of marine mammals exposed to sounds (NMFS 2018). NOAA's National Marine Fisheries Service (NMFS) currently uses a step function to assess behavioral impact (NOAA 2005). The step function sets an SPL of 160 dB re 1 µPa as the behavioral disruption threshold based on the 50% response rate of collated responses in the HESS (1999) report. An SPL of 120 dB re 1 µPa was set as the behavioral disruption threshold for migrating mysticetes (NOAA 2005), which was based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1983, 1984). The HESS team recognized that behavioral responses to sound may occur at lower levels, but substantial responses were only likely to occur above an SPL of 140 dB re 1 µPa.

An extensive review of behavioral responses to sound was undertaken by Southall et al. (2007, their Appendix B). Southall et al. (2007) found varying responses for most marine mammals between an SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions. In 2012, Wood et al. proposed a graded probability of response for impulsive sounds using a frequency weighted SPL metric. Wood et al. (2012)

also designated behavioral response categories for sensitive species (including harbor porpoises and beaked whales) and for migrating mysticetes. For this analysis, both the unweighted NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria are used to estimate Level B exposures to impulsive pile-driving sounds (Table 9).

Table 9. Acoustic sound pressure level (SPL) thresholds used to evaluate potential behavioral impacts to marine mammals. Probabilities are not additive

Marine mammal group	Frequency weighted probabilistic response (L_p; dB re 1 µPa)				Unweighted probabilistic response
	>120	>140	>160	>180	160
Beaked whales and harbor porpoises	50%	90%			100%
Migrating mysticete whales	10%	50%	90%		
All other species		10%	50%	90%	

[a] Wood et al. (2012)
[b] NOAA (2005)

2.4.2. Acoustic Criteria for Fish and Sea Turtles

In a cooperative effort between Federal and State transportation and resource agencies, interim criteria were developed to assess the potential for injury to fish exposed to pile driving sounds (Stadler and Woodbury 2009) and described by the Fisheries Hydroacoustic Working Group (FHWG 2008). Injury and behavioral response thresholds were based on past literature that was compiled and listed in the NOAA Fisheries Greater Atlantic Regional Fisheries Office acoustics tool (GARFO 2020) for assessing the potential effects to Endangered Species Act (ESA) listed animals exposed to elevated levels of underwater sound from pile driving. Dual acoustic thresholds for physiological injury included in the tool are 206 dB re 1 µPa PK and either 187 dB re 1 µPa^2·s SEL (>2 grams [g] fish weight) or 183 dB SEL (<2 g fish weight) (FHWG 2008, Stadler and Woodbury 2009) (Table 10). The behavioral threshold for fish is ≥150 dB SPL (Andersson et al. 2007, Wysocki et al. 2007, Mueller-Blenkle et al. 2010, Purser and Radford 2011).

A technical report by an American National Standards Institute (ANSI) registered committee (Popper et al. 2014) reviewed available data and suggested metrics and methods for estimating acoustic impacts for fish. Their report includes thresholds for potential injury but does not define sound levels that may result in behavioral response, though it does indicate a high likelihood of response near impact pile driving (tens of meters), a moderate response at intermediate distances (hundreds of meters), and a low response far (thousands of meters) from the pile (Popper et al. 2014).

Injury, impairment, and behavioral thresholds for sea turtles were developed for use by the US Navy (Finneran et al. 2017) based on exposure studies (e.g., McCauley et al. 2000b). Dual criteria (PK and SEL) have been suggested for PTS and TTS, along with auditory weighting functions published by Finneran et al. (2017) used in conjunction with SEL thresholds for PTS and TTS . The behavioral threshold recommended in the GARFO acoustic tool (GARFO 2020) is an SPL of 175 dB re 1 µPa (McCauley et al. 2000b, Finneran et al. 2017) (Table 10).

Table 10. Acoustic metrics and thresholds for fish and sea turtles currently used by NMFS GARFO and Bureau of Ocean Energy Management (BOEM) for impulsive pile driving.

Faunal group	Injury		Impairment		Behavior
	PTS		TTS		
	L_{pk}	$L_{E,\ 24hr}$	L_{pk}	$L_{E,\ 24hr}$	L_p
Fish equal to or greater than 2 g[a,b]	206	187	-	-	150
Fish less than 2 g[a,b]		183	-	-	
Fish without swim bladder[c]	213	216	-	-	-
Fish with swim bladder not involved in hearing[c]	207	203	-	-	-
Fish with swim bladder involved in hearing[c]	207	203	-	-	-
Sea turtles[d,e]	232	204	226	189	175

L_{pk} – peak sound pressure (dB re 1 µPa), L_E – sound exposure level (dB re 1 µPa^2·s), L_p – root mean square sound pressure (dB re 1 µPa).
PTS = permanent threshold shift; TTS = temporary threshold shift, which are recoverable hearing effects.

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

[b] Andersson et al. (2007), Mueller-Blenkle et al. (2010), Purser and Radford (2011), Wysocki et al. (2007).

[c] Popper et al. (2014).

[d] Finneran et al. (2017).

[e] McCauley et al. (2000b).

2.5. Animal Movement Modeling and Exposure Estimation

JASMINE was used to estimate the probability of exposure of animals to sound arising from pile driving operations during construction of the RWF. Sound exposure models such as JASMINE use simulated animals (animats) to sample the predicted 3-D sound fields with movement rules derived from animal observations (Appendix J, Figure 4). The parameters used for forecasting realistic behaviors (e.g., diving, foraging, aversion, and surface times) were determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species (Appendix J). The predicted sound fields were sampled by the model receiver in a way that real animals are expected to by programming animats to behave like marine species that may be present near the RWF. The output of the simulation is the exposure history for each animat within the simulation. An individual animat's sound exposure levels are summed over a specified duration, i.e., 24 h (Appendix J.1.1), to determine its total received acoustic energy (SEL) and maximum received PK and SPL. These received levels are then compared to the thresholds described in Section 2.4 within each analysis period. Appendix J provides a fuller description of animal movement modeling and the parameters used in the JASMINE simulations.

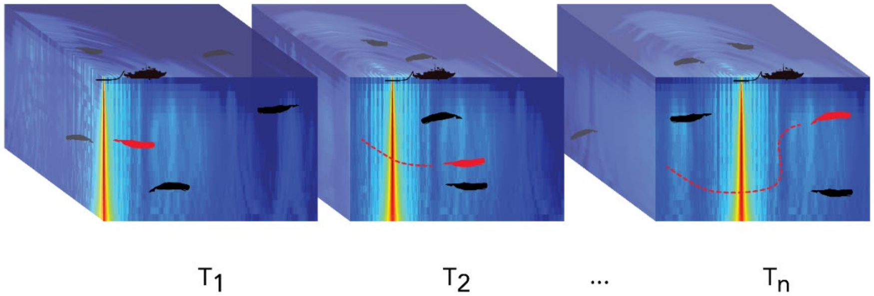

Figure 4. Depiction of animats in an environment with a moving sound field. Example animat (red) shown moving with each time step. The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

2.6. Estimating Monitoring Zones for Mitigation

Monitoring zones used for mitigation purposes have traditionally been estimated by determining the distance to injury and behavioral thresholds based only on acoustic information (see Appendix G.5). This traditional method tacitly assumes that all receivers (animals) in the area remain stationary for the duration of the sound event. Because both where an animal is in a sound field, and the pathway it takes through the sound field, determine the received level of the animal, treating animals as stationary may not produce realistic estimates for monitoring zones.

Animal movement modeling can be used to account for the movement of receivers when estimating distances for monitoring zones. The closest point of approach (CPA) for each of the species-specific animats (simulated animals) in a simulation is recorded and then the CPA distance that accounts for 95% of the animats that exceed an acoustic impact threshold is determined (Figure 5). The $ER_{95\%}$ (95% exposure range) is the horizontal distance that includes 95% of the CPAs of animats exceeding a given impact threshold. $ER_{95\%}$ is reported for marine mammals and sea turtles. If used as an exclusion zone, keeping animals farther away from the source than the $ER_{95\%}$ will reduce exposure estimates by 95%.

Unlike marine mammals and sea turtles for which animal movement modeling was performed, fish were considered static (not moving) receivers, so exposure ranges were not calculated. Instead, the acoustic ranges to fish impact criteria thresholds were calculated by determining the isopleth at which thresholds could be exceeded.

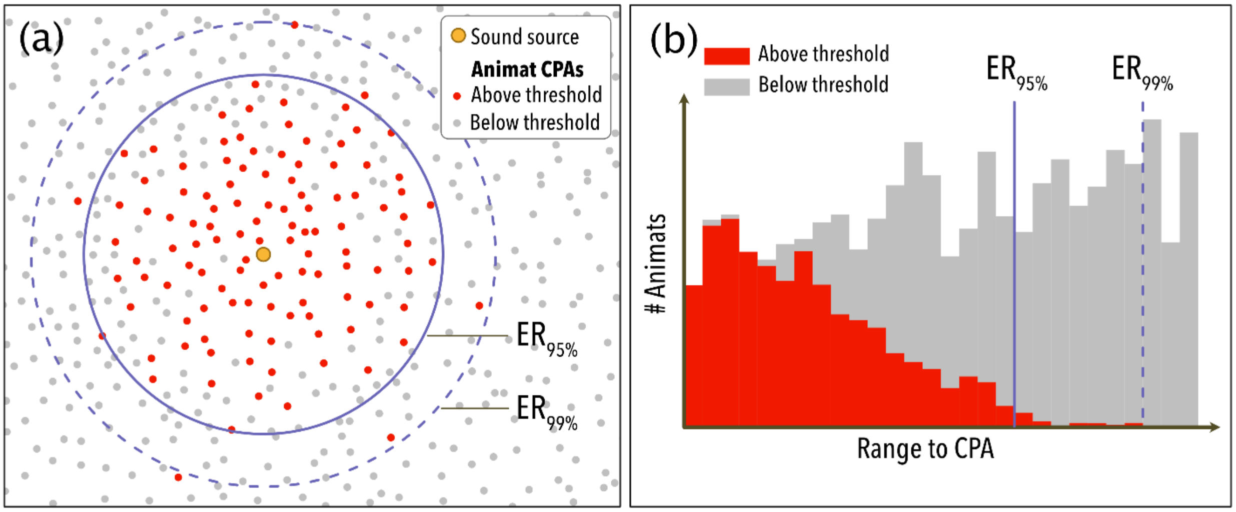

Figure 5. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows a stacked bar plot of the distribution of ranges to animat CPAs. The 95% and 99% Exposure Ranges ($ER_{95\%}$ and $ER_{99\%}$) are indicated in both panels.

3. Marine Fauna Included in Acoustic Assessment

Marine mammals, sea turtles, and fish that may occur near the Project area were considered in this assessment. C*ommon* and *uncommon* marine mammals and sea turtle species (Table 11) were selected for quantitative assessment by acoustic impact analysis and exposure modeling. Quantitative assessment of *rare* species was not conducted because impacts to those species approach zero due to their low densities. The modeled species are designated with an asterisk in Table 11 (marine mammals) and Table 12 (sea turtles).

Table 11. Marine mammals potentially occurring within the regional waters of the Western North Atlantic Outer Continental Shelf and Project Area (Sources: NOAA Fisheries n.d.[a], 2020b; USFWS 2019).

Species	Scientific name	Stock	Regulatory Status [a]	Relative occurrence in RWF	Abundance [b]
Baleen whales (Mysteceti)					
Blue whale	*Balaenoptera musculus*	Western North Atlantic	ESA Endangered MMPA Depleted and Strategic	Rare	402
Fin whale*	*Balaenoptera physalus*	Western North Atlantic	ESA Endangered MMPA Depleted and Strategic	Common	6,802
Humpback whale*	*Megaptera novaeangliae*	Gulf of Maine	MMPA Non-strategic	Common	1,396
Minke whale*	*Balaenoptera acutorostrata*	Canadian Eastern Coastal	MMPA Non-strategic	Common	21,968
North Atlantic right whale*	*Eubalaena glacialis*	Western	ESA Endangered MMPA Depleted and Strategic	Common	412[c]
Sei whale*	*Balaenoptera borealis*	Nova Scotia	ESA Endangered MMPA Depleted and Strategic	Common	6,292
Toothed Whales and Dolphins (Odontoceti)					
Atlantic spotted dolphin*	*Stenella frontalis*	Western North Atlantic	MMPA Non-strategic	Uncommon	39,921
Atlantic white-sided dolphin*	*Lagenorhynchus acutus*	Western North Atlantic	MMPA Non-strategic	Common	93,233
Bottlenose dolphin*	*Tursiops truncatus*	Western North Atlantic, offshore [d]	MMPA Non-strategic	Common	62,851
Bottlenose dolphin	*Tursiops truncatus*	Western North Atlantic, Northern Migratory Coastal	MMPA Depleted and Strategic	Rare	6,639
Clymene dolphin	*Stenella clymene*	Western North Atlantic	MMPA Non-strategic	Rare	4,237

False killer whale	*Pseudorca crassidens*	Western North Atlantic	MMPA Non-strategic	Rare	1,791
Fraser's dolphin	*Lagenodelphis hosei*	Western North Atlantic	MMPA Non-strategic	Rare	Unknown
Killer whale	*Orcinus orca*	Western North Atlantic	MMPA Non-strategic	Rare	Unknown
Melon-headed whale	*Peponocephala electra*	Western North Atlantic	MMPA Non-strategic	Rare	Unknown
Pan-tropical spotted dolphin	*Stenella attenuata*	Western North Atlantic	MMPA Non-strategic	Rare	6,593
Pilot whale, long-finned*	*Globicephala melas*	Western North Atlantic	MMPA Non-strategic	Uncommon	39,215
Pilot whale, short-finned*	*Globicephala macrorhynchus*	Western North Atlantic	MMPA Non-strategic	Uncommon	28,924
Pygmy killer whale	*Feresa attenuata*	Western North Atlantic	MMPA Non-strategic	Rare	Unknown
Risso's dolphin*	*Grampus griseus*	Western North Atlantic	MMPA Non-strategic	Uncommon	35,493
Rough-toothed dolphin	*Steno bredanensis*	Western North Atlantic	MMPA Non-strategic	Rare	136
Short-beaked common dolphin*	*Delphinus delphis*	Western North Atlantic	MMPA Non-strategic	Common	172,974
Sperm whale*	*Physeter macrocephalus*	North Atlantic	ESA Endangered MMPA Depleted and Strategic	Uncommon	4,349
Spinner dolphin	*Stenella longirostris*	Western North Atlantic	MMPA Non-strategic	Rare	4,102
Striped dolphin	*Stenella coeruleoalba*	Western North Atlantic	MMPA Non-strategic	Rare	67,036
Beaked whales (Ziphiidae)					
Cuvier's beaked whale	*Ziphius cavirostris*	Western North Atlantic	MMPA Non-strategic	Rare	5,744
Blainville's beaked whale	*Mesoplodon densirostris*	Western North Atlantic	MMPA Non-strategic	Rare	10,107[e]
Gervais' beaked whale	*Mesoplodon europaeus*	Western North Atlantic	MMPA Non-strategic		
Sowerby's beaked whale	*Mesoplodon bidens*	Western North Atlantic	MMPA Non-strategic		
True's beaked whale	*Mesoplodon mirus*	Western North Atlantic	MMPA Non-strategic		
Northern bottlenose whale	*Hyperoodon ampullatus*	Western North Atlantic	MMPA Non-strategic	Rare	Unknown
Dwarf and pygmy sperm whales (Kogiidae)					
Dwarf sperm whale	*Kogia sima*	Western North Atlantic	MMPA Non-strategic	Rare	7,750[f]

Pygmy sperm whale	*Kogia breviceps*	Western North Atlantic	MMPA Non-strategic	Rare	7,750[f]
Porpoises (Phocoenidae)					
Harbor porpoise*	*Phocoena phocoena*	Gulf of Maine/ Bay of Fundy	MMPA Non-strategic	Common	95,543
Earless seals (Phocidae)					
Gray seal*	*Halichoerus grypus*	Western North Atlantic	MMPA Non-strategic	Common	27,131[g]
Harbor seal*	*Phoca vitulina*	Western North Atlantic	MMPA Non-strategic	Common	75,834
Harp seal*	*Pagophilus groenlandicus*	Western North Atlantic	MMPA Non-strategic	Uncommon	Unknown[h]
Hooded seal	*Cystophora cristata*	Western North Atlantic	MMPA Non-strategic	Rare	Unknown
	Sirenia				
Florida manatee	*Trichechus manatus latirostris*	Florida	ESA Threatened MMPA Depleted and Strategic	Rare	4,834

* = modeled species

[a] Denotes the highest federal regulatory classification. A strategic stock is defined as any marine mammal stock: 1) for which the level of direct human-caused mortality exceeds the potential biological removal level; 2) that is declining and likely to be listed as threatened under the ESA; or 3) that is listed as threatened or endangered under the ESA or as depleted under the MMPA (NOAA Fisheries 2019).

[b] Best available abundance estimate is from NOAA Fisheries Stock Assessment Reports (Hayes et al. 2021).

[c] Best available abundance estimate is from NOAA Fisheries Stock Assessment (Hayes et al. 2021). NARW consortium has released the preliminary 2020 report card results predicting a NARW population of 356 (Pettis and et al. 2021 in draft). However, the consortium "alters" the methods of Pace et al. (2017) to subtract additional mortality. This method is used in order to estimate all mortality, not just the observed mortality, therefore the (Hayes et al. 2021) SAR will be used to report an unaltered output of the Pace et al. (2017) model (DoC and NOAA 2020).

[d] Bottlenose dolphins occurring in the RWF likely belong to the Western North Atlantic Offshore stock (Hayes et al. 2021).

[e] This estimate includes all undifferentiated Mesoplodon spp. beaked whales in the Atlantic. Sources: Kenney and Vigness-Raposa (2009), Rhode Island Ocean Special Area Management Plan (2011), Waring et al. (2011, 2013, 2015), Hayes et al. (2017, 2018, 2019, 2020)[f]
This estimate includes both dwarf and pygmy sperm whales. Source: Hayes et al. (2021)

[g] Estimate of gray seal population in US waters. Data are derived from pup production estimates; Hayes et al. (2019, 2020, 2021) notes that uncertainty about the relationship between whelping areas along with a lack of reproductive and mortality data make it difficult to reliably assess the population trend.

[h] Hayes et al. (2021) report insufficient data to estimate the population size of harp seals in US waters; the best estimate for the whole population is 7.4 million.

Table 12. Sea turtle species potentially occurring within the regional waters of the Western North Atlantic Outer Continental Shelf (OCS) and Project Area.

Species[b]	Distinct Population Segment	Current listing status[a]	Relative occurrence in RWF
Leatherback sea turtle* (*Dermochelys coriacea*)	N/A	ESA Endangered	Common
Loggerhead sea turtle* (*Caretta caretta*)	Northwest Atlantic	ESA Threatened	Common
Kemp's ridley sea turtle* (Lepidochelys kempii)	N/A	ESA Endangered	Uncommon
Green sea turtle (*Cheloria mydas*)	North Atlantic	ESA Threatened	Uncommon

* = modeled species

[a] Listing status as stated in NOAA Fisheries n.d., MA NHESP 2019; RI DEM 2011; NYSDEC 2020a

[b] Hawksbill sea turtle (*Eretmochelys imbricata*) is not included in this report because this species is extralimital to the Mid-Atlantic and New England waters (85 FR 3880, January 23, 2020).

Atlantic and shortnose sturgeon (*Acipenser oxyrinchus oxyrinchus* and *A. brevirostrum*) are endangered fish species that may occur off the northeast Atlantic coast. Atlantic sturgeon distribution varies by season, but they are primarily found in shallow coastal waters (bottom depth less than 20 m) during the summer months (May to September) and move to deeper waters (20–50 m) in winter and early spring (December to March) (Dunton et al. 2010). It is therefore unlikely that Atlantic sturgeon will be in the Project Area during the pile installation phase of this Project. Shortnose sturgeon occur primarily in fresh and estuarine waters and only occasionally enter the coastal ocean. Adults ascend rivers to spawn from February to April, and eggs are deposited over hard bottom, in shallow, fast-moving water (Dadswell et al. 1984). Because of their preference for mainland rivers and fresh and estuarine waters, shortnose sturgeon are unlikely to be found in the vicinity of the Project Area.

3.1. Mean Monthly Marine Mammal Density Estimates

Mean monthly marine mammal density estimates (animals per 100 square kilometers [animals/100 km^2]) for all modeled species are provided in Table 13. These were obtained using the Duke University Marine Geospatial Ecological Laboratory model results (Roberts et al. 2016a, 2016b, 2017, 2018, 2021b, 2021a) and include recently updated model results for North Atlantic right whale (NARW). The updated model includes new estimates for NARW abundance in Cape Cod Bay in December. Additionally, model predictions are summarized over three eras, 2003–2018, 2003–2009, and 2010–2018, to reflect the apparent shift in NARW distribution around 2010. The modeling conducted in this report uses the 2010–2018 density predictions.

Densities were calculated within a 50 km buffered polygon around the lease area perimeter. The 50 km limit is derived from studies of mysticetes that demonstrate received levels, distance from the source, and behavioral context are known to influence the probability of behavioral response (Dunlop et al. 2017b).

The mean density for each month was determined by calculating the unweighted mean of all 10 × 10 km (5 × 5 km for NARW) grid cells partially or fully within the analysis polygon (Figure 7). Densities were computed for an entire year to coincide with possible planned activities. In cases where monthly densities were unavailable, annual mean densities were used instead.

Long-finned and short-finned pilot whales were modeled separately, although there is only one density model for pilot whales from Roberts et al. (2016a, 2016b, 2017). Densities were adjusted based on their relative abundances, e.g.,

$$D_{long\text{-}finned} = D_{\text{overall}} \times N_{\text{long-finned}} / (N_{\text{long-finned}} + N_{\text{short-finned}}) \tag{1}$$

where *D* is density and *N* is abundance.

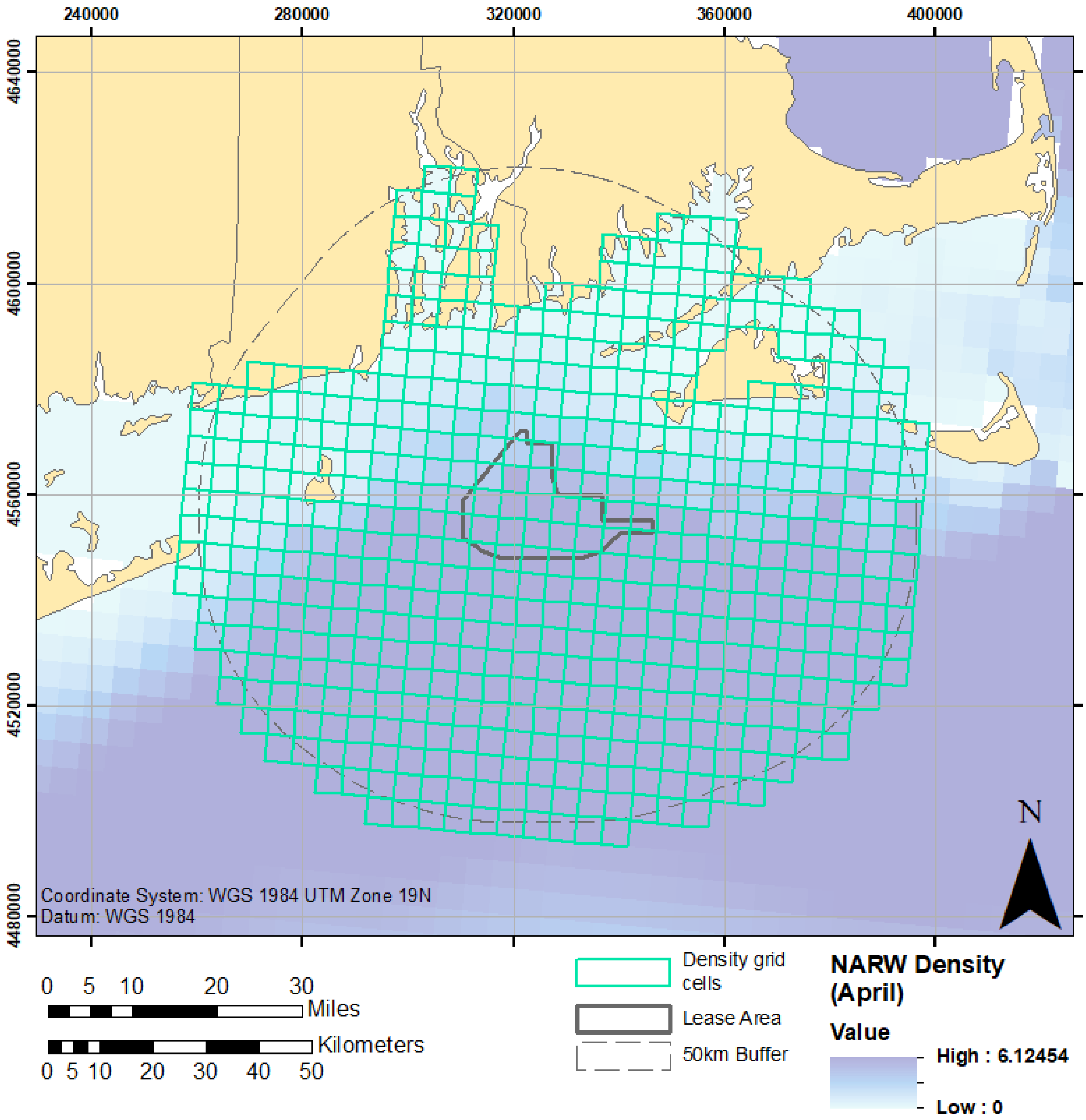

Figure 6. Marine mammal (e.g., NARW) density map showing highlighted grid cells used to calculate mean monthly species estimates within a 50 km buffer around full OCS-A 0486 lease area (Roberts et al. 2016a, 2021b, 2021a).

Table 13. Mean monthly marine mammal density estimates for all modeled species within a 50 km buffer around OCS-A 0486 lease area.

Species of interest	Monthly densities (animals/100 km^2)[a]												Annual mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Fin whale[b]	0.120	0.110	0.115	0.223	0.197	0.210	0.244	0.230	0.203	0.121	0.093	0.095	0.164
Minke whale	0.041	0.051	0.052	0.112	0.157	0.136	0.045	0.029	0.032	0.045	0.021	0.030	0.063
Humpback whale	0.047	0.025	0.028	0.123	0.103	0.111	0.083	0.067	0.210	0.127	0.044	0.078	0.087
North Atlantic right whale[b]	0.345	0.424	0.467	0.532	0.175	0.011	0.002	0.001	0.002	0.005	0.028	0.153	0.179
Sei whale[b]	0.001	0.001	0.001	0.021	0.020	0.012	0.003	0.002	0.003	0.001	0.001	0.001	0.005
Atlantic white sided dolphin	1.922	1.065	1.192	2.558	4.194	3.900	2.470	1.346	1.554	2.252	2.257	2.806	2.293
Atlantic spotted dolphin	0.001	0.001	0.001	0.007	0.013	0.022	0.041	0.059	0.062	0.070	0.039	0.006	0.027
Short-beaked common dolphin	9.604	1.914	0.747	1.789	3.469	3.820	3.775	5.731	9.296	10.926	8.249	15.858	6.265
Bottlenose dolphin	0.504	0.042	0.012	0.673	1.114	4.341	9.527	8.435	7.488	3.838	1.995	1.286	3.271
Risso's dolphin	0.009	0.004	0.002	0.002	0.006	0.007	0.021	0.034	0.022	0.007	0.011	0.020	0.012
Long-finned pilot whale[c]	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301
Short-finned pilot whale[c]	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222	0.222
Sperm whale[b]	0.001	0.001	0.001	0.001	0.004	0.009	0.025	0.021	0.009	0.008	0.007	0.001	0.007
Harbor porpoise	3.820	7.116	10.462	5.608	3.152	0.476	0.328	0.320	0.281	0.483	2.910	3.180	3.178
Seals	19.754	15.856	8.929	12.084	13.470	4.784	1.204	0.525	0.736	1.579	3.859	16.488	8.272

[a] Density estimates are from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) (Roberts et al. 2016a, 2016b, 2017, 2018, 2021b, 2021a).

[b] Listed as Endangered under the ESA.

[c] Density adjusted by relative abundance.

3.2. Sea Turtle Density Estimates

There are limited density estimates for sea turtles in the lease area. For this analysis, sea turtle densities were obtained from the US Navy Operating Area Density Estimate (NODE) database on the Strategic Environmental Research and Development Program Spatial Decision Support System (SERDP-SDSS) portal (DoN, 2012, 2017) and from the Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles (Kraus et al. 2016). These data are summarized seasonally (winter, spring, summer, and fall). Since the results from Kraus et al. (2016) use data that were collected more recently, those were used preferentially where possible.

Sea turtles were most commonly observed in summer and fall, absent in winter, and nearly absent in spring during the Kraus et al. (2016) surveys of the MA WEA and RI/MA WEAs. Because of this, the more conservative winter and spring densities from SERDP-SDSS are used for all species. It should be noted that SERDP-SDSS densities are provided as a range, where the maximum density will always exceed zero, even though turtles are unlikely to be present in winter. As a result, winter and spring sea turtle densities in the lease area, while low, are likely still overestimated.

For summer and fall, the more recent leatherback and loggerhead densities extracted from Kraus et al. (2016) were used. These species were the most commonly observed sea turtle species during aerial surveys by Kraus et al. (2016) in the MA/RI and MA WEAs. However, Kraus et al. (2016) reported seasonal densities for leatherback sea turtles only, so the loggerhead densities were calculated for summer and fall by scaling the averaged leatherback densities from Kraus et al. (2016) by the ratio of the seasonal sighting rates of the two species during the surveys. The Kraus et al. (2016) estimates of loggerhead sea turtle density for summer and fall are slightly higher than the SERDP-SDSS densities, and thus more conservative.

Kraus et al. (2016) reported only six total Kemp’s ridley sea turtle sightings, so the estimates from SERDP-SDSS were used for all seasons. Green sea turtles are rare in this area and there are no density data available for this species, so the Kemp’s ridley sea turtle density is used as a surrogate to provide a conservative estimate.

Sea turtle densities used in exposure estimates are provided in Table 14.

Table 14. Sea turtle density estimates for all modeled species within a 50 km buffer around OCS-A 0486 lease area.

Common name	Density (animals/100 km^2)[a]			
	Spring	Summer	Fall	Winter
Kemp’s ridley sea turtle[b]	0.006	0.006	0.006	0.006
Leatherback sea turtle[b]	0.034	0.630[c]	0.873[c]	0.034
Loggerhead sea turtle	0.084	0.206[d]	0.755[d]	0.084
Green sea turtle[e]	0.006	0.006	0.006	0.006

[a] Density estimates are extracted from SERDP-SDSS NODE database within a 50 km buffer of the 501 South area, unless otherwise noted.

[b] Listed as Endangered under the ESA.

[c] Densities calculated as averaged seasonal densities from 2011 to 2015 (Kraus et al. 2016).

[d] Densities calculated as the averaged seasonal leatherback sea turtle densities scaled by the relative, seasonal sighting rates of loggerhead and leatherback sea turtles (Kraus et al. 2016).

[e] Kraus et al. (2016) did not observe any green sea turtles in the RI/MA WEA. Densities of Kemp’s ridley sea turtles are used as a conservative estimate.

4. Results

Sound fields from 7/12 m WTG monopiles were modeled at two locations: L024-002 in the northwest section of the RWF area and L024-114 in the southeast (L024_002 and L024_114 in Table 3 and Figure 2). The OSS monopile foundations were modeled at three proposed installation locations within the RWF area (OSS1, OSS2, and OSS3 in Table 3 and Figure 2). This section summarizes the source modeling results (Section 4.1), the acoustic propagation modeling results (Section 4.2), exposure estimates and exposure ranges from animal movement modeling of marine mammals and sea turtles (Sections 4.3and Section 4.4), and the acoustic ranges to thresholds for fish (Section 4.5).

For exposure-based range estimates ($ER_{95\%}$), animal movement modeling is used to estimate ranges to regulatory-defined acoustic thresholds for marine mammals and turtles for two pile types (Section 4.1). Results based on both summer and winter sound speed profiles are reported. NAS mitigation was considered by attenuating the sound fields in the simulations by 0, 6, 10, and 15 dB.

4.1. Modeled Source Characteristics

Forcing functions were computed for each pile type using GRLWEAP 2010 (GRLWEAP, Pile Dynamics 2010). The model assumed direct contact between the hammers, helmets, and piles (i.e., no cushion material) (Figures 7–8). The forcing functions serve as the inputs to JASCO's impact pile driving source models used to estimate equivalent acoustic source characteristics detailed in Appendix F. Decidecade spectral source levels for each pile type, hammer energy, and modeled location for both summer and winter sound speed profiles are shown in Figures 9-14.

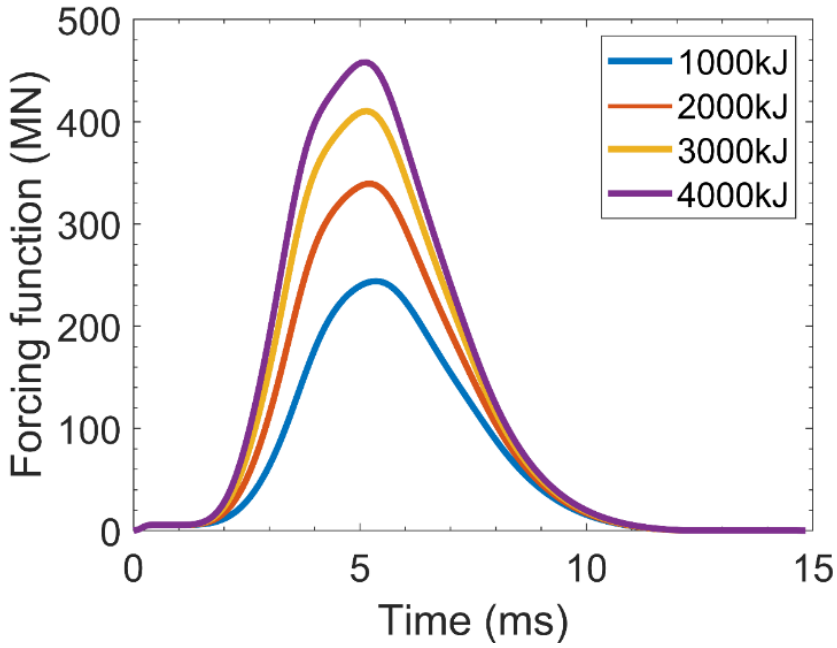

Figure 7. Modeled forcing functions versus time for the IHC S-4000 impact hammer for a 12 m monopile as a function of hammer energy.

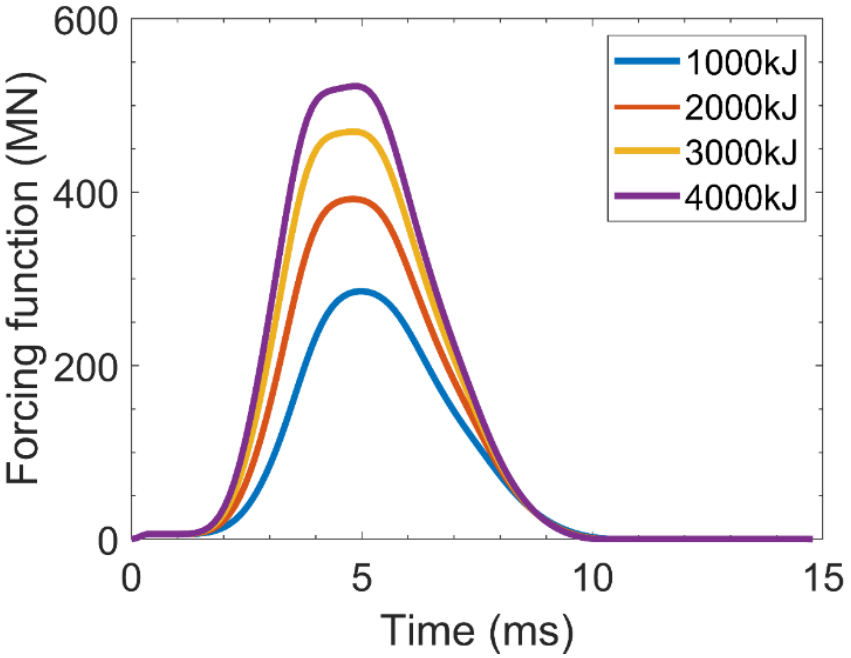

Figure 8. Modeled forcing functions versus time for the IHC S-4000 impact hammer for a 15 m monopile as a function of hammer energy.

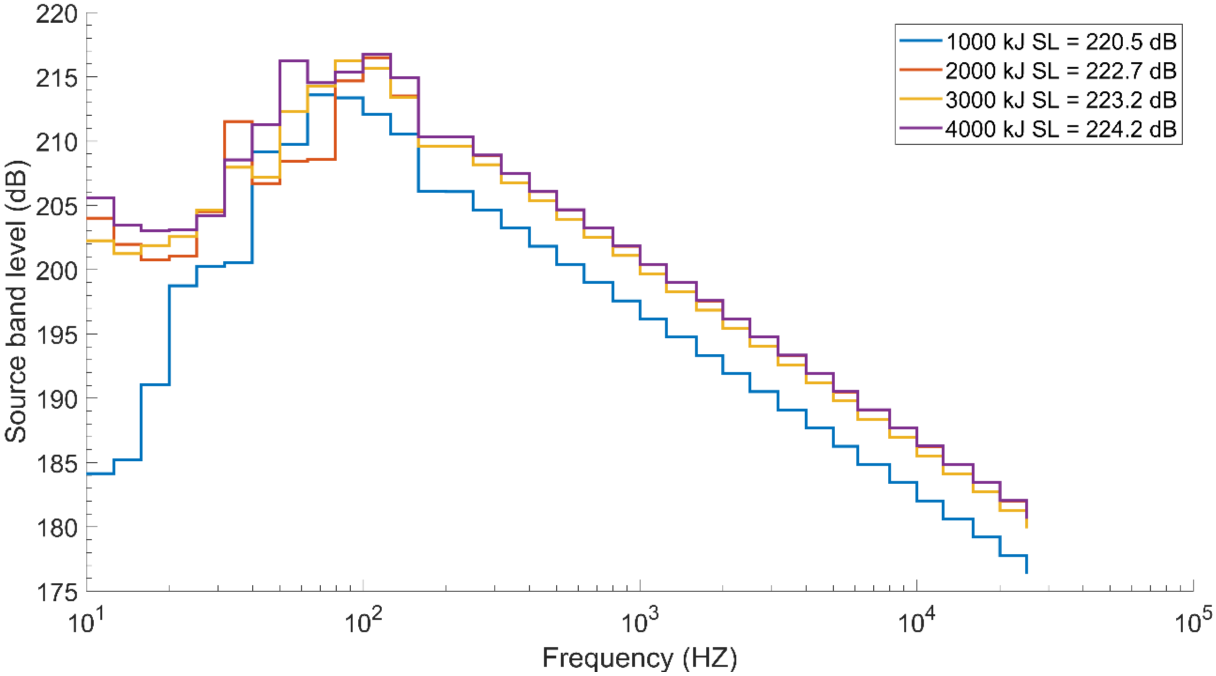

Figure 9. Decidecade band spectral source levels for monopile (12 m) installation using an IHC S-4000 hammer at site L024-002 with a summer sound speed profile.

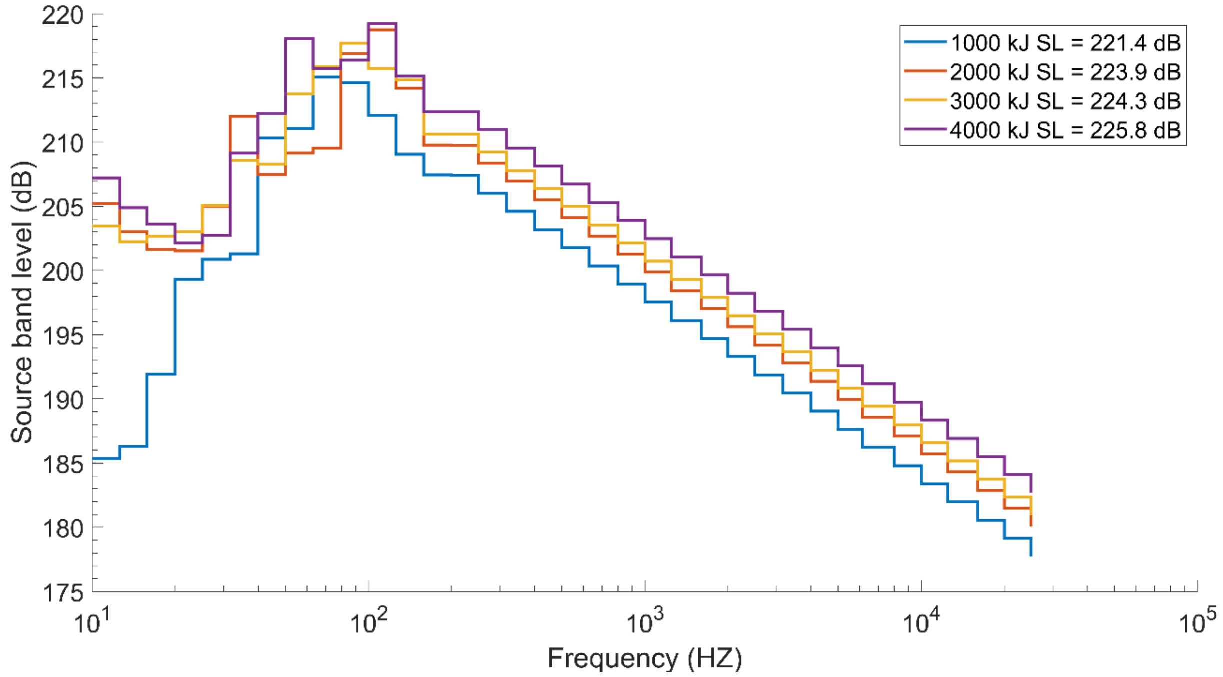

Figure 10. Decidecade band spectral source levels for monopile (12 m) installation using an IHC S-4000 hammer at site L024-002 with a winter sound speed profile.

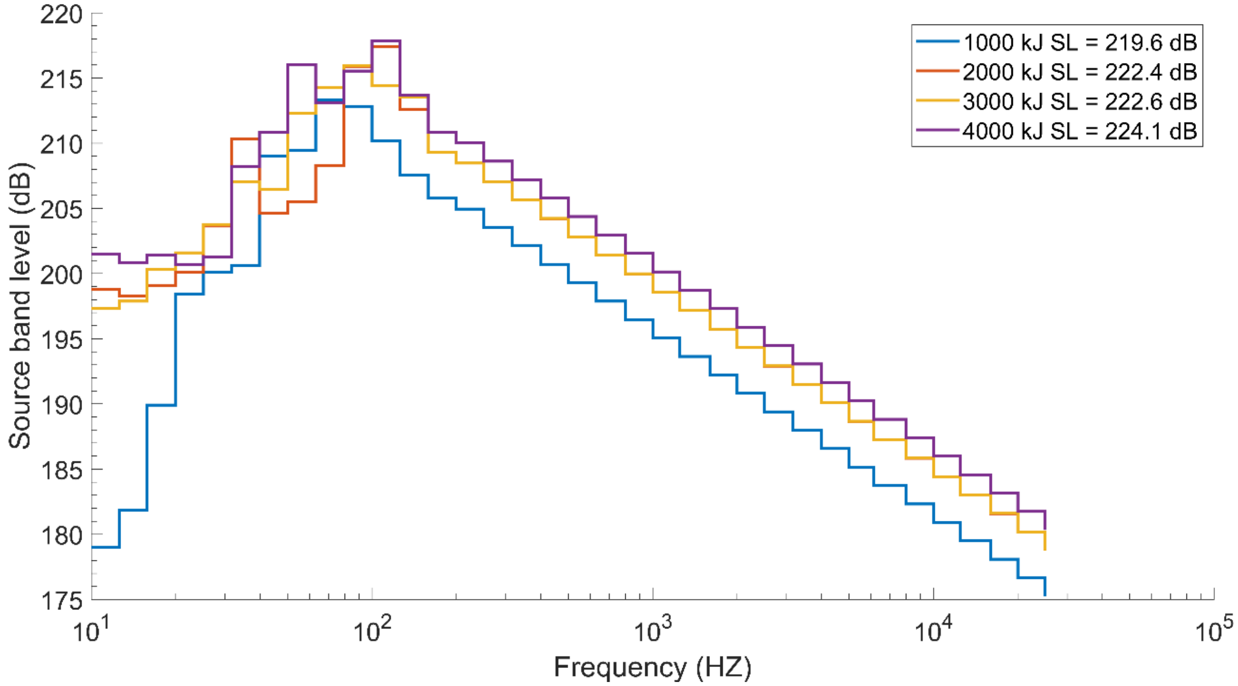

Figure 11. Decidecade band spectral source levels for monopile (12 m) installation using an IHC S-4000 hammer at site L024-114 with a summer sound speed profile.

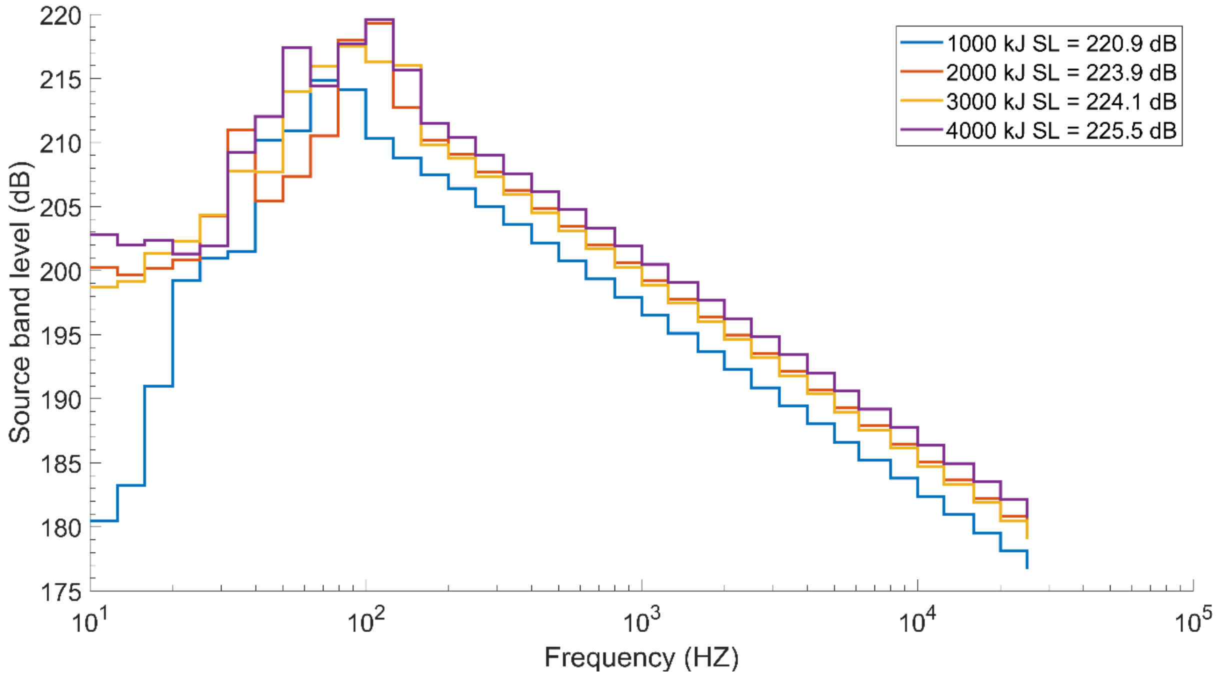

Figure 12. Decidecade band spectral source levels for monopile (12 m) installation using an IHC S-4000 hammer at site L024-114 with a winter sound speed profile.

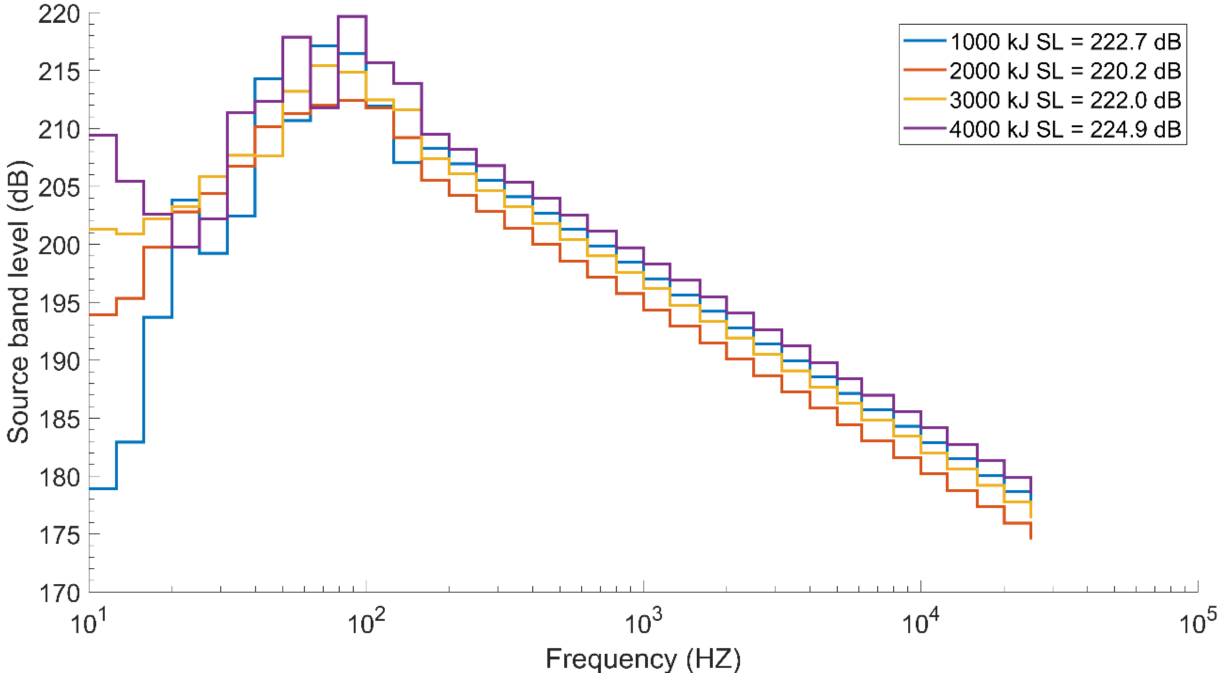

Figure 13. Decidecade band spectral source levels for monopile (15 m) installation using an IHC S-4000 hammer with a summer sound speed profile.

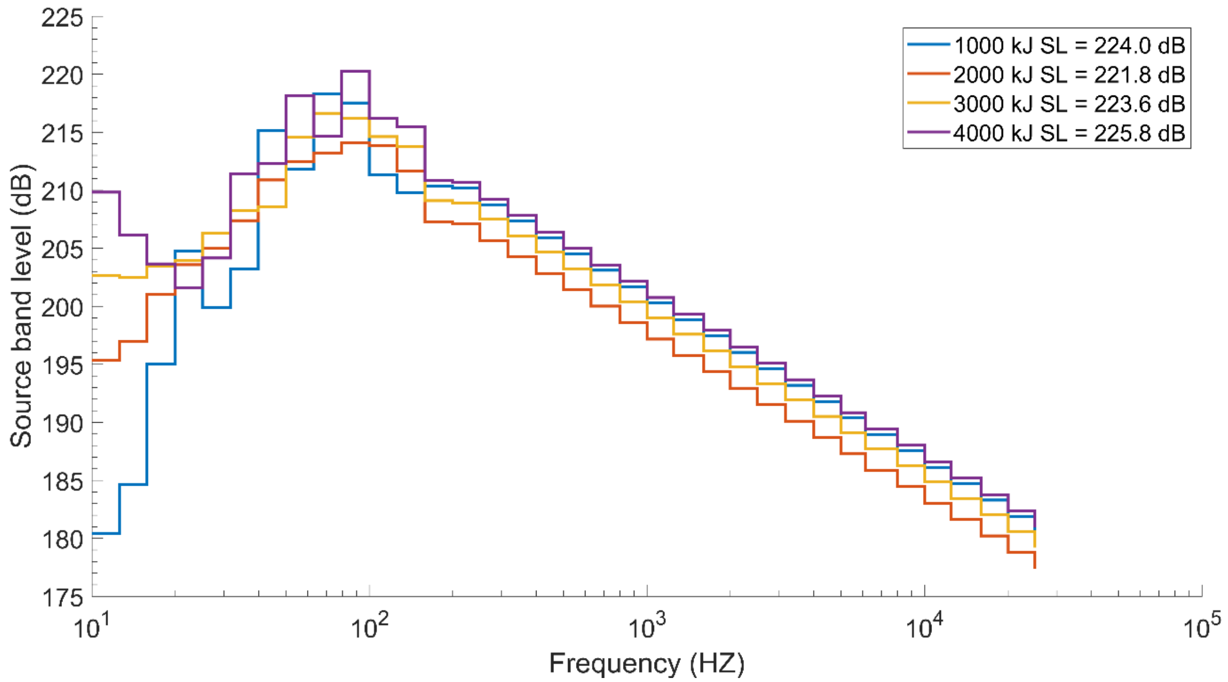

Figure 14. Decidecade band spectral source levels for monopile (15 m) installation using an IHC S-4000 hammer with a winter sound speed profile.

4.2. Modeled Sound Fields

Three dimensional (3-D) sound fields for 7/12 m monopiles and 7/15 m monopiles were calculated using the source characteristics (Section 4.1 and Appendix F) at representative locations (Table 3). Environmental parameters (bathymetry, geoacoustic information, and sound speed profiles) chosen for the propagation modeling and the modeling procedures are found in Appendix G. Subsequent ranges to various isopleths for single hammer strikes at the different hammer energy levels are shown in Appendix H. A comparison of unweighted, broadband, received levels at 750 m was made between the computed sound fields in this study and forecasted levels for 7/12 m monopiles and 7/15 m monopiles, from the ITAP empirical model (Bellmann et al. 2020a) (Appendix I).

4.3. Exposure Estimates

Exposure estimates were calculated for marine mammals and sea turtles using the proposed construction schedule assumptions shown in Construction schedules cannot be fully predicted because of environmental factors like weather and because of installation variation such as drivability. To estimate the number of animals likely to be exposed above the regulatory thresholds a conservative construction schedule that maximizes activity during the highest density months for each species was assumed – 90 WTG monopiles (3 per day for 30 days) are assumed installed in the highest density month of each species (see Sections 3.1 and 3.2 for details on animal density estimates) and 10 WTG monopiles (3 per day for 3 days and 1 per day for 1 day) are assumed installed during the month with the second highest density. The two OSS monopile foundations (1 per day for 2 days) are assumed installed during the second highest density month. Construction schedule assumptions are summarized in Table 5.

Sections 4.3.1 and 4.3.2 include results for each species and metric, assuming 10 dB attenuation and a summer sound speed profile. For full results, including all modeled attenuation levels, see Appendices J.2.1 and J.2.2.

4.3.1. Marine Mammals

Table 15. WTG and OSS monopile foundations: Number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation for a total of 100 WTG and two OSS monopiles. Construction schedule assumptions are summarized in Section 1.2.2.

Species		Injury		Behavior	
		$L_{E,24h}$	L_{PK}	L_p [a]	L_p [b]
LF	Fin whale[c]	6.73	0	15.54	12.64
	Minke whale	6.80	0.01	21.28	49.36
	Humpback whale	8.04	0.02	14.14	11.63
	North Atlantic right whale[c]	6.47	<0.01	16.55	14.39
	Sei whale[c]	0.46	0	1.43	4.22
MF	Atlantic white sided dolphin	0.31	0	598.80	241.23
	Atlantic spotted dolphin	0	0	0	0
	Short-beaked common dolphin	0	0	3401.35	2604.95
	Bottlenose dolphin	0	0	898.71	352.53
	Risso's dolphin	<0.01	0	3.45	1.47
	Long-finned pilot whale	0	0	24.32	10.21
	Short-finned pilot whale	0.01	0	25.61	10.41
	Sperm whale[c]	0	0	2.14	0.85
HF	Harbor porpoise	238.60	16.34	507.04	4501.20
PW	Gray seal	38.25	0	1036.82	1611.76
	Harbor seal	79.62	0	1329.47	1726.33
	Harp seal	75.80	0	1244.67	1791.37

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

4.3.1.1. Effect of Aversion

The mean exposure estimates reported in Table 15 do not consider animals avoiding loud sounds (aversion) or implementation of mitigation measures other than sound attenuation using NAS. Some marine mammals are well known for their aversive responses to anthropogenic sound (e.g., harbor porpoise), although it is assumed that most species will avert from noise. The Wood et al. (2012) step function includes a probability of response that is based primarily on observed aversive behavior in field studies. Additional exposure estimates with aversion based on the Wood et al. (2012) response probabilities were calculated for NARW and harbor porpoise in this study. For comparative purposes only, the results are shown with and without aversion (Table 16).

Table 16. WTG and OSS monopile foundations: Number of marine mammals predicted to receive sound levels above exposure criteria with 10 dB attenuation for a total of 100 WTG and two OSS monopiles and with and without aversion. Construction schedule assumptions are summarized in Section 1.2.2

Species	10 dB attenuation – no aversion				10 dB attenuation – with aversion			
	Injury		Behavior		Injury		Behavior	
	$L_{E,\,24h}$	L_{pk}	L_p [a]	L_p [b]	$L_{E,\,24h}$	L_{pk}	L_p [a]	L_p [b]
North Atlantic right whale[c]	6.47	<0.01	16.55	14.39	1.11	0	8.57	9.84
Harbor porpoise	238.60	16.34	507.04	4501.20	0.93	0	20.14	2745.18

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

4.3.2. Sea Turtles

As was done for marine mammals (see Section 4.3.1), the numbers of individual sea turtles predicted to receive sound levels above threshold criteria were determined using animal movement modeling. The construction schedule described in Construction schedules cannot be fully predicted because of environmental factors like weather and because of installation variation such as drivability. To estimate the number of animals likely to be exposed above the regulatory thresholds a conservative construction schedule that maximizes activity during the highest density months for each species was assumed – 90 WTG monopiles (3 per day for 30 days) are assumed installed in the highest density month of each species (see Sections 3.1 and 3.2 for details on animal density estimates) and 10 WTG monopiles (3 per day for 3 days and 1 per day for 1 day) are assumed installed during the month with the second highest density. The two OSS monopile foundations (1 per day for 2 days) are assumed installed during the second highest density month. Construction schedule assumptions are summarized in Table 5.

Table 5 was used to calculate the total number of real-world individual turtles predicted to receive sound levels above injury and behavior thresholds (Finneran et al. 2017) in the RWF. Table 17 includes results assuming broadband attenuation of 10 dB, calculated in the same way as the marine mammal exposures.

Table 17. WTG and OSS monopile foundations: Number of sea turtles predicted to receive sound levels above exposure criteria with 10 dB attenuation for a total of 100 WTG and two OSS monopiles. Construction schedule assumptions are summarized in Section 1.2.2.

Species	Injury		Behavior
	$L_{E,\,24h}$	L_{PK}	L_p
Kemp's ridley turtle[a]	<0.01	0	0.06
Leatherback turtle[a]	0.69	0	7.52
Loggerhead turtle	0.16	0	3.81
Green sea turtle	<0.01	0	0.06

[a] Listed as Endangered under the ESA.

4.4. Exposure Range Estimates

The following subsections contain tables of exposure ranges ($ER_{95\%}$) calculated for Level A sound exposure thresholds (SEL) and peak thresholds (PK), as well as Level B exposure thresholds (SPL) described in Sections 2.4 and 2.4.2. $ER_{95\%}$, values were calculated for both marine mammals and sea turtles, and these results are summarized in Figure 15 for each of the foundation types and installation schedules. Sections 4.4.1 and 4.4.2 provide additional detail for each species and metric, assuming 10 dB attenuation and a summer sound speed profile. For full results, including all modeled attenuation levels and both summer and winter sound speed profiles, see Appendices J.2.3 and J.2.4.

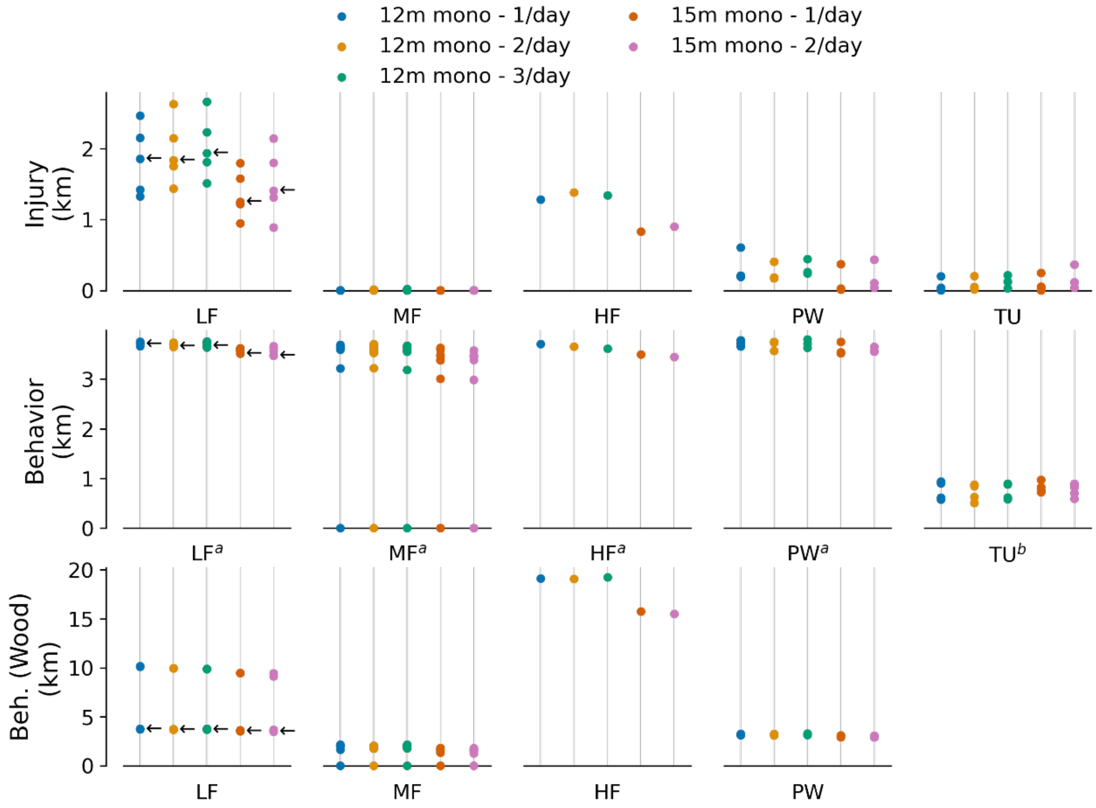

Figure 15. Maximum exposure ranges ($ER_{95\%}$) for injury and behavior thresholds, shown for each hearing group, assuming an attenuation of 10 dB and summer sound speed profile. The middle row represents ranges to Level B from unweighted SPL acoustic thresholds (NOAA 2005), and the bottom row represents ranges to Level B from m-weighted SPL acoustic thresholds (Wood et al. 2012). Each dot represents a species within the indicated hearing group (LF = low frequency, MF = mid frequency, HF = high frequency, PW = pinniped in water, TU = turtle, and arrows indicate NARW), and dot color represents a combination of foundation type and installation schedule (number of piles installed per day). Note the difference in y-axis scaling between the injury and behavior plots.

4.4.1. Marine Mammals

Exposure ranges ($ER_{95\%}$) to Level A SEL and PK acoustic thresholds are presented for WTG monopile and OSS monopile (Tables 18 and 19). Results are reported for 1, 2, and 3 piles per day for WTG monopiles, and 1 and 2 piles per day for OSS monopiles. Ranges to Level B unweighted SPL acoustic thresholds (NOAA 2005) and m-weighted SPL acoustic thresholds (Wood et al. 2012) are also included. Results are presented for summer and assume 10 dB broadband attenuation. It is noted that exposure ranges for multiple piles per day may be similar to the ranges for one pile per day because they are effectively separate events, and the differences primarily result from the statistical nature of the modeling process. Results for different seasons and at different attenuation levels can be found in Appendix J.2.3.

Table 18. WTG monopile foundation (7 to 12 m diameter, summer): Exposure ranges (ER95%) in km to marine mammal threshold criteria with 10 dB sound attenuation.

Species		One pile per day				Two piles per day				Three piles per day			
		Injury		Behavior		Injury		Behavior		Injury		Behavior	
		$L_{E,24h}$	L_{PK}	L_{p}[a]	L_{p}[b]	$L_{E,24h}$	L_{PK}	L_{p}[a]	L_{p}[b]	$L_{E,24h}$	L_{PK}	L_{p}[a]	L_{p}[b]
LF	Fin whale[c]	2.15	0	3.74	3.73	2.14	0	3.73	3.73	2.23	0	3.76	3.77
	Minke whale	1.32	<0.01	3.71	10.09	1.43	0	3.65	9.92	1.51	<0.01	3.63	9.84
	Humpback whale	2.46	<0.01	3.75	3.76	2.62	0	3.70	3.72	2.66	<0.01	3.72	3.73
	North Atlantic right whale[c]	1.85	0	3.70	3.72	1.83	<0.01	3.66	3.66	1.93	0	3.67	3.67
	Sei whale[c]	1.42	0	3.66	10.15	1.75	0	3.68	9.95	1.81	0	3.67	9.88
MF	Atlantic white sided dolphin	0	0	3.59	1.96	0.01	0	3.57	2.01	0.01	0	3.63	2.02
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0	0	3.63	2.01	0	0	3.59	2.05	0	0	3.56	2.07
	Bottlenose dolphin	0	0	3.21	1.64	0	0	3.22	1.74	0	0	3.18	1.77
	Risso's dolphin	0	0	3.69	2.15	<0.01	0	3.70	2.01	<0.01	0	3.67	2.15
	Long-finned pilot whale	0	0	3.65	2.05	0.01	0	3.53	1.96	0	0	3.55	1.98
	Short-finned pilot whale	<0.01	0	3.62	2.06	<0.01	0	3.62	2.01	0.02	0	3.57	2.01
	Sperm whale[c]	0	0	3.66	2.10	0	0	3.66	2.02	0	0	3.63	2.08
HF	Harbor porpoise	1.28	0.18	3.71	19.13	1.38	0.16	3.66	19.05	1.34	0.16	3.62	19.24
PW	Gray seal	0.60	0	3.78	3.25	0.40	0	3.73	3.24	0.44	0	3.80	3.29
	Harbor seal	0.21	0	3.66	3.13	0.18	0	3.57	3.10	0.24	0	3.63	3.13
	Harp seal	0.19	0	3.72	3.12	0.17	0	3.75	3.20	0.26	0	3.71	3.17

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

Table 19. OSS monopile foundation (7 to 15 m diameter, summer): Exposure ranges (ER95%) in km to marine mammal threshold criteria with 10 dB sound attenuation.

Species		One pile per day				Two piles per day			
		Injury		Behavior		Injury		Behavior	
		$L_{E,\,24h}$	L_{PK}	L_p [a]	L_p [b]	$L_{E,\,24h}$	L_{PK}	L_p [a]	L_p [b]
LF	Fin whale[c]	1.57	0	3.62	3.62	1.80	0	3.66	3.67
	Minke whale	0.94	0	3.56	9.44	0.89	0	3.47	9.11
	Humpback whale	1.79	0	3.61	3.61	2.14	<0.01	3.57	3.57
	North Atlantic right whale[c]	1.25	<0.01	3.51	3.51	1.40	0	3.47	3.47
	Sei whale[c]	1.22	0	3.58	9.47	1.31	<0.01	3.61	9.43
MF	Atlantic white sided dolphin	0	0	3.46	1.54	0	0	3.48	1.65
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0	0	3.49	1.78	0	0	3.46	1.68
	Bottlenose dolphin	0	0	3.00	1.33	0	0	2.98	1.26
	Risso's dolphin	0	0	3.59	1.79	0	0	3.46	1.79
	Long-finned pilot whale	0	0	3.38	1.75	0	0	3.38	1.69
	Short-finned pilot whale	0	0	3.39	1.59	0	0	3.45	1.54
	Sperm whale[c]	0	0	3.63	1.81	0	0	3.57	1.52
HF	Harbor porpoise	0.83	0.11	3.50	15.76	0.90	0.15	3.45	15.49
PW	Gray seal	0.37	0	3.75	3.10	0.43	0	3.65	3.06
	Harbor seal	0.01	0	3.54	2.95	0.04	0	3.55	2.89
	Harp seal	0.03	0	3.52	2.91	0.10	0	3.56	2.91

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

4.4.2. Sea Turtles

Similar to the results presented for marine mammals (Section 4.4.1), exposure ranges ($ER_{95\%}$) for sea turtles are summarized for WTG monopile and OSS monopile foundations for the summer season and assuming 10 dB broadband attenuation in Tables 15-17. Again, it is noted that exposure ranges for multiple piles per day may be similar to, or smaller than, the ranges for one pile per day because they are effectively separate events, and the differences primarily result from the statistical nature of the modeling process. Results for different seasons and at different attenuation levels can be found in Appendix J.2.4.

Table 20. WTG monopile foundation (7 to 12 m diameter, summer): Exposure ranges (ER95%) in km to sea turtle threshold criteria with 10 dB sound attenuation.

Species	One pile per day			Two piles per day			Three piles per day		
	Injury		Behavior	Injury		Behavior	Injury		Behavior
	$L_{E,\,24h}$	L_{PK}	L_p	$L_{E,\,24h}$	L_{PK}	L_p	$L_{E,\,24h}$	L_{PK}	L_p
Kemp's ridley turtle[a]	0.04	0	0.90	0.05	0	0.84	0.12	0	0.88
Leatherback turtle[a]	<0.01	0	0.61	0.03	0	0.63	0.12	0	0.62
Loggerhead turtle	0.02	0	0.57	0.01	0	0.50	0.03	0	0.58
Green sea turtle	0.20	0	0.94	0.20	0	0.87	0.21	0	0.89

[a] Listed as Endangered under the ESA.

Table 21. OSS monopile foundation (7 to 15 m diameter, summer): Exposure ranges (ER95%) in km to sea turtle threshold criteria with 10 dB sound attenuation.

Species	One pile per day			Two piles per day		
	Injury		Behavior	Injury		Behavior
	$L_{E,\,24h}$	L_{PK}	L_p	$L_{E,\,24h}$	L_{PK}	L_p
Kemp's ridley turtle[a]	0.05	0	0.97	0.11	0	0.89
Leatherback turtle[a]	0	0	0.72	0.12	0	0.70
Loggerhead turtle	0.04	0	0.76	0.04	0	0.59
Green sea turtle	0.25	0	0.82	0.36	0	0.82

[a] Listed as Endangered under the ESA.

4.5. Acoustic Threshold Ranges for Impact Pile Driving: Fish

Ranges to regulatory defined acoustic thresholds (Section 2.4.2) are presented for fish for WTG monopile and OSS monopile (Tables 22 to 25), at two locations for two seasons with 10 dB attenuation.

Table 22. Ranges ($R_{95\%}$ in meters) to thresholds for fish (GARFO 2016) due to impact hammering of two 12 m monopile in 12 hr, using an IHC S-4000 hammer at two selected modeling locations (L024-002 and L024-114). The duration of impact pile driving will be <12 hr per day, so 12 and 24 hr SEL are equivalent.

Group	Metric	Threshold (dB)	L024-002								L024-114							
			Winter				Summer				Winter				Summer			
			Hammer energy (kJ)								Hammer energy (kJ)							
			1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000
GARFO (2016)																		
Small fish	$L_{E,12hr}$	183	12,003				6,967				11,190				6,351			
	L_{pk}	206	41	70	94	115	50	69	88	89	49	67	88	105	51	66	82	99
Large fish	$L_{E,12hr}$	187	8,717				5,420				7,997				4,968			
	L_{pk}	206	41	70	94	115	50	69	88	89	49	67	88	105	51	66	82	99
Small fish	L_p	150	7,085	9,862	9,562	10,664	4,916	5,829	5,952	6,301	6,063	8,755	8,992	9,758	4,390	5,413	5,343	5,805
Large fish	L_p	150	7,085	9,862	9,562	10,664	4,916	5,829	5,952	6,301	6,063	8,755	8,992	9,758	4,390	5,413	5,343	5,805

Small fish are defined as having a total mass of <2 g.
Large fish are defined as having a total mass of ≥2 g.

Table 23. Ranges ($R_{95\%}$ in meters) to thresholds for fish groups (Popper et al. 2014) due to impact hammering of two 12 m monopile in 24 hr, using an IHC S-4000 hammer at two selected modeling locations (L024-002 and L024-114).

Group	Metric	Threshold (dB)	L024-002								L024-114							
			Winter				*Summer*				*Winter*				*Summer*			
			Hammer energy (kJ)								Hammer energy (kJ)							
			1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000
Mortality and Potential Mortal Injury																		
Fish without swim bladder	$L_{E,24hr}$	219	89				72				108				82			
	L_{pk}	213	5	14	11	18	5	15	11	12	5	14	12	18	5	15	12	18
Fish with swim bladder not involved in hearing	$L_{E,24hr}$	210	494				330				512				354			
	L_{pk}	207	21	48	85	106	21	60	80	81	29	59	78	97	41	58	73	91
Fish with swim bladder involved in hearing	$L_{E,24hr}$	207	805				581				838				580			
	L_{pk}	207	21	48	85	106	21	60	80	81	29	59	78	97	41	58	73	91
	L_{pk}	207	21	48	85	106	21	60	80	81	29	59	78	97	41	58	73	91
Eggs and larvae	$L_{E,24hr}$	210	494				330				512				354			
	L_{pk}	207	21	48	85	106	21	60	80	81	29	59	78	97	41	58	73	91
Recoverable injury																		
Fish without swim bladder	$L_{E,24hr}$	216	161				128				184				144			
	L_{pk}	213	5	14	11	18	5	15	11	12	5	14	12	18	5	15	12	18
Fish with swim bladder	$L_{E,24hr}$	203	1,509				1056				1619				1056			
	L_{pk}	207	21	48	85	106	21	60	80	81	29	59	78	97	41	58	73	91
Temporary Threshold Shift																		
All fish	$L_{E,24hr}$	186	9437				5805				8712				5300			

Table 24. Ranges ($R_{95\%}$ in meters) to thresholds for fish (Popper et al. 2014) due to impact hammering of one 15 m monopile in 24 hr, using an IHC S-4000 hammer at two selected modeling locations (OSS1 and OSS2). The duration of impact pile driving will be <12 hr per day, so 12 and 24 hr SEL are equivalent.

Group	Metric	Threshold (dB)	OSS1								OSS2							
			Winter				Summer				Winter				Summer			
			Hammer energy (kJ)								Hammer energy (kJ)							
			1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000
Mortality and Potential Mortal Injury																		
Fish without swim bladder	$L_{E,24hr}$	219	240				188				243				189			
	L_{pk}	213	10	10	12	19	10	10	12	19	10	10	12	19	10	10	12	19
Fish with swim bladder not involved in hearing	$L_{E,24hr}$	210	1,024				840				1,054				860			
	L_{pk}	207	38	60	74	91	41	58	72	87	38	60	74	91	41	58	72	87
Fish with swim bladder involved in hearing	$L_{E,24hr}$	207	1,528				1,184				1,583				1,243			
	L_{pk}	207	38	60	74	91	41	58	72	87	38	60	74	91	41	58	72	87
Eggs and larvae	$L_{E,24hr}$	210	1,024				840				1,054				860			
	L_{pk}	207	38	60	74	91	41	58	72	87	38	60	74	91	41	58	72	87
Recoverable injury																		
Fish without swim bladder	$L_{E,24hr}$	216	400				301				412				340			
	L_{pk}	213	10	10	12	19	10	10	12	19	10	10	12	19	10	10	12	19
Fish with swim bladder	$L_{E,24hr}$	203	2,443				1,871				2,513				1,951			
	L_{pk}	207	38	60	74	91	41	58	72	87	38	60	74	91	41	58	72	87
Temporary Threshold Shift																		
All fish	$L_{E,24hr}$	186	9,964				6,286				11,733				7,310			

Table 25. Ranges ($R_{95\%}$ in meters) to thresholds for fish (GARFO 2016) due to impact hammering of one 15 m monopile in 12 hr, using an IHC S-4000 hammer at two selected modeling locations (OSS1 and OSS2). The duration of impact pile driving will be <12 hr per day, so 12 and 24 hr SEL are equivalent.

Group	Metric	Threshold (dB)	OSS1								OSS2							
			Winter				*Summer*				*Winter*				*Summer*			
			Hammer energy (kJ)								Hammer energy (kJ)							
			1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000	1000	2000	3000	4000
Small fish	$L_{E,12hr}$	183	12,550				7,317				14,609				8,542			
	L_{pk}	206	47	67	84	99	47	66	78	93	47	67	84	99	47	66	78	93
Large fish	$L_{E,12hr}$	187	9,275				5,943				10,940				6,895			
	L_{pk}	206	47	67	84	99	47	66	78	93	47	67	84	99	47	66	78	93
Small fish	L_p	150	7,128	7,160	8,149	9,221	5,082	4,620	5,114	5,959	8,417	8,389	9,561	10,888	5,781	5,063	5,786	6,921
Large fish	L_p	150	7,128	7,160	8,149	9,221	5,082	4,620	5,114	5,959	8,417	8,389	9,561	10,888	5,781	5,063	5,786	6,921

Small fish are defined as having a total mass of <2 g.
Large fish are defined as having a total mass of ≥2 g.

5. Discussion

This study predicted underwater sound levels associated with the installation of piles supporting WTG and OSS foundations. Sounds fields produced during impact pile driving for installation of 7/11 m WTG monopile foundations and 7/15 OSS monopile foundations were found by modeling the vibration of the pile when struck with a hammer, determining a far-field representation of the pile as a sound source, and then propagating the sound from the apparent source into the environment. A comparison of the modeled sound fields was made with a forecasting, empirical model (ITAP) that predicts broadband pile driving sound levels at 750 m from the pile (Appendix I).

Sound fields were sampled by simulating animal movement within the sound fields and determining if simulated marine mammal and sea turtle animats (simulated animals) exceed regulatory thresholds. The mean number of individuals of each species likely to exceed the thresholds was determined by scaling the animat results using the real-world density of each species. For those animats that exceeded thresholds, the closest point of approach to the source was found and the distance accounting for 95% of exceedances was reported as the exposure range, $ER_{95\%}$. The species-specific $ER_{95\%}$ (see tables in Section 4.4) were determined with different broadband attenuation levels (0, 6, 10, 15, and 20 dB) to account for the use of noise reduction systems, such as bubble curtains. $ER_{95\%}$ can be used for mitigation purposes, like establishing monitoring or exclusion areas. Fish were considered as static receivers, so exposure ranges were not calculated. Instead, the acoustic distance to their regulatory thresholds were determined and reported, with the different broadband attenuation levels (see tables in Section 4.5).

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Appendix A. Glossary

1/3-octave

One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band

Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave band increases with increasing center frequency.

A-weighting

Frequency-selective weighting for human hearing in air that is derived from the inverse of the idealized 40-phon equal loudness hearing function across frequencies.

absorption

The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.

ambient noise

All-encompassing sound at a given place, usually a composite of sound from many sources near and far ([ANSI] American National Standards Institute S1.1-1994 (R2004)), e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

attenuation

The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

Auditory frequency weighting (auditory weighting function, frequency-weighting function)

The process of band-pass filtering sounds to reduce the importance of inaudible or less-audible frequencies for individual species or groups of species of aquatic mammals (ISO 2017). One example is M-weighting introduced by Southall et al. (2007) to describe “Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds”.

azimuth

A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation, it is also called bearing.

bandwidth

The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) ([ANSI] American National Standards Institute and [ASA] Acoustical Society of America S1.13-2005 (R2010)).

boxcar averaging

A signal smoothing technique that returns the averages of consecutive segments of a specified width.

broadband sound level

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

cavitation

A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of noise.

cetacean

Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave

A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

continuous sound

A sound whose sound pressure level remains above ambient sound during the observation period ([ANSI] American National Standards Institute and [ASA] Acoustical Society of America S1.13-2005 (R2010)). A sound that gradually varies in intensity with time, for example, sound from a marine vessel.

decade

Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 2006).

decidecade

One-tenth of a decade (ISO 2017). Note: An alternative name for decidecade (symbol ddec) is “one-tenth decade”. A decidecade is approximately equal to one-third of an octave (1 ddec ≈ 0.3322 oct) and for this reason is sometimes referred to as a “one-third octave”.

decidecade band

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

decibel (dB)

One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power ([ANSI] American National Standards Institute S1.1-1994 (R2004)).

delphinid

Family of oceanic dolphins, or Delphinidae, composed of approximately thirty extant species, including dolphins, porpoises, and killer whales.

ensonified

Exposed to sound.

frequency

The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: f. 1 Hz is equal to 1 cycle per second.

geoacoustic

Relating to the acoustic properties of the seabed.

hearing group

Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

hertz (Hz)

A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean

The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for hearing high frequencies.

impulsive sound

Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA and US Dept of Commerce 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency (LF) cetacean

The functional cetacean hearing group that represents mysticetes (baleen whales) specialized for hearing low frequencies.

mid-frequency (MF) cetacean

The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for mid-frequency hearing.

Monte Carlo simulation

The method of investigating the distribution of a non-linear multi-variate function by random sampling of all of its input variable distributions.

mysticete

Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but they use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound

Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have ([ANSI] American National Standards Institute and [ASA] Acoustical Society of America S3.20-1995 (R2008)). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).

octave

The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete

The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The skulls of toothed whales are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid

A common term used to describe members of the Otariidae, eared seals, commonly called sea lions and fur seals. Otariids are adapted to a semi-aquatic life; they use their large fore flippers for propulsion. Their ears distinguish them from phocids. Otariids are one of the three main groups in the superfamily Pinnipedia; the other two groups are phocids and walrus.

parabolic equation (PE) method

A computationally-efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is *negligible* for most ocean-acoustic propagation problems.

particle acceleration

The rate of change of particle velocity. Unit: meter per second squared (m/s^2). Symbol: *a*.

particle velocity

The physical speed of a particle in a material moving back and forth in the direction of the pressure wave. Unit: meter per second (m/s). Symbol: *v*.

peak pressure level (PK)

The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak sound pressure level. Unit: decibel (dB).

permanent threshold shift (PTS)

A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

phocid

A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.

pinniped

A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source

A source that radiates sound as if from a single point ([ANSI] American National Standards Institute S1.1-1994 (R2004)).

pressure, acoustic

The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: p.

pressure, hydrostatic

The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

propagation loss

The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also called transmission loss.

received level (RL)

The sound level measured (or that would be measured) at a defined location.

rms

root-mean-square.

shear wave

A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

sound

A time-varying pressure disturbance generated by mechanical vibration waves traveling through a fluid medium such as air or water.

sound exposure

Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) ([ANSI] American National Standards Institute S1.1-1994 (R2004)).

sound exposure level (L_ESEL)

A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound field

Region containing sound waves ([ANSI] American National Standards Institute S1.1-1994 (R2004)).

sound pressure level (SPL)

The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure ([ANSI] American National Standards Institute S1.1-1994 (R2004)).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 μPa^2:

$$L_p = 10\log_{10}(p^2/p_0^2) = 20\log_{10}(p/p_0)$$

Unless otherwise stated, SPL refers to the root-mean-square (rms) pressure level. See also 90% sound pressure level and fast-average sound pressure level. Non-rectangular time window functions may be applied during calculation of the rms value, in which case the SPL unit should identify the window type.

sound speed profile

The speed of sound in the water column as a function of depth below the water surface.

source level (SL)

The sound level measured in the far-field and scaled back to a standard reference distance of 1 meter from the acoustic center of the source. Unit: dB re 1 μPa·m (pressure level) or dB re 1 μPa^2·s·m (exposure level).

spectral density level

The decibel level (10·log$_{10}$) of the spectral density of a given parameter such as SPL or SEL, for which the units are dB re 1 μPa^2/Hz and dB re 1 μPa^2·s/Hz, respectively.

spectrum

An acoustic signal represented in terms of its power, energy, mean-square sound pressure, or sound exposure distribution with frequency.

temporary threshold shift (TTS)

Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)

The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also referred to as propagation loss.

Appendix B. Summary of Study Assumptions

Table B-1. Summary of model inputs, assumptions, and methods.

Parameter	Description
12 m WTG Monopile Impact Pile Driving Source Model	
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; hammer forcing functions computed using GRLWEAP. Hammer above water.
Impact hammer model	IHC S4000
Ram weight	1977 kN (200 ton)
Helmet weight	3234 kN (330 ton)
Impact hammer energy	1000, 2000, 3000, 4000 kJ
Modeled seabed penetration for each hammer energy	6, 11, 23, 38 m
Final pile seabed penetration	50 m
Penetration rate for each hammer energy	10, 5, 6, 5 mm/bl
Pile self-settling penetration	3 m
Strike rate	50 min^{-1}
Estimated number of strikes to drive pile at each energy	500, 1000, 2000, 3000
Total number of strikes per pile	6500
Expected duration to drive one pile	~220 min
Number of piles per site per day	2–3
Pile length	110 m
Pile diameter	12 m
Pile thickness	16 cm
Monopile modeled locations (ID, easting, northing, water depth)	L024-002, 320793.48, 4569669.5, 41.3 L024-114, 336403.93, 4551413.22, 36.8
15 m OSS Monopile Impact Pile Driving Source Model	
Modeling method	Finite-difference structural model of pile vibration based on thin-shell theory; hammer forcing functions computed using GRLWEAP. Hammer above water.
Impact hammer model	IHC S4000
Ram weight	1977 kN (202 ton)
Helmet weight	3234 kN (330 ton)
Impact hammer energy	1000, 2000, 3000, 4000 kJ

Modeled seabed penetration for each hammer energy	10, 18, 28, 48 m
Final pile seabed penetration	50 m
Penetration rate for each hammer energy	18, 8, 5, 2.5 mm/bl
Pile self-settling penetration	3 m
Strike rate	50 min^{-1}
Estimated number of strikes to drive pile at each energy	500, 1000, 2000, 8000
Total number of strikes per pile	11500
Expected duration to drive one pile	~380 min
Number of piles per site per day	0.5–1
Pile length	120 m
Pile diameter	15 m
Pile thickness	20 cm
Monopile modeled locations (ID, easting, northing, water depth)	OSS1, 327480.00, 4554999.69, 34.18 OSS2, 321190.00, 4564259.69, 34.42 OSS(Backup), 321190.00, 4558703.69, 33.49
Environmental Parameters	
Sound speed profile	Sound speed profile from GDEM data averaged over region
Bathymetry	SRTM data combined with bathymetry data provided by client
Geoacoustics	Fine sand. Elastic seabed properties based on USGS East coast sediment analysis for modeling region.
Propagation Model	
Modeling method	Parabolic-equation propagation model with 2.5° azimuthal resolution; FWRAM full-waveform parabolic equation (PE) propagation model for 4 radials.
Source representation	Vertical line array
Frequency range	10–2000 Hz extrapolated to 63000 Hz (frequency and range dependent absorption applied to propagation loss from 2000 Hz estimates for higher frequencies)
Synthetic trace length	1000 ms
Maximum modeled range	70 km

Appendix C. Secondary Sound Sources in the Project Area

The primary sources of underwater sound generated during the project are associated with installation of monopile foundations. These primary sound sources are the focus of the quantitative analysis presented in the main text. The objective of this Appendix is to provide a qualitative description and evaluation of other underwater sound sources associated with project construction and operation, collectively referred to as secondary sound sources. Secondary sound sources are anthropogenic sound sources that are only likely to cause behavioral responses and short-term stress in marine fauna. Secondary sound sources are expected to be of very low or low risk (Table C-1), and, because of their limited risk, a qualitative (instead of quantitative) evaluation of these sound sources was undertaken and is detailed for each source type below.

C.1. Vessels

All vessels emit sound from propulsion systems while in transit, and engines and machinery emit noise through the hull while in use. The emitted sounds are typically broadband, non-impulsive, continuous, low-frequency noise. A vessel's acoustic signature depends on the vessel type (e.g., tanker, bulk carrier, tug, container ship, recreational vessel) and vessel characteristics (e.g., engine specifications, propeller dimensions and number, length, draft, hull shape, gross tonnage, and speed). Large shipping vessels and tankers produce lower frequency sounds with primary acoustic energy ~40 Hz and apparent underwater source levels (SLs) of SPL 177 to 188 dB re 1 µPa·m (McKenna et al. 2012). Dynamically positioned (DP) vessels use thrusters to maneuver and maintain station, and generate substantial underwater noise with apparent SLs ranging from SPL 150 to 180 dB re 1 µPa·m depending on operations and thruster use (BOEM 2014). Smaller, high-speed vessels may produce higher-frequency sound (1,000 to 5,000 Hz) with apparent SLs between SPL 150 and 180 dB re 1 µPa·m (Kipple 2002, Kipple and Gabriele 2003).

Marine mammals, sea turtles, fish, and invertebrates in many locations are regularly subjected to vessel activity and may be habituated to vessel noise as a result of frequent or prolonged exposure (BOEM 2014). Non-Project vessel traffic in the vicinity of the Project may include recreational vessels, fishing vessels, cargo vessels, tankers, passenger vessels, and other vessels. Vessels associated with the project during construction and operation will not contribute considerably more vessel traffic above baseline conditions and therefore the potential risk of impact from Project vessel noise is low to very low.

C.1.1. Potential Impacts to Marine Fauna

C.1.2. Marine Mammals

The vessel sounds emitted by ship engines, propellers, thrusters, and hulls are within the (assumed) best hearing frequency ranges of low-frequency cetaceans and are audible by all marine mammals (NMFS 2018). Vessel activities in the Project Area will add to the existing ambient vessel sound level of regular vessel traffic in the area, which could cause behavioral impacts to marine mammals (Kraus et al. 2005, Southall 2005, Clark et al. 2009, Geo-Marine 2010). As with other anthropogenic sound, the potential effects from vessel noise depends on factors such as the marine mammal species, the marine mammal's location and activity, the novelty of the sound, habitat, and oceanographic conditions.

Marine mammals exposed to vessel sounds have reported variable behavioral responses. Analyses of observations made during the Behavioral Response of Australian Humpback whales (*Megaptera novaeangliae*) to Seismic Surveys (BRAHSS) study, Dunlop et al. (2015, 2016a, 2016b, 2017a, 2017b, 2018), found only minor and temporary changes in the migratory behavior of humpback whales in response to exposure to vessel and seismic airgun sounds. Increased proximity of vessels, however, led to aversive reactions (Dunlop et al. 2017b) and to reduced social interactions between migrating humpback whales (Dunlop et al. 2020). In other studies of humpback whales, most individuals did not respond to sonar vessels with the sonar turned off (Sivle et al. 2016, Wensveen et al. 2017), and Tsujii et al. (2018) found that humpback whales moved away from large vessels, while others noted temporary changes in respiratory behavior (Baker and Herman 1989, Frankel and Clark 2002)) or temporary cessation of foraging activities (Blair et al. 2016). Researchers have also reported a temporary change in the distribution and behavior of marine mammals in areas experiencing increased vessel traffic, particularly associated with whale watching, likely due to increases in ambient noise from concentrated vessel activity (Erbe 2002, Nowacek et al. 2004). The large number of studies on humpback whales and the resulting variety of documented responses clearly demonstrate how context affects behavior.

Marine mammals in the Project Area are regularly subjected to commercial shipping traffic and other vessel noise and could potentially be habituated to vessel noise (BOEM 2014). Hatch et al. (2012) estimated that calling North Atlantic right whales (*Eubalaena glacialis*) (NARWs) may have lost 63 to 67% of their communication “space” due to shipping noise. Although received levels of sound may, at times, be above the non-impulsive sound threshold for Level B harassment (120 dB SPL), NARWs have been known to continue to feed in Cape Cod Bay, Massachusetts despite disturbance from passing vessels (Brown et al. 2000). In another study, NARWs showed no behavioral response to ship sounds at all, or at least not to received levels of 132 to 142 dB re 1 µPa from large ships passing within 1 nm (1.9 km) distance, nor to received levels of 129 to 139 dB re 1 µPa (main energy between 50 and 500 Hz) to artificial playback of ship noise (Nowacek et al. 2004).

Studies of responses by mid-frequency cetaceans to vessel sounds, conducted in various parts of the world and with a variety of species, have also shown mixed results. Groups of Pacific humpback dolphins (*Sousa chinensis*) in eastern Australia that included mother-calf pairs, increased their rate of whistling after a vessel transited the area (Van Parijs and Corkeron 2001). The authors postulated that vessel sounds disrupted group cohesion, especially between mother-calf pairs, requiring re-establishment of vocal contact after vessel noise temporarily masked their communication. Lesage et al. (1999) revealed that beluga whales (*Delphinapterus leucas*) reduced their overall call rate in the presence of vessels but increased the emission and repetition of specific calls and shifted to higher frequency bands. In response to high levels of vessel traffic, killer whales increased the duration (Foote et al. 2004) or the amplitude (Holt et al. 2009) of their calls. Other studies of killer whales (*Orcinus orca)* showed temporary changes in behavior in response to vessel noise, including less foraging and increased surface-active behavior, respiration, swim speed, and direction, occurring at received levels above 130 dB re 1 µPa (0.01 to 50 kHz) (Williams et al. 2002, Lusseau et al. 2009, Noren et al. 2009, Williams et al. 2014). Marley et al. (2017) found that Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Fremantle Inner Harbor, Australia significantly increased their average movement speed in the presence of high vessel densities during resting behavior. Behavioral budgets also changed in the presence of vessels, with animals spending more time traveling and less time resting or socializing.

Mid-frequency Cuvier’s beaked whales (*Ziphius cavirostris*) responded to ship sounds by decreasing their vocalizations when they attempted to catch prey (Aguilar Soto et al. 2006), and foraging changes were observed in Blainville’s beaked whales (*Mesoplodon densirostris*) when they were exposed to vessel noise (Pirotta et al. 2012). Harbor porpoises (*Phocoena phocoena*) tend to swim away from approaching vessels emitting high frequency noise in the Bay of Fundy, Canada (Polacheck and Thorpe 1990) and have been observed to move rapidly out of the path of a survey vessel within 1 km on the western coast of North America (Barlow 1988). Both harbor porpoises and beaked whale species are known to avoid relatively low levels of anthropogenic sound, and are generally recognized as behaviorally sensitive species (Wood et al. 2012 criteria).

In response to vessel noise, a tagged seal changed its diving behavior, switching quickly from a dive ascent to descent (Mikkelsen et al. 2019). This observation agrees with descriptions of changes in diving reported from juvenile northern elephant seals (*Mirounga angustirostris*) (Fletcher et al. 1996, Burgess et al. 1998). The tagging study also found that harbor seals (*Phoca vitulina*) and grey seals (Halichoerus grypus) are routinely exposed to vessel noise 2.2 to 20.5% of their time at sea (Mikkelsen et al. 2019).

Sound levels and the presence of vessels associated with the Project may result in behavioral responses by marine mammals, but within the context of an already highly trafficked region, the intermittent nature of vessel activity suggests that the impacts due to Project vessels are likely to be low.

C.1.3. Sea Turtles

Most of the underwater sound produced by ships is low frequency (~20–500 Hz) and overlaps with the known or assumed best hearing frequency range of all sea turtles. The broadband (20–1,000 Hz) apparent source level of a modern commercial ship (54,000 gross ton container ship traveling at 21.7 knots) is up to 188 dB re 1 µPa (McKenna et al. 2012). This source level is below the non-impulsive acoustic injury threshold of 200 dB re 1 µPa for sea turtles Finneran et al. (2017), meaning that only behavioral responses could be expected from sea turtles exposed to Project related vessel noise. Underwater noise that is detectable by sea turtles can mask signal detection and influence behavior, but the consequences of masking and attendant behavioral changes on the survival of sea turtles are not known (Popper et al. 2014).

Many of the proposed Project-related vessels are significantly smaller than cargo ships and most will transit at slower speeds than cargo ships. The apparent source levels of smaller, slower vessels may be below the behavioral response thresholds of sea turtles or limited to the area immediately adjacent to the vessel. As with marine mammals, sea turtles are regularly subjected to commercial shipping traffic and other vessel noise and may be habituated to vessel noise as a result of this exposure (BOEM 2014). Given the lower sound levels associated with vessel transit and operation and the limited ensonified area produced by this source, the risk of impact to sea turtles is expected to be very low to low.

C.1.4. Fish

Vessel noise may interfere with feeding and breeding, alter schooling behaviors and migration patterns (Buerkle 1973, Olsen et al. 1983, Schwarz and Greer 1984, Soria et al. 1996, Vabø et al. 2002, Mitson and Knudsen 2003, Ona et al. 2007, Sarà et al. 2007), mask important environmental auditory cues (CBD 2012, Barber 2017), and induce endocrine stress response (Wysocki et al. 2006). Fish communication is mainly in the low-frequency (<1000 Hz) range (Ladich and Myrberg 2006, Myrberg and Lugli 2006). Thus masking is a particular concern because many fish species have unique vocalizations that allow for inter- and intra-species identification, as well as because fish vocalizations are generally not loud, usually ~120 dB SPL with the loudest sounds reaching 160 dB SPL (Normandeau Associates 2012). Behavioral responses in fishes differ depending on species and life stage, with younger, less mobile age classes being the most vulnerable to vessel noise impacts (Popper and Hastings 2009, Gedamke et al. 2016).

Underwater sound from vessels can cause avoidance behavior, which has been observed for Atlantic herring (*Clupea harengus*) and Atlantic cod (*Gadus morhua*), and is a likely behavior of other species as well (Vabø et al. 2002, Handegard et al. 2003). Fish may respond to approaching vessels by diving towards the seafloor or by moving horizontally out of the vessel's path, with reactions often initiated well before the vessel reaches the fish (Ona et al. 2007, Berthe and Lecchini 2016). The avoidance of vessels by fish has been linked to high levels of infrasonic and low-frequency sound (~10 to 1,000 Hz) emitted by vessels. Accordingly, it was thought that quieter vessels would result in less avoidance (and consequently quieter vessels would have a higher chance of encountering fish) (De Robertis et al. 2010). By comparing the effects of a quieted and conventional research vessel on schooling herring, it was found that the avoidance reaction initiated by the quieter vessel was stronger and more prolonged than the one initiated by the conventional vessel (Ona et al. 2007). In a comment to this publication, Sand et al. (2008) pointed out that fish are sensitive to particle acceleration and that the cue in this case may have been low-frequency particle acceleration caused by displacement of water by the moving hull. This could explain the stronger response to the larger, noise-reduced vessel in the study by Ona et al. (2007), which would have displaced more water as it approached.

Nedelec et al. (2016) investigated the response of reef-associated fish by exposing them in their natural environment to playback of vessel engine sounds. They found that juvenile fish increased hiding and ventilation rate after a short-term vessel sound playback, but responses diminished after long-term playback, indicating habituation to sound exposure over longer durations. These results were corroborated by Holmes et al. (2017) who also observed short-term behavioral changes in juvenile reef fish after exposure to vessel noise as well as desensitization over longer exposure periods.

While sounds emitted by vessel activity are unlikely to injure fish, vessel sound has been documented to cause temporary behavioral responses (Holmes et al. 2017). Fish in the area are already exposed to vessels sounds in this high-traffic area. Project-related vessel noise will be intermittent and of short duration, so the overall impacts to fish are expected to be low.

C.1.5. Invertebrates

Although the study of effects of sound on invertebrates (e.g., crustaceans, cephalopods, and bivalves) is in its nascency, it is evident that invertebrates are sensitive to particle motion (as opposed to pressure) (Popper and Hawkins 2018) and that they can detect vibrations in the sea bed (Roberts et al. 2015, Roberts and Breithaupt 2016, Roberts and Elliott 2017). While there are currently no agreed upon metrics or clearly defined levels (in terms of sound pressure or particle motion) for assessing the effects or impacts of sound on invertebrates (Hawkins and Popper 2017), recent experiments have measured sound pressure levels and particle motion associated with trauma in cuttlefish (*Sepia officinalis*) (Solé et al. 2017) and longfin squid (*Doryteuthis pealeii*) (Mooney et al. 2016, Jones et al. 2020, Jones et al. 2021). Additionally, some studies have found potential behavioral effects (e.g., flight or retraction) or physiological (e.g., stress) responses in invertebrates. For example, shore crabs (*Carcinus maenas*) in the presence of vessel noise ceased feeding and were slower to retreat to shelter (Wale et al. 2013a). The common prawn (*Palaemon serratus*) had fewer intra-specific interactions and spent more time outside of their shelters where the sound pressure levels were lower (Filiciotto et al. 2016). Lobsters (*Nephrops norvegicus*) reduced locomotor activity and clams (*Ruditapes philippinarum*) exhibited behaviors that ultimately prevented feeding (Solan et al. 2016).

Shore crabs exposed to playbacks of vessel noise demonstrated an increase in oxygen consumption that was presumed to indicate a higher metabolic rate and/or stress (Wale et al. 2013b). A similar response was observed in the blue mussel (*Mytilus edulis*), which not only increased oxygen consumption but also had more fragmentation of cellular DNA (Wale et al. 2016). In Pacific oysters (*Magallana gigas*), chronic exposure to vessel noise was shown to depress activity and food uptake, ultimately limiting growth (Charifi et al. 2018). Evidence from a field experiment with sea hares (*Stylocheilus striatus*) demonstrated a significant increase in the likelihood of developmental failure at the embryonic stage and mortality at the free-swimming stage, when exposed to play-backs of vessel noise (Nedelec et al. 2014).

Overall, while there are preliminary indications of potential impacts of vessel noise on some invertebrates, most research has been conducted in a laboratory setting, where tank boundaries may affect the acoustic field and observed behavioral response (Rogers et al. 2016, Popper and Hawkins 2018). Further, nearly all studies measured sound pressure rather than particle motion (Jesus et al. (2020). Although high-intensity noise may produce high sound pressure levels and high levels of particle motion concurrently, it is impossible to determine this relationship without proper measurements (Popper and Hawkins 2018). It is unlikely, however, that these stimuli have more than short-term consequences. For example, the shore crabs that showed an increase in oxygen consumption did not respond after repeated exposures to vessel noise (Wale et al. 2013b). Thus, overall risks of impacts to invertebrates associated with vessel noise are expected to be low.

C.1.6. Monitoring and Mitigation

Sound levels associated with vessels vary with vessel class, speed, and activity. High speeds and the use of thrusters increase noise levels significantly (Richardson et al. 1995), although marine fauna are regularly subjected to commercial shipping traffic and other vessel noise and are likely habituated to vessel noise as a result (BOEM 2014). Many of the proposed Project-related vessels are much smaller than cargo ships that frequently transit the area and, for mitigation purposes, will typically transit at slower speeds.

C.2. Aircraft

Aircraft, both fixed wing and helicopter, may be used during Project construction and operation for crew transfers and biological monitoring activities. The evaluation of aircraft sound on marine fauna differs from other underwater sound sources in that sound generated by aircraft is produced within the air, transmitted through the water surface, and propagated underwater. Most sound energy from aircraft reflects off the air-water interface; only sound radiated downward within a 26-degree cone penetrates below the water surface (Urick 1972).

In general, underwater sound levels produced by fixed wing aircraft and helicopters are typically low frequency (16-500 Hz) and range between 84-159 dB re 1 µPa (Richardson et al. 1995, Patenaude et al. 2002, Erbe et al. 2018). (Patenaude et al. 2002) recorded the transmission of sound into water from two types of aircraft: a Twin Otter fixed-wing airplane and a Bell 212 helicopter. Sound levels were measured at 3 m and 18 m below the water surface while the aircraft flew at various airspeeds and four altitudes overhead. Maximum received levels in the 10 to 500 Hz frequency band at 18 m water depth were approximately 120 dB re 1 µPa for both the Twin Otter and Bell 212 (Patenaude et al. 2002). Received PK sound levels were generally higher at 3 m depth than at 18 m depth by an average of 2.5 dB, but varied considerably with both the altitude and speed of the aircraft (Patenaude et al. 2002). Because underwater sound from aircraft depends on height, angle, speed, and sound propagation in different environmental conditions (temperature, humidity in air, and salinity in water) (Hubbard 1991, Erbe et al. 2018), underwater sound levels from aircraft are highly variable.

There is limited research on the impacts of aircraft sounds to marine fauna. However, sound emitted by aircraft that propagates underwater has the potential to cause behavioral responses in marine mammals, sea turtle, and fish (McCauley et al. 2000a, Popper et al. 2014, Todd et al. 2015, Finneran et al. 2017, [NMFS] National Marine Fisheries Service (US) 2018). Further information is required to determine the potential underwater effects of aircraft on invertebrates (Hawkins et al. 2015). Given that the majority of sound emitted by aircraft is reflected off the surface of the water, impacts to marine fauna are expected to be very low to low.

C.2.1. Potential Impacts to Marine Fauna

C.2.2. Marine mammals

Aircraft noise is typically low- to mid-frequency, overlapping with cetacean calls and has the potential to cause temporary changes in behavior and localized displacement of marine mammals when transmitted from air through the water surface (Richardson et al. 1985a, Richardson and Würsig 1997, Nowacek et al. 2007). Marine mammals react to aircraft noise more often when the aircraft is lower in altitude, closer in lateral distance, and flying over shallow water (Richardson et al. 1985b, Patenaude et al. 2002). Temporary reactions displayed by marine mammals include short surfacing, hasty dives, aversion from the aircraft, or dispersal from the incoming aircraft (Bel'kovich 1960, Kleĭnenberg et al. 1964, Richardson et al. 1985a, Richardson et al. 1985b, Luksenburg and Parsons 2009). The response of cetaceans to aircraft noise largely depends on the species as well as the animals' behavioral state at the time of exposure (e.g., migrating, resting, foraging, socializing) (Würsig et al. 1998).

Cetaceans within the low frequency hearing group showed varied behavioral response when exposed to aircraft noise. Bowhead whales (*Balaena mysticetus*) displayed frequent behavioral reactions to fixed-wing aircraft and helicopter sounds at altitudes <305 m (Dahlheim 1981, Richardson et al. 1985b, Koski et al. 1988, Richardson and Malme 1993). However, Patenaude et al. (2002) noted that only 17% of observed bowhead whales showed behavioral response to passing helicopters, even at the lower altitudes (150 m) and lateral distances of 250 m. Behavioral changes were also seen in gray whales (*Eschrichtius robustus*) in response to the sound from a Bell 212 helicopter (Malme et al. 1984).

Variable behavioral reactions to aircraft sound were also observed in mid-frequency cetaceans. In the Gulf of Mexico, beaked whales, pygmy and dwarf sperm whales (*Kogia spp*.), and various delphinids (pantropical spotted [*Stenella attenuate*], Clymene [*Stenella clymene*], striped [*Stenella coeruleoalba*], and spinner [*Stenella longirostris*] dolphins) showed a strong behavioral response to an approaching fixed-winged aircraft by quickly diving (Würsig et al. 1998). Several studies reported defensive behavioral responses to approaching aircraft in sperm whales (Würsig et al. 1998, Richter et al. 2003, Richter et al. 2006, Smultea et al. 2008). In contrast, only 3.2% (or 24 of 760) of beluga whales responded to fixed wing aircraft at heights above the water ranging from 182 to 427 m (Patenaude et al. 2002). Given that recorded SPL at 18 m was approximately equivalent (~120 dB SPL) to the regulatory defined acoustic behavioral response threshold level for marine mammals, the lack of response is unsurprising in this study (Patenaude et al. 2002).

The sound emitted by aircraft has the potential to elicit temporary behavioral responses in marine mammals and Project-related aircraft can be at low altitude, but due to the intermittent nature and the small ensonified area of this sound source, the risks of aircraft impact to marine mammals are expected to be low.

C.2.3. Sea turtles

Although aircraft sounds can be within the hearing frequency range of turtles, very few studies have analyzed the impacts of aircraft noise on sea turtles. The only documented behavioral responses were from nesting sea turtles near (1.7 km) a military jet airfield in which the turtles exhibited postnatal behavioral reactions to in-air aircraft noise (Balazs and Ross 1974).

Given the frequency range and sound levels produced by aircraft, sea turtles may have adverse behavioral responses to this source. However, the intermittent nature and the small area of ensonification produced by aircraft is unlikely to impact sea turtles. Risk of impact are therefore expected to be very low.

C.2.4. Fish

Because documented sound levels in water from aircraft can be higher than the regulatory-defined non-impulsive behavioral acoustic thresholds for fish (Andersson et al. 2007, Wysocki et al. 2007, Mueller-Blenkle et al. 2010, Purser and Radford 2011), it can be inferred that aircraft may cause behavioral responses in fish. It is unlikely, however, that the underwater sound from aircraft associated with the Project will have much impact on fish because the sound produced by these aircraft is intermittent and has a small ensonified area. The risks of impacts to fish from aircraft sound are expected to be very low.

C.2.5. Invertebrates

Aircraft may produce low-frequency sounds within the hearing range of marine invertebrates but there are currently no data available on the potential impacts of this underwater sound on marine invertebrates. As with fish, the risks of impacts to invertebrates from aircraft sound propagated underwater are expected to be very low due to the small ensonified area and intermittent nature of the source.

C.2.6. Monitoring and Mitigation

To mitigate potential impacts to marine fauna from aircraft noise during aerial surveys, uncrewed aerial systems (drones) equipped with a camera system may be used for real time monitoring of marine mammals. With uncrewed aerial systems, Protected Species Observers (PSOs) monitor high-definition drone camera footage in real time from shore or a vessel. This monitoring approach minimizes traditional, more intrusive methods to detect marine mammals and limits sound from fixed-wing aircraft that is typically used in marine mammal and sea turtle aerial surveys. The underwater sound levels recorded from drones (<100 dB re 1 µPa) is well below underwater noise regulatory thresholds (Erbe et al. 2017). Helicopter and fixed-wing aircraft used during the Project construction and operation phase will be in operation intermittently and primarily maintain safe altitudes (150 to 300 m) above sea level. At these heights, and with the use of drones for aerial surveys, overall aircraft noise may elicit only short-term behavioral response in marine mammals such that the impact risk is very low.

C.3. High Resolution Geophysical (HRG) Surveys

High resolution geophysical (HRG) surveys are required to characterize the seafloor and inform the Project design. Seafloor mapping and bottom-penetrating imaging systems differ primarily in the frequency range that the various sources produce. Higher frequencies resolve smaller features so seafloor mapping is conducted using high-frequency sources, while lower frequencies are used to characterize conditions below the seabed.

Acoustic signals produced by HRG sources are impulsive, tonal, or frequency-modulated (FM) chirp pulses (short duration signals that sweep through a band of frequencies) (Halvorsen and Heaney 2018). Impulsive signals are produced by a variety of sources such as airguns, boomers, and sparkers using a variety of mechanisms (e.g., release of compressed air and electrostatic discharge) (Crocker and Fratantonio 2016). Tonal and FM chirp signals are produced by electromechanical sonars. Sub-bottom profilers are electromechanical sources that (typically) produce FM chirp signals at low frequencies able to penetrate the seafloor. Other electromechanical HRG sources, such as side-scan and multibeam sonars, as well as echosounders, produce tonal or FM chirp signals at higher frequencies for seafloor mapping. The source level, beamwidth, pulse duration, and pulse repetition rate of such sources are typically adjustable and are selected for the needs of each survey. For regulatory purposes, sound signals are classified as either impulsive or non-impulsive with accompanying thresholds for assessing potential impacts on animals. Airguns, boomers, sub-bottom profilers, and sparkers are classified by NMFS as impulsive sound sources, while all electromechanical HRG sources are classified as non-impulsive.

Penetrating HRG systems produce low frequency sounds with high source levels. Mini-airguns emit sounds <5 kHz with source levels of 217-228 re 1 µPa·m (Crocker and Fratantonio 2016). Sub-bottom profilers produce sounds with primary acoustic energy in frequency bands 2-115 kHz at levels from 178 to 241 dB re 1 µPa·m and penetrating seismic profilers produce sound at lower frequencies (0.25-15 kHz) with source levels 205-206 dB re 1 µPa·m range (Crocker and Fratantonio 2016). Many seafloor mapping systems are operated at frequencies >200 kHz, which is above the hearing range of all marine animals and not expected to have any impacts. Some electromechanical systems, however, operate at lower frequencies and are audible to marine mammals. These systems produce sounds within the 0.4-170 kHz frequency range and sound levels from 177-247 dB re 1 µPa·m (Crocker and Fratantonio 2016). For example, multibeam echosounders (MBES) produced sounds ~30 to 70 kHz at source levels up to ~230 dB re 1 µPa. And, though not used for imaging, underwater positioning equipment (e.g., ultra-short baseline, USBL, systems) used during HRG surveys emit sound in the 20-50 kHz band with source levels up to 188-191 dB re 1 µPa·m.

There is an overall paucity of information on the effects of HRG sounds on marine fauna. Impulsive sources used for imaging below the seabed such as sub-bottom profilers and airguns are likely audible to all marine fauna and their use may result in injury and behavioral disruption. If such sources are used, a quantitative impact analysis following established guidelines should be conducted. Electromechanical HRG sources operating within the established hearing range of marine fauna are classified as non-impulsive by NMFS, eliminating the potential for injury, but do have the potential to cause behavioral disturbance. These sources tend to be highly directive with narrow beams and small ensonified areas, so animals are likely to receive only short-duration exposures. Impacts to marine fauna from HRG sounds are expected to be low.

C.3.1. Potential Impacts to Marine Fauna

C.3.2. Marine Mammals

Many HRG sources operate at frequencies (>200 kHz) above the hearing range of marine mammals, so are not expected to result in impacts. Research suggests that sound levels produced by HRG sources operating within the hearing range of marine mammals are unlikely to cause injury but could result in temporary behavioral responses.

While Varghese et al. (2020) found no consistent changes in Cuvier's beaked whale foraging behavior during multibeam echosounder surveys, analogous studies assessing mid-frequency active sonar on beaked whale foraging found that individuals would stop echolocating and leave the area. Other studies have focused on the responses of marine mammals exposed to sonar. For example, minke whales (*Balaenoptera acutorostrata*) demonstrated strong avoidance to mid-frequency sonar at 146 dB re 1 µPa (Sivle et al. 2015, Kvadsheim et al. 2017), and Wensveen et al. (2019) showed that northern bottlenose whales (*Hyperoodon ampullatus*) had a greater response to (military) sonar signals. Surface-feeding blue whales showed no changes in behavior to mid-frequency sonar, but blue whales (*Balaenoptera musculus*) feeding at deeper depths and non-feeding whales displayed temporary reactions to the source; including cessation of feeding, reduced initiation of deep foraging dives, generalized avoidance responses, and changes to dive behavior (DeRuiter et al. 2013, Goldbogen et al. 2013, Sivle et al. 2015). Several behavioral reactions were seen in beaked whale species in response to mid-frequency sonar sounds (12-400 kHz and 230 dB re 1 µPa) including cessation of clicking, termination of foraging dives, changes in direction to avoid the sound source, slower ascent rates to the surface, longer deep and shallow dive durations, and other atypical dive behavior (Tyack et al. 2011, DeRuiter et al. 2013, Stimpert et al. 2014, Miller et al. 2015, Cholewiak et al. 2017). Exposure to mid-frequency sonar at various sound levels (125–185 dB re 1 µPa) caused behavioral responses in California sea lions (*Zalophus californianus*), including a refusal to participate in trials, hauling out, an increase in respiration rate, and an increase in the time spent submerged (Houser et al. 2013, Houser et al. 2016). Hooded seals (*Cystophora cristata*) showed initial avoidance behavior to 1–7 kHz sonar signals at levels between 160 and 170 dB re 1 µPa, but these animals did adapt to the sound and stopped avoiding the source (Kvadsheim et al. 2010).

Non-impulsive, sonar-type HRG sources operating within the hearing range of marine mammals are unlikely to produce injury but could cause behavioral responses. These sources typically have narrow beams that would expose marine mammals for short time periods and only negligible effects on marine mammal species could be expected. A previous analysis by BOEM (2014) on the potential effects of sound associated with HRG surveys on marine mammals in the Mid- and South-Atlantic wind planning areas concluded that impacts are expected to be minimal with the implementation of mitigation measures for sources operating at or below 200 kHz. With mitigation and monitoring practices, impacts to marine mammals from HRG sound sources are expected to be low.

C.3.3. Sea Turtles

HRG surveys that use non-impulsive sources are not expected to impact sea turtles because they operate at frequencies above the sea turtle hearing range (<1 kHz). Low-frequency impulsive HRG equipment may produce sounds within the hearing ranges of sea turtles and impacts should be evaluated using a quantitative approach.

C.3.4. Fish

Non-impulsive sounds produced by HRG survey operations are outside of fish hearing range and are not expected to produce injury or behavioral responses in fish (BOEM 2014, Popper et al. 2014, Popper and Hawkins 2019). Potential impacts of low frequency impulsive HRG sources on fish may include behavioral responses, masking of biologically important sounds, temporary hearing loss, and physiological effects (BOEM 2014, Popper et al. 2014, Popper and Hawkins 2019). Given the mobile and therefore intermittent nature of HRG surveys, the short-duration and infrequent surveying of small areas of the seafloor relative to the overall area, and the likelihood that fish will move away from the sound source, the impacts of underwater noise from impulsive HRG source surveys are expected to be low.

C.3.5. Invertebrates

As with sea turtles and fish, non-impulsive HRG sound sources are above the hearing range of invertebrates and are not expected to cause impacts, but impulsive sources may be within the hearing range of some invertebrates. For most marine invertebrate species sensitivity to underwater sound and susceptibility to noise-induced effects has not been investigated. Anatomical and experimental evidence suggests that particle motion (not sound pressure) is the primary mode for marine invertebrates perceiving acoustic stimuli. Nearly all studies on noise-induced effects on marine invertebrates, however, have measured sound pressure rather than particle motion reducing the relevance of their findings. There are currently no appropriate metrics or clearly defined levels (sound pressure or particle motion) for assessing the effect of underwater sound on marine invertebrates (Hawkins and Popper 2017). Even though criteria and thresholds are not available for invertebrates, the short-term and infrequent nature of impulsive HRG surveys are expected to be of low risk of impact to invertebrates.

C.3.6. Monitoring and Mitigation

Monitoring and mitigation during HRG surveys can decrease the potential impacts to marine mammals from HRG sound exposure by reducing the zone of influence (ZOI) and therefore the likelihood of sound exposures exceeding regulatory thresholds. The National Oceanic and Atmospheric Administration (NOAA) and BOEM have advised that HRG sources that operate at and below 200 kilohertz (kHz) have the potential to cause acoustic harassment to marine species, including marine mammals, and therefore require the establishment and monitoring of exclusion zones (BOEM 2014). Standard mitigation employed during HRG surveys includes the use of PSOs, time of year restrictions, protective zones, ramp-up of active sound sources and shut down of sources should marine mammals or sea turtles enter the established exclusion zones.

C.4. Drilling

Project construction activities will likely include drilling for geotechnical surveys and horizontal directional drilling (HDD). Geotechnical studies are conducted using drill rigs or other excavating tools to characterize the subsurface conditions in locations where foundational structures are expected to be installed (Shell Gulf of Mexico Inc. 2015). In some areas, such as the export cable landfall location, an HDD rig may be needed to create a conduit for the cable to be pulled through.

For both activities, a drill head produces vibrations that propagate as sound through the sediment and water column (Hall and Francine 1991, Nguyen 1996, Willis et al. 2010). Geotechnical drilling operations can emit sound both from the drill at the seabed and from the machinery on the barge (Gales 1982). HDD emits sound at the mouth of the borehole and the drill head. Unlike offshore drill rigs used for geotechnical drilling that are acoustically connected to the water column via drill ships (floating rigs) or drill rigs (bottomed rigs), HDD rigs are installed on shore and the sound they produce that enters the water is often negligible (Hall and Francine 1991, Nguyen 1996, Willis et al. 2010).

Most measurements of offshore drilling sounds have been made for oil exploration and production drilling. The sound levels associated with those drilling operations have been documented to be within the hearing range of many marine species and above the recommended marine mammal, sea turtle, and fish injury and behavioral thresholds (Greene 1987, NOAA 2005, Popper et al. 2014, Finneran et al. 2017, NMFS 2018). The underwater sounds from those drilling activities are non-impulsive, low frequency (20 - 1000 Hz), and of varying levels ranging from an SPL of 117 to 184 dB re 1 µPa·m (Greene 1987, Blackwell et al. 2004a, Dow Piniak et al. 2012). However, the types of drilling likely to be used during project construction are of a smaller scale and are unlikely to produce the maximum sounds reported for oil drilling. Schlesinger et al. (2016) estimated a broadband source level of 170.7 dB re 1 µPa·m for offshore rock socket drilling in British Columbia. The modeled maximum distance to an SPL of 120 dB re 1 µPa was 5.8 km for that drilling activity. Only two papers have measured sounds from geotechnical drilling. Erbe and McPherson (2017) measured broadband (30 Hz to 2 kHz) sound source levels of 142 and 145 dB re 1 µPa·m for small-core drilling from a jack-up rig at two locations off western Australia. The sound levels were up to 35 dB above ambient sound levels at some frequencies, and thus audible to marine fauna, but much less than oil production drilling sounds, and were below levels used in marine noise regulations. Willis et al. (2010) recorded a peak sound level of 107 dB re 1 µPa$_{0\text{-pk}}$ at 7.5 m from hard-rock drilling.

Underwater sound emitted by project construction drilling activities is not expected to produce injury to marine fauna but is likely to be audible and could elicit temporary behavioral responses. Impacts associated with this activity are expected to be low.

C.4.1. Potential Impacts to Marine Fauna

C.4.2. Marine Mammals

Impacts to marine mammals from underwater sound from drilling depend on the species, distance from the source, and type of drilling activity (Awbrey and Stewart 1983, Richardson et al. 1990a, Richardson et al. 1990b, Miller et al. 2005, Blackwell et al. 2017). Observed responses can include changes in migratory pathways, avoidance, changes in calling behavior, and altered diving and feeding patterns . For prolonged, large, drilling activities, acoustic masking may be a concern for marine mammals if the sounds interfere with their ability to detect or recognize important biological acoustic signals (Richardson et al. 1999, Houser and Cross 2014).

While underwater drilling sounds can have a negative effect on some marine mammals (bowhead and beluga whales), others (ringed seals and harbor porpoises) have been documented to be far more tolerant to drilling activities (Moulton et al. 2003, Todd et al. 2009). Received sound levels of drilling from construction operations were within the hearing range of phocid seals (<100 Hz); however, no aversion to sound was observed for ringed seals (Blackwell et al. 2004b). In the North Sea, high frequency odontocete species, such as harbor porpoises, have been found feeding around offshore drilling rigs and platforms during routine drilling and production operations at relatively low sound pressure levels (120 dB re 1 µPa) (Todd et al. 2009). The lack of behavioral response from harbor porpoises to drilling sounds could cause acoustic masking; however, this impact was not discussed within this study (Todd et al. 2009).

The potential impacts on marine mammals from underwater sound exposure produced by drilling operations may be behavioral disruption, acoustic masking, and physiological responses (i.e. stress) (Richardson et al. 1999, Miller et al. 2005, Blackwell et al. 2017). These responses are expected when underwater sounds associated with drilling activities are above marine mammal behavioral thresholds (NOAA 2005). However, past research suggests not all marine mammals respond negatively to drilling operations and any reactions to this source are short-term (Blackwell et al. 2004b, Todd et al. 2009). In addition, most behavioral reactions have been reported in response to oil production drilling, whereas drilling operations associated with wind farm construction activities would be of a much smaller magnitude. Sounds emitted by offshore drilling activities for wind farm development are non-impulsive and intermittent, which makes this activity unlikely to cause prolonged behavioral responses or acoustic masking. Given the short-duration and non-impulsive nature of this source, behavioral responses to underwater marine drilling sounds during the construction phase are expected to be minor.

C.4.3. Sea Turtles

There is insufficient information on the impacts of underwater drilling sounds to sea turtles. Sea turtle hearing sensitivity is within the frequency range (100-1000 Hz) of sound produced by low-frequency sources such as marine drilling (for a summary, see Popper et al. 2014). Sound levels emitted by construction drilling operations are likely to be audible to sea turtles. However, it is unlikely that the sound from construction drilling operations will reach behavioral thresholds, and even more unlikely that the sound will reach injury thresholds, unless the sea turtle is within close proximity to the drilling activity (McCauley et al. 2000b, Dow Piniak et al. 2012, Finneran et al. 2017). Risks of impact are expected to be low, but further research is required to understand the potential effects of marine drilling noise during wind turbine installation to sea turtles.

C.4.4. Fish

It is unclear whether or not the sound emitted by marine drilling activities impact fish. The available literature suggests that noise effects on fish produced by continuous drilling operations may mask acoustic signals conveying important environmental information (McCauley 1994, Popper et al. 2014). Masking may arise when sounds exceed the hearing thresholds of fish and it is probable that, within close proximity to drilling operations, sounds would reach above the recommend thresholds. McCauley (1998) determined that any noise effects to fish from marine drilling activity would likely be temporary behavioral changes within a few hundred meters of the source. For instance, measured levels during drilling operations reached 120 dB re 1 µPa at 3-5 km, which may have caused fish avoidance (McCauley 1998). Recordings show that planktivorous fish choruses persisted during drilling operations off the coast of the Timor Sea; however, it is likely that partial masking of their calls would have occurred (McCauley 1998). The sounds emitted by marine drilling operations for wind farm construction are expected to be short-term and intermittent. It is therefore unlikely that the acoustic characteristics of this source will cause prolonged acoustic masking to fish and the risk of impact from this activity is expected to be low.

C.4.5. Invertebrates

There are no data on the effect of sound from drilling on marine invertebrates. However, evidence from research on the levels of particle motion associated with behavioral responses in blue mussels indicates that the threshold of sensitivity in this species falls within vibration levels measured near blasting, pile driving, and impact drilling (Roberts et al. 2015). Only a small number of studies have indicated reception of vibration in bivalves and an associated behavioral response, which included closing syphons and, in more active mollusks, moving away from the substrate (Mosher 1972, Ellers 1995, Kastelein 2008). Anticipated drilling for the Project is typically short duration and intermittent, so it is unlikely that drilling has more than short-term consequences. Risk of impact to invertebrates from sounds emitted by marine drilling are expected to be low.

C.4.6. Monitoring and Mitigation

Recorded drilling operation source levels were highly variable, ranging from SPL 123 dB to 184 dB re 1 µPa·m for oil production drilling (Greene 1987, Blackwell et al. 2004a, Dow Piniak et al. 2012). While received sound levels could exceed behavioral response thresholds for some marine fauna, the limited area of ensonification and intermittent nature of drilling operations mean the noise impacts from this activity are expected to be very low to low. Currently, no monitoring or mitigation practices are used for sound produced by underwater drilling.

C.5. Dredging

Dredging is most often used to create or maintain depth in channels or harbors by removing materials from the seafloor, but other uses for dredging include contaminated sediment removal, flood/storm protection, extraction of mineral resources, and fishing benthic species. As it pertains to offshore wind, dredging may be used to remove materials from the seafloor in preparation of offshore foundation and export cable locations.

There are two fundamental types of dredging that could be used by the Project – mechanical and hydraulic. Mechanical dredging refers to crane-operated buckets, grabs (clamshell), or backhoes used to remove seafloor material. Hydraulic (suction) dredging and controlled flow excavation (CFE) dredging involve the use of a suction to either remove sediment from the seabed or relocate sediment from a particular location on the seafloor. There are a variety of hydraulic and CFE dredge types including trailing suction, cutter-suction, auger suction, jet-lift, and air-lift. The sound produced by hydraulic dredging results from the combination of sounds generated by the impact and abrasion of the sediment passing through the draghead, suction pipe, and pump. The frequency of the sounds produced range from ~1 to 2 kHz, with reported sound levels from 172 to 190 dB re 1 µPa·m for suction dredges (Robinson et al. 2011, Todd et al. 2015, McQueen 2019).

There is limited research on the impacts of underwater noise related to dredging activity on marine fauna. It is unlikely that dredging operations will exceed the marine mammal, sea turtle, and fish injury thresholds unless animals are within the immediate vicinity of the operating equipment (McCauley et al. 2000a, Popper et al. 2014, Todd et al. 2015, Finneran et al. 2017, NMFS 2018). Further information is required to determine the effects of dredging activity to underwater invertebrates (Hawkins et al. 2015). Overall, the impacts of dredging are expected to be expected to be very low to low.

C.5.1. Potential Impacts to Marine Fauna

C.5.1.1. Marine Mammals

Few studies have investigated the direct effects of sound of dredging on marine mammals. The topic is further confounded by the difficulty of separating the effects of dredging from other anthropogenic activity (such as vessel noise). Most marine mammals would not be expected to exceed PTS (injury) thresholds, but as dredging occurs in one area for relatively long periods, they may experience TTS and behavioral responses (Todd et al. 2015, NMFS 2018). A case study by McQueen et al. (2020) on the expected effects of underwater dredging noise concluded that although harbor porpoises may experience TTS within 74 m from the sound source there was no evidence of significant behavioral avoidance. However, while the modeling scenario was based on relatively simple sound exposure estimates, there was uncertainty about sound propagation in the environment and uncertainty in the exposure-response relationship in the behavior of the animals, leading the authors to conclude that the impacts may be underestimated (McQueen et al. 2020).

Although most research cannot isolate the acoustic impacts of dredging from other anthropogenic activity, there is evidence to suggest that it at least contributes to the negative effects observed on some marine mammals, including displacement in bowhead whales(Richardson et al. (1990b), grey whales Bryant et al. (1984), minke whales, Anderwald et al. (2013), and grey seals (*Halichoerus grypus*, Anderwald et al. (2013)). Diederichs et al. (2010) found short-term avoidance in harbor porpoises at ranges of 600 m from a dredger operating in the North Sea. However, the most compelling evidence for potential impacts of dredging is from research that used models to differentiate the observed impacts of dredging from the vessel traffic in a busy Scotland harbor (Pirotta et al. 2013). Despite a documented tolerance of high vessel presence, bottlenose dolphins spent less time in the area during periods of high-intensity dredging (Pirotta et al. 2013).

The few existing studies suggest that acoustic exposure from dredging operations may elicit behavioral responses or cause TTS to marine mammals close to the source. With the short-duration and intermittent sounds produced by dredging activities, risks to marine mammals are expected to be low.

C.5.1.2. Sea Turtles

While the acoustic impacts of dredging to sea turtles are expected to be similar to other secondary sound sources, the response thresholds for sea turtles are not well researched and are poorly understood relative to marine mammals. There are no thresholds suggested for sea turtles exposed to non-impulsive noise, but suction dredging may produce sounds up to 190 dB re 1 µPa (Robinson et al. 2011, Todd et al. 2015), which exceeds the impulsive threshold of 175 dB re 1 µPa for behavioral disruption suggested by Finneran et al. (2017) (based on impulsive sounds studied by (McCauley et al. 2000b). Accumulated sound energy will not exceed the recommended sea turtle cumulative sound exposure threshold for TTS or PTS (SEL: 189 and 204 dB re 1 µPa, respectively) (Popper et al. 2014, Finneran et al. 2017).

There is currently no information on the direct effects of dredging noise on sea turtles (Popper et al. 2014). There is evidence, however, of potentially positive impacts of dredging to breeding flatback turtles (*Natator depressus*), which increased their use of a dredging area and made longer and deeper resting dives during dredging operations (Whittock et al. 2017). The most likely driver for the observed behavioral response was speculated to be the absence of predators which were displaced by the noise from dredging operations. In general, sound emitted by dredging operations is intermittent and typically short-term. The impacts of noise from dredging operations are likely to be very low to low.

C.5.1.3. Fish

Sound generated by dredging operations is assumed to be primarily relevant to fish that are sensitive to sound pressure (i.e., have swim bladders) (McQueen et al. 2020). However, underwater sound from activities such as dredging can cause avoidance behavior, which has been observed in Atlantic herring and Atlantic cod (Vabø et al. 2002, Handegard et al. 2003). It is unlikely that fish would be exposed to noise levels from dredging that would result in impairment or injury, but behavioral effects, such as auditory masking, could result from exposure to dredging noise (Popper et al. 2014, McQueen et al. 2020). Given that dredging operations are short-term and localized, the impacts from underwater noise to fish from are expected to be low.

C.5.1.4. Invertebrates

There is no available research on the effect of sound from dredging on invertebrates. Contact of the draghead with the seabed may result in substrate-borne vibration, which is likely to be of greater concern to benthic invertebrates than sound pressure (Roberts et al. 2015, Roberts and Breithaupt 2016, Roberts and Elliott 2017). Only a small number of studies have indicated reception of vibration in bivalves and an associated behavioral response, which included closing syphons and, in more active mollusks, moving away from the substrate (Mosher 1972, Ellers 1995, Kastelein 2008). Nevertheless, to date, there is no convincing evidence for any significant effects induced by non-impulsive noise in benthic invertebrates. It is unlikely that these stimuli have more than short-term consequences so the potential impacts of dredging sounds to invertebrates are expected to be very low.

C.6. Wind Turbine Generator Operations

Sound is generated by operating wind turbine generators (WTGs) due to pressure differentials across the airfoils of moving turbine blades and from mechanical noise of bearings and the generator converting kinetic energy to electricity. Sound generated by the airfoils, like aircraft, is produced in air and may enter the water through the air water interface. Mechanical noise associated with the operating WTG is transmitted into the water as vibration through the foundation and subsea cable. There is also a known particle motion component to noise from wind turbines (Sigray and Andersson 2012). Both airfoil sound and mechanical vibration may result in continuous underwater noise.

Underwater sound radiated from operating WTGs is low-frequency and low level (Nedwell and Edwards 2004). At distances of 14 to 20 m from operational WTGs in Europe, underwater sound pressure levels ranged from 109 dB to 127 dB re 1µPa (Tougaard et al. 2009). Pangerc et al. (2016) recorded sound levels at ~50 m from two individual 3.6 megawatt (MW) WTGs monopile foundations over a 21-day operating period. The sound pressure level increased with wind speed up to an average value of 128 dB re 1 µPa at a wind speed of ~10 m/s, and then showed a general decrease in sound levels with increasing wind speed as the turbine blades were feathered. Miller and Potty (2017) measured an SPL of 100 dB re 1 µPa within 50 m of five General Electric Haliade 150-6 MW wind turbines with a peak signal frequency of 72 Hz. At the Block Island Wind Farm off of Rhode Island, sound levels were found to be 112 -120 dB re 1 µPa near the WTG when wind speeds were 2 to 12 m/s, and the WTG sound levels declined to ambient within 1 km from the WTG (Elliott et al. 2019). Tougaard et al. (2009) found that sound level from three different WTG types in European waters was only measurable above ambient sound levels at frequencies below 500 Hz, and Thomsen et al. (2016) suggest that at approximately 500 m from operating WTGs, sound levels are expected to approach ambient levels.

WTG foundation design was found to influence sound levels in the water as a function of distance. Sound levels measured at 150 m from a steel monopile WTG foundation were 133 dB re 1 µPa with peak frequencies between 50-140 Hz, while measurements at 150 m from a jacket WTG foundation were 122 dB re 1 µPa with a peak frequency of 50 Hz and secondary peaks at 150, 400, 500, and 1,200 Hz. However, at 40 m the sound pressure levels were comparable between the steel monopile (135 dB) and jacket foundation types (137 dB) (Thomsen et al. 2016).

Two recent meta-papers (Tougaard et al. 2020, Stöber and Thomsen 2021) assessed WTG operational sounds by extracting sound levels measured at various distances from operating WTGs from currently available reports. Tougaard et al. (2020) used a linear model to fit sound levels as a function of turbine size, wind speed, and distance. Their model suggested that sound from multiple WTGs would be detectable out to a few km in areas with very low ambient noise levels but would be below ambient unless "very close" to individual WTGs in areas with high ambient noise from shipping or wind. Notably, the available data were from lower-power WTGs than are currently being planned for the U.S. east coast, and primarily from geared, rather than direct drive, WTGs. Stöber and Thomsen (2021) attempted to fill this knowledge gap by extracting a strictly defined subset of the data used by Tougaard et al. (2020) to extrapolate sound levels to larger turbine sizes and to direct drive turbines. However, the small size of their data subset greatly increases the already considerable uncertainty of the modeling results. Additionally, their model assumed that SPL increases linearly with WTG capacity, which contrasts with what is known of typical mechanical systems. Both studies found sounds to generally be higher for higher powered WTGs, and thus distances to a given sound threshold are likely to be greater for higher powered WTGs. However, as Stöber and Thomsen (2021) point out, direct drive technology could reduce these distances substantially. Importantly, no measurements exist for these larger turbine sizes and few measurements have been made for direct drive turbines so the uncertainty in these estimates is large.

The frequency and sound level generated from operating WTGs depend on WTG size, wind speed and rotation, foundation type, water depth, seafloor characteristics, and wave conditions (Cheesman 2016, Elliott et al. 2019). Operational noise from WTGs is low frequency (60 to 300 Hz) and at relatively low sound pressure levels near the foundation (100 to 151 dB re 1 µPa) and decreases to ambient within 1 km (Tougaard et al. 2009, Lindeboom et al. 2011, Dow Piniak et al. 2012). Underwater sounds emitted by WTGs are audible to marine mammals, sea turtles, fish, and invertebrates but are lower than the regulatory injury thresholds and typically lower than the behavioral thresholds for marine fauna, and often are lower than the ambient sound levels that these animals typically experience. It is unlikely that WTG operations will cause injury or behavioral responses to marine fauna, so the risk is of impact is expected to be low.

C.6.1. Potential Impacts to Marine Fauna

C.6.1.1. Marine Mammals

While underwater noise from WTGs has been measured within the hearing frequency range of marine mammals, impacts at the anticipated noise levels are limited to behavioral response and auditory masking (Bergström et al. 2014) (MMS 2007). Behavioral responses may include changes in foraging, socialization, or movement, including avoidance of the area. For example, there is evidence that harbor porpoises avoided WTGs during construction and initial operation (Teilmann and Carstensen 2012). However, they appeared to slowly increase their use of the WTG area during continued operation, demonstrating potential long-term habituation. This result also suggests that noise impacts are greater during construction than operation (Madsen et al. 2006). Harbor seals also show avoidance behavior when exposed to simulated sound from WTGs. However this response was limited to distances of less than 500 m to the source (Hastie et al. 2018). Finally, research into both harbor porpoises and harbor seals demonstrated fewer surfacings when exposed to playbacks of noise from WTGs, but this response was limited to 200 m from the source (Koschinski et al. 2003)

Auditory masking could also impact marine mammals, potentially affecting foraging, social interactions, and predator avoidance (Weilgart 2007, Erbe et al. 2016b). The potential for masking is highly dependent on the species in question, and those with low-frequency hearing will be more susceptible due to the overlap with the frequency range of WTG underwater noise.

Research with captive harbor porpoises indicated the potential for auditory masking from simulated WTG underwater noise. As with behavioral responses, the area of impact was predicted to be relatively close to the source (10-20 m) (Lucke et al. 2007).Therefore, the potential for auditory masking is likely limited to short ranges from the WTG.

Tougaard et al. (2020) estimated that WTG sounds would drop below the 120-dB re 1 µPa U.S. regulatory threshold for marine mammal behavioral impacts from continuous sounds (NMFS 2005) within approximately 50-100 m of the WTG, using currently available sound measurements taken at various distances from operational WTGs. These WTGs all had a lower capacity than those planned for installation off the US east coast, and most were from geared-drive WTGs. Thus, Stöber and Thomsen (2021) extrapolated sound levels to larger WTG sizes and found the distance to the behavioral threshold could extend out to several kilometers. However, both the small size of their dataset and choice of modeling methods make these predicted distances unreliable. Additionally, those authors suggest that this distance could be reduced substantially (almost fivefold) for newer direct drive WTGs. The authors also noted that larger sized wind farms, for which data are nonexistent, might only have limited impacts related to behavioral response in marine mammals.

Overall, noise generated from WTG operation is minor and does not cause injury or lead to permanent avoidance at distances greater than 0.5 nm (1 km) for the species studied (e.g., harbor porpoise, seals, and fish) (Wahlberg and Westerberg 2005, Stenberg et al. 2015), with potential to have minimal effects at much closer distances up to within a few meters of the WTG (Bergström et al. 2013). Underwater noise impact to marine mammals associated with WTG operation is expected to be very low to low.

C.6.1.2. Sea Turtles

Low-frequency sound emitted by WTG is of concern for sea turtles. Their most sensitive hearing range is confined to low frequencies (Ridgway et al. 1969, Bartol et al. 1999), and sea turtles have shown behavioral avoidance to low frequency sound (O'Hara and Wilcox 1990, Dow Piniak et al. 2012). Operational WTG underwater noise may be slightly higher than ambient sound however, WTG sound levels decline to ambient levels within 1 km from the turbine (Kraus et al. 2016, Elliott et al. 2019). Because of these lower sound levels, sea turtles are unlikely to detect sounds generated by WTGs at large distances away from the Project in the presences of ambient sound. Therefore, sea turtles are at very low risk from exposure due to WTG noise. Any behavioral changes caused by exposure to WTG underwater sounds are expected to be short-term and localized to areas near the WTGs.

C.6.1.3. Fish

Underwater sound generated by operating WTGs is in the best hearing frequency range of fish but is of low intensity (Madsen et al. 2006). The measured sound levels are well below existing non-impulsive acoustic thresholds for injury or behavioral response in fish (McCauley et al. 2000a, Popper et al. 2014, Finneran et al. 2017). While the underwater sound levels are related to WTG power and wind speed, with increased wind speeds creating increased underwater sound levels, even at high wind speeds Wahlberg and Westerberg (2005) estimated permanent avoidance by fish would only occur within four meters of a WTG foundation. Stöber and Thomsen (2021) extrapolated measured sound levels to larger WTG sizes and found larger distances to a given sound threshold but noted that impacts might be limited to behavioral responses in fishes that could be offset by benefits from lower fishing effort and the creation of artificial reefs at wind farm sites.

In a study on fish near the Svante wind farm in Sweden, Atlantic cod, and roach (*Rutilus rutilus*) catch rates were significantly higher near turbines when the rotors were stopped, which could indicate fish attraction to turbine structure and avoidance to noise when operational (Westerberg 2000 as cited in Thomsen et al. 2006). In another study, no avoidance behavior was observed as fish densities increased around turbine foundations of the Lillgrund offshore wind farm in Sweden (Bergström et al. 2014). It is important to note that ambient sound levels can influence how fish detect other sounds and a change in background noise could alter how fish perceive and react to biological stimuli (Popper and Fay 1993). Current understanding is that underwater noise generated by WTG operation is of minor significance for fish (Wahlberg and Westerberg 2005, Stenberg et al. 2015). Underwater noise risks to fish associated with WTG operation is expected to be low.

C.6.1.4. Invertebrates

There is limited data on the effects of underwater sound from operating WTGs on invertebrates. Pine et al. (2012) found potential impacts on the median time to metamorphosis of estuarine crabs (*Austrohelice crassa* and *Hemigrapsus crenulatus*), although this experiment only measured the sound pressure level, not particle motion. Invertebrates may be susceptible to detecting particle motion produced by operational WTGs at the seabed, which could cause a behavioral response (Roberts et al. 2015, Roberts and Breithaupt 2016, Roberts and Elliott 2017). However, there is a paucity of data regarding responses of invertebrates to acoustic exposure, and no studies of noise-induced hearing effects. Overall, risks are expected to be very low.

C.6.1.5. Monitoring and Mitigation

Noise generated by operating WTGs is typically below regulatory thresholds for injury and behavioral disruption, and does not lead to permanent avoidance at distances >1 km for the species studied (e.g., harbor porpoise, seals, and fish) (Wahlberg and Westerberg 2005, Stenberg et al. 2015). Although there are potential behavioral impacts within a few meters of an operational WTG (Bergström et al. 2013), the risks are very low to low and no mitigation or monitoring is used for underwater sound produced by WTG operations.

C.7. Impact Risk Definitions

Risk rankings of secondary sound sources are very low, low, moderate, or high based on the probability of marine fauna exposure and the vulnerability of the marine species to a particular development stressor (Table C-1). Marine species occurrence and their relationships to the established criteria were evaluated using: 1) existing literature on marine mammal, sea turtle, fish distribution and presence/use of Lease Area OCS-A 0487, 2) information on the potential impacts of offshore wind farm construction and operations in both the U.S and globally, 3) studies that provide a general understanding of hearing, response to anthropogenic sound, and 4) other factors that influence the potential underwater noise impacts of offshore wind construction, operations, and decommissioning activities on marine fauna.

Table C-1. Definitions of Impact Risk, Exposure, and Vulnerability used in Impact Assessment

Risk level	Exposure	Individual vulnerability
Very low	• No or limited observations of the species in or near the proposed Project infrastructure and acoustic exposure zones (low expected occurrence), and/or • Species tends to occur mainly in other habitat (e.g., deeper water or at lower/higher latitudes), and/or • No indication that the Lease Area has regional importance as it pertains to a particular species life history characteristics.	• Literature and/or research suggest the affected species and timing of the stressor are not likely to overlap, and/or • Literature suggests limited sensitivity to the stressor, and/or • Little or no evidence of impacts from the stressor in the literature.
Low	• Few observations of the species in or near the proposed Project infrastructure and noise exposure zones (occasional occurrence), and/or • Seasonal pattern of occurrence in or near the proposed Project infrastructure and acoustic exposure zones.	• Literature and/or research suggest the affected species and timing of the stressor may overlap and/or • Literature suggests some low sensitivity to the stressor and/or • Literature suggests impacts are typically short-term (end within days or weeks of exposure) and/or • Literature describes mitigation/best management practices (BMPs) that reduce risk
Moderate	• Moderate year-round use of the areas associated with proposed Project infrastructure and acoustic exposure zones	• Literature and/or research suggest the affected species and timing of the stressor are likely to overlap, and/or • Literature and/or research suggest a moderate susceptibility to the stressor exists in the region and/or from similar activities elsewhere, and • Literature does not describe mitigation/BMPs that reduce risk.
High	• Significant year-round use of the areas associated with proposed Project infrastructure and acoustic exposure zones	• Literature and/or research suggest the affected species and timing of the stressor will overlap, and • Literature suggests significant use of WTA and ECC and acoustic exposure zones for feeding, breeding, or migration, and • Literature does not describe mitigation/BMPs that reduce risk.

Appendix D. Underwater Acoustics

D.1. Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa in water and p_0 = 20 µPa in air. Because the perceived loudness of sound, especially impulsive noise such as from seismic airguns, impact pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate noise and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,pk}$; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

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

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure (PK-PK or $L_{p,pk\text{-}pk}$; dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure, possibly filtered in a stated frequency band, attained by an impulsive sound, $p(t)$:

$$L_{p,\mathrm{pk\text{-}pk}} = 10\log_{10}\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2} \qquad \text{(D-2)}$$

The sound pressure level (SPL or L_p; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to a rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right)\ \mathrm{dB} \qquad \text{(D-3)}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying L_p function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $g(t)$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,\mathrm{fast}}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,\mathrm{boxcar\ 125ms}}$. Another approach, historically used to evaluate L_p of impulsive signals underwater, defines $g(t)$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 µPa^2·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \middle/ T_0 p_0^2\right)\ \mathrm{dB} \tag{D-4}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right)\ \mathrm{dB} \tag{D-5}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related numerically by the following expression, which depends only on the duration of the time window T:

$$L_p = L_E - 10\log_{10}(T) \tag{D-6}$$

$$L_{p90} = L_{\mathrm{E}} - 10\log_{10}(T_{90}) - 0.458 \tag{D-7}$$

where the 0.458 dB factor accounts for the 10% of pulse SEL missing from the SPL(T_{90}) integration time window.

Energy equivalent SPL (L_{eq}; dB re 1 µPa) denotes the SPL of a stationary (constant amplitude) sound that generates the same SEL as the signal being examined, $p(t)$, over the same time period, T:

$$L_{\mathrm{eq}} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)\,dt \middle/ p_0^2\right) \tag{D-8}$$

The equations for SPL and the energy-equivalent SPL are numerically identical. Conceptually, the difference between the two metrics is that the SPL is typically computed over short periods (typically of 1 s or less) and tracks the fluctuations of a non-steady acoustic signal, whereas the L_{eq} reflects the average SPL of an acoustic signal over time periods typically of 1 min to several hours.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LF,24h}$; see Appendix E) or auditory-weighted SPL ($L_{p,\mathrm{ht}}$). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

D.2. Decidecade Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analyzing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into decidecade bands, which are approximately one-tenth of a decade wide and often referred to as 1/3-octave-bands. Each octave represents a doubling in sound frequency. The center frequency of the *i*th band, $f_\mathrm{c}(i)$, is defined as

$$f_\mathrm{c}(i) = 10^{\frac{i}{10}}\,\mathrm{kHz} \tag{D-9}$$

and the low (f_lo) and high (f_hi) frequency limits of the *i*th decade band are defined as:

$$f_{\mathrm{lo},i} = 10^{\frac{-1}{20}} f_\mathrm{c}(i) \quad \text{and} \quad f_{\mathrm{hi},i} = 10^{\frac{1}{20}} f_\mathrm{c}(i) \tag{D-10}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure D-1). The acoustic modeling spans from band 1 (f_c (1) = 10 Hz) to band 44 (f_c (44) = 25 kHz).

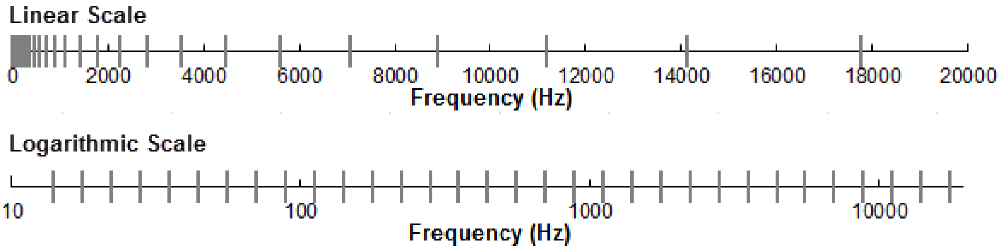


Figure D-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

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

$$L_{p,i} = 10\log_{10} \int_{f_{\mathrm{lo},i}}^{f_{\mathrm{hi},i}} S(f)\,df \tag{D-11}$$

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

$$\text{Broadband SPL} = 10\log_{10} \sum_i 10^{\frac{L_{p,i}}{10}}. \tag{D-12}$$

Figure D-2 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient noise signal. Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the spectral levels, at higher frequencies. Acoustic modeling of decidecade bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

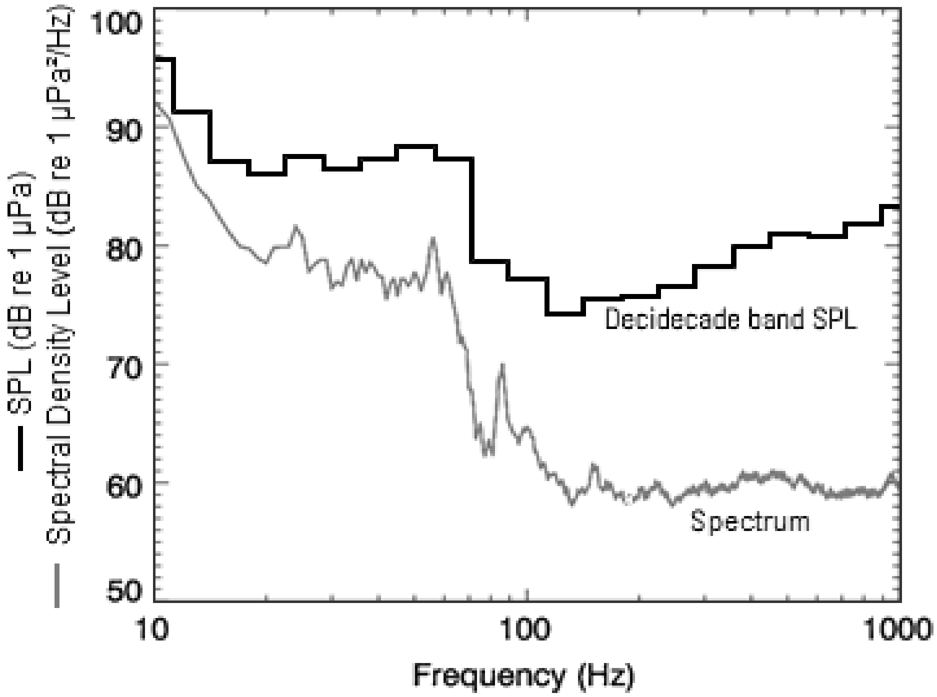


Figure D-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

Appendix E. Auditory (Frequency) Weighting Functions

The potential for noise to affect animals of a certain species depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

E.1. Frequency Weighting Functions-Technical Guidance (NMFS 2018)

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. This frequency-weighting function is expressed as:

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

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS, 2018). Table E-1 lists the frequency-weighting parameters for each hearing group. Figure E-1 shows the resulting frequency-weighting curves.

In 2017, the Criteria and Thresholds for US Navy Acoustic and Explosive Effects Analysis (Finneran et al. 2017) updated the auditory weighting functions to include sea turtles. The sea turtle weighting curve uses the same equation used for marine mammal auditory weighting functions (Equation E-1). Parameters are provided in Table E-1.

Table E-1. Parameters for the auditory weighting functions recommended by NMFS (2018).

Hearing group	a	b	f_{lo} (Hz)	f_{hi} (kHz)	K (dB)
Low-frequency cetaceans	1.0	2	200	19,000	0.13
Mid-frequency cetaceans	1.6	2	8,800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds in water	1.0	2	1,900	30,000	0.75
Otariid pinnipeds in water	2.0	2	940	25,000	0.64
Sea turtles	1.4	2	77	440	2.35

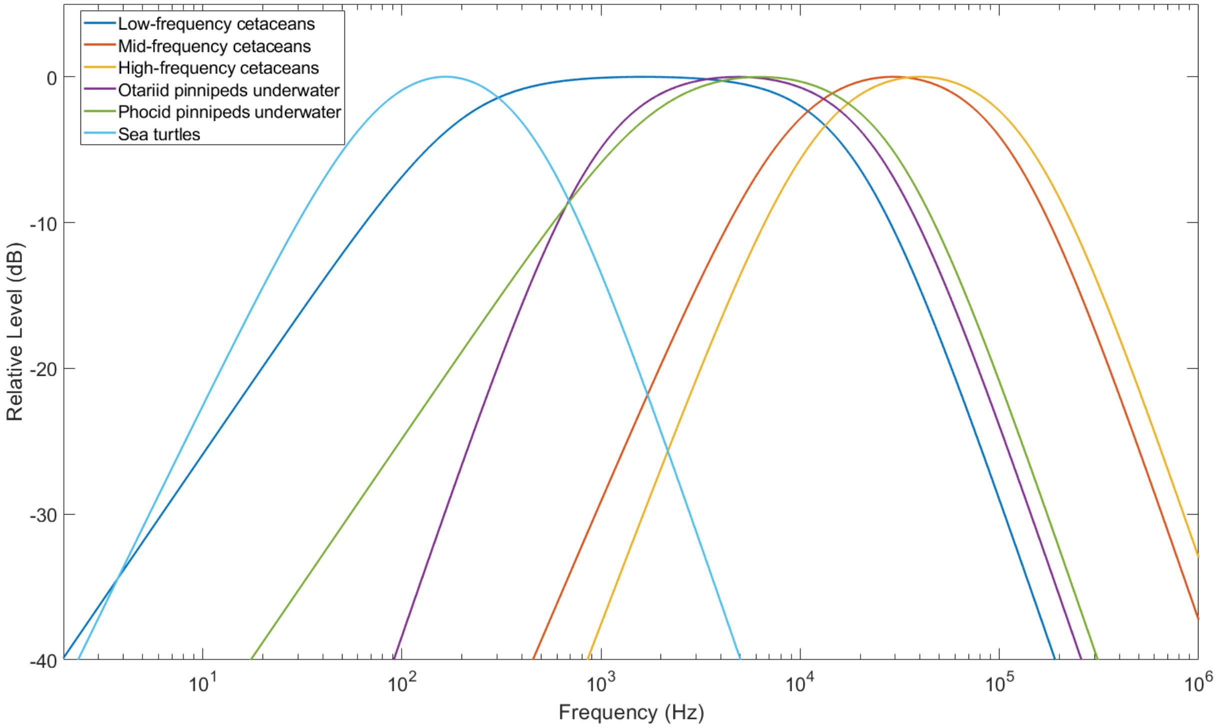


Figure E-1. Auditory weighting functions for the functional marine mammal hearing groups as recommended by NMFS (2018) and sea turtles as recommended by Finneran et al. (2017).

E.2. Southall et al. (2007) Frequency Weighting Functions

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

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

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

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

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

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

Functional hearing group	*a* (Hz)	*b* (Hz)
Low-frequency cetaceans	7	22,000
Mid-frequency cetaceans	150	160,000
High-frequency cetaceans	200	180,000
Pinnipeds in water	75	75,000

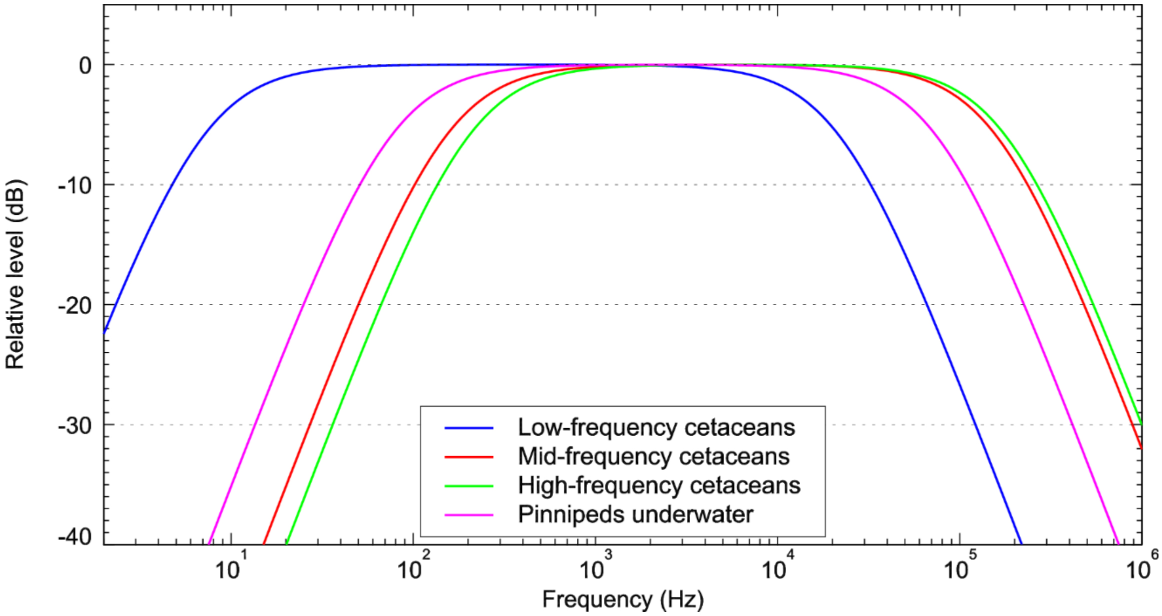


Figure E-2. Auditory weighting functions for the functional marine mammal hearing groups as recommended by Southall et al. (2007).

Appendix F. Pile Driving Source Model

A physical model of pile vibration and near-field sound radiation is used to calculate source levels of piles. The physical model employed in this study computes the underwater vibration and sound radiation of a pile by solving the theoretical equations of motion for axial and radial vibrations of a cylindrical shell. These equations of motion are solved subject to boundary conditions, which describe the forcing function of the hammer at the top of the pile and the soil resistance at the base of the pile (Figure F-1). Damping of the pile vibration due to radiation loading is computed for Mach waves emanating from the pile wall. The equations of motion are discretised using the finite difference (FD) method and are solved on a discrete time and depth mesh.

To model the sound emissions from the piles, the force of the pile driving hammers also had to be modeled. The force at the top of each pile was computed using the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010), which includes a large database of simulated hammers—both impact and vibratory—based on the manufacturer's specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

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

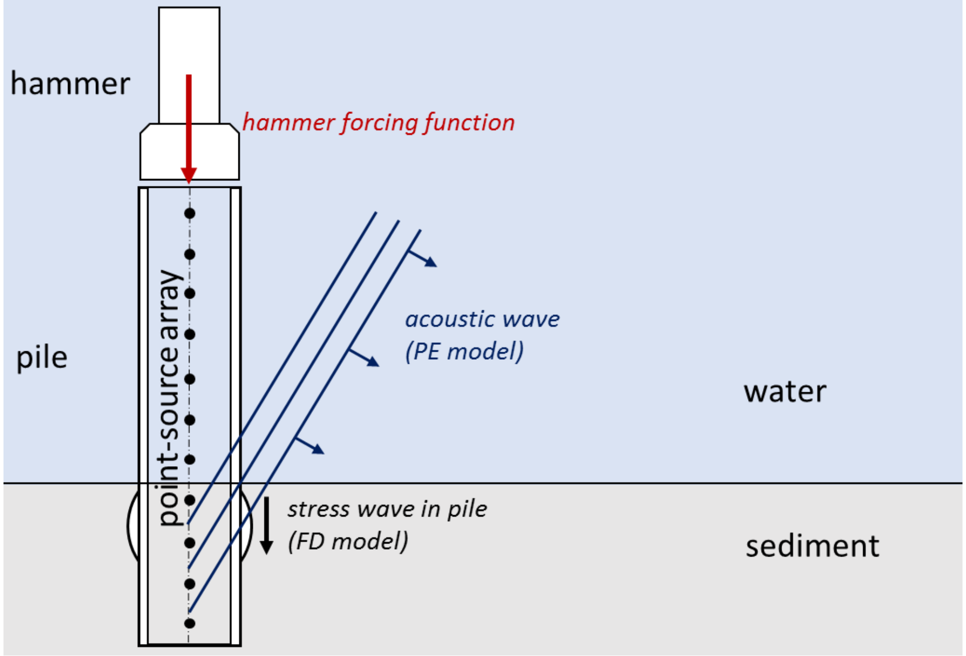


Figure F-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical array of point sources is used with the parabolic equation (PE)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

Appendix G. Sound Propagation Modeling

G.1. Environmental Parameters

G.1.1. Bathymetry

A bathymetry grid for the acoustic propagation model was compiled based on data provided by Deepwater Wind South Fork, LLC (DWSF, Denes et al. 2018) and Shuttle Radar Topography Mission (SRTM) referred to as SRTM-TOPO15+ (Becker et al. 2009).

G.1.2. Geoacoustics

In shallow water environments where there is increased interaction with the seafloor, the properties of the substrate have a large influence over the sound propagation. Compositional data of the surficial sediments were provided by DWSF (Denes et al. 2018). The dominant soil type is expected to be sand. Table G-1 shows the sediment layer geoacoustic property profile based on the sediment type and generic porosity-depth profile using a sediment grain-shearing model (Buckingham 2005).

Table G-1. Estimated geoacoustic properties used for modeling, as a function of depth. Within an indicated depth range, the parameter varies linearly within the stated range.

Depth below seafloor (m)	Material	Density (g/cm³)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–5	Sand	1.99–2.04	1,488–1,662	0–1.0	275	3.65
5–10		2.2	1,662–1,950	1.0–1.2		
10–100			1,950–2,040	1.2–2.1		
>100			2,604	2.1		

G.1.3. Sound Speed Profile

The speed of sound in sea-water is a function of temperature, salinity and pressure (depth) (Coppens 1981). Sound velocity profiles were obtained from the US Navy's Generalized Digital Environmental Model (GDEM; NAVO 2003). The sound speed profiles change little with depth near the proposed construction area (Figure G-1). The months of April through October are weakly downwardly refracting (Figure G-1), leading to more interaction with the seabed and (somewhat) greater attenuation with propagation distance. The months of November through March are nearly isovelocity (same velocity with depth), though with slower sound speed, and will interact (somewhat) less with the seabed. The absolute velocity of November and December is greater than January, February, and March. For this study, a representative sound speed profile for summer and winter are both used to produce results for comparison.

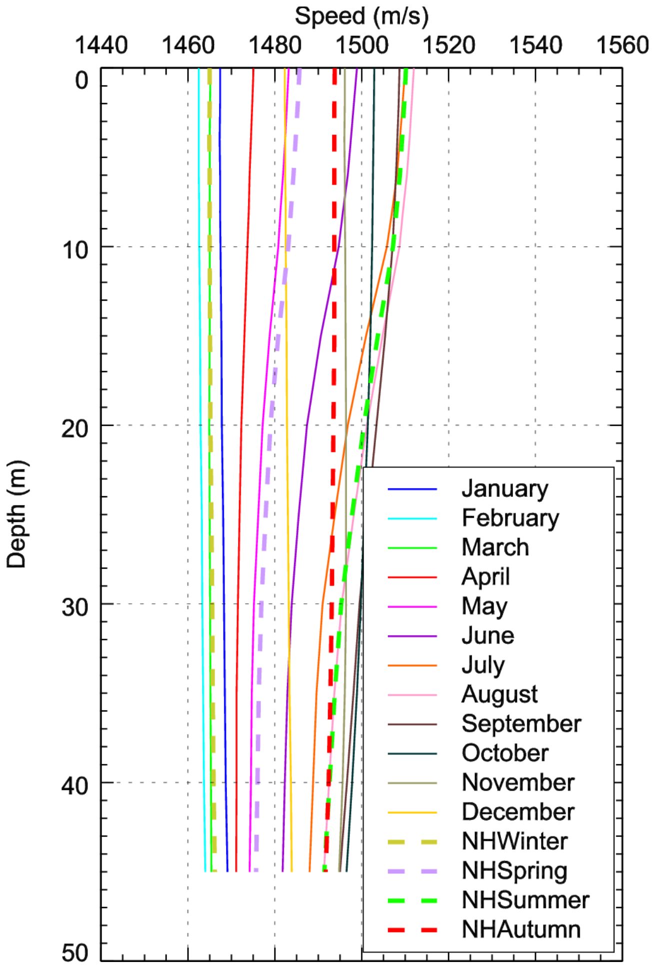


Figure G-1. Month and seasonal average sound velocity profiles in proposed construction area.

G.2. Propagation Loss

The propagation of sound through the environment can be modeled by predicting the acoustic propagation loss—a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which propagation loss occurs. Propagation loss also happens when the sound is absorbed and scattered by the seawater, and absorbed, scattered, and reflected at the water surface and within the seabed. Propagation loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

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

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

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

G.3. Sound Propagation with MONM

Underwater sound propagation (i.e., transmission loss) at frequencies of 10 Hz to 2 kHz was predicted with JASCO's Marine Operations Noise Model (MONM). MONM computes received per-pulse SEL for directional impulsive sources, and SEL over 1 s for non-impulsive sources, at a specified source depth. MONM computes acoustic propagation via a wide-angle parabolic equation (PE) solution to the acoustic wave equation (Collins 1993) based on a version of the US Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). The PE method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modeled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM computes acoustic fields in three dimensions by modeling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure G-2).

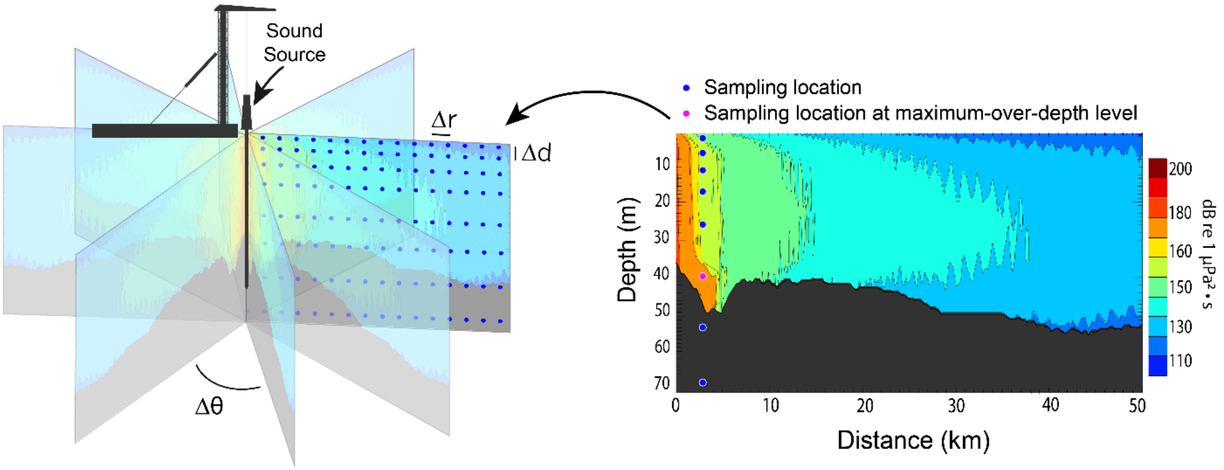


Figure G-2. Modeled three-dimensional sound field (N×2-D method) and maximum-over-depth modeling approach. Sampling locations are shown as blue dots on both figures. On the right panel, the pink dot represents the sampling location where the sound level is maximum over the water column. This maximum-over-depth level is used in calculating distances to sound level thresholds for some marine animals.

G.4. Sound Propagation with FWRAM

For impulsive sounds from impact pile driving, time-domain representations of the pressure waves generated in the water are required for calculating SPL and peak pressure level. Furthermore, the pile must be represented as a distributed source to accurately characterize vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle PE algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seabed geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Synthetic pressure waveforms were modeled over the frequency range 10–2048 Hz, inside a 1 s window (e.g., Figure G-3). The synthetic pressure waveforms were post-processed, after applying a travel time correction, to calculate standard SPL and SEL metrics versus range and depth from the source.

Besides providing direct calculations of the peak pressure level and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

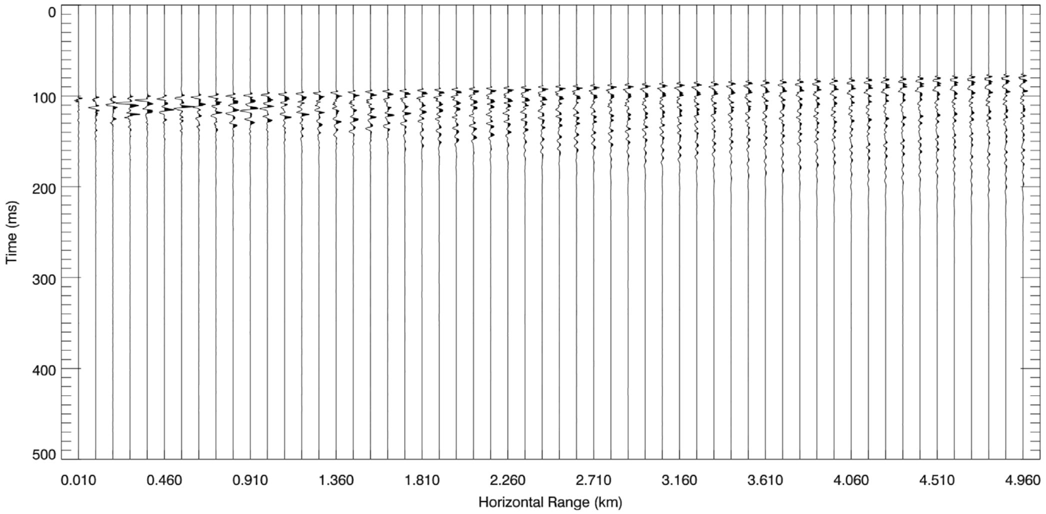
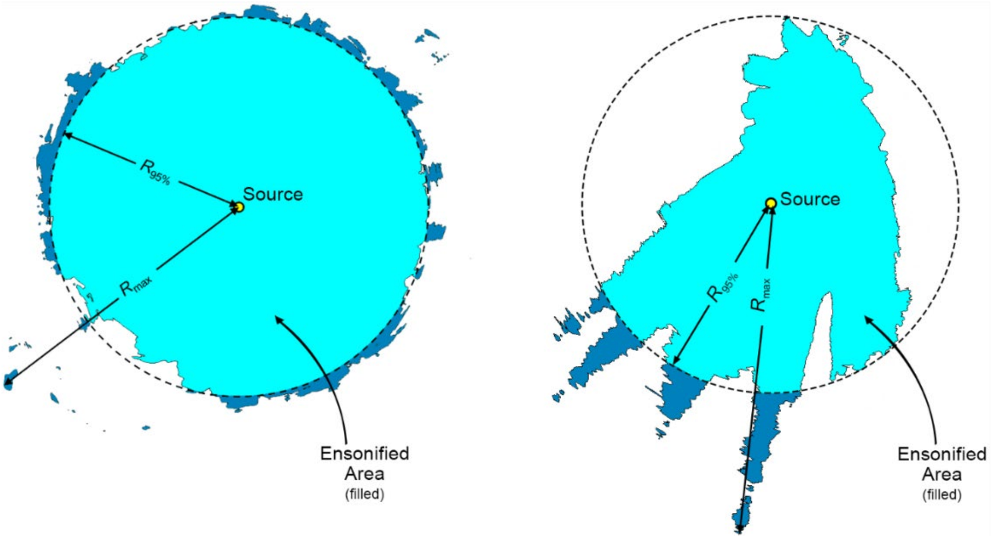


Figure G-3. Example of synthetic pressure waveforms computed by FWRAM for at multiple range offsets. Receiver depth is 35 m and the amplitudes of the pressure traces have been normalised for display purposes.

G.5. Estimating Range to Acoustic Thresholds

A maximum-over depth approach is used to determine ranges to the defined thresholds (ranges to isopleths). That is, at each horizontal sampling range, the maximum received level that occurs within the water column is used as the value at that range. The ranges to a threshold typically differ along different radii and may not be continuous because sound levels may drop below threshold at some ranges and exceed threshold at farther ranges. Figure G-4 shows an example of an area with sound levels above threshold and two methods of reporting the injury or behavioral disruption range: (1) R_{max}, the maximum range at which the sound level was encountered in the modeled maximum-over-depth sound field, and (2) $R_{95\%}$, the maximum range at which the sound level was encountered after the 5% farthest such points were excluded. $R_{95\%}$ is used because, regardless of the shape of the maximum-over-depth footprint, the predicted range encompasses at least 95% of the horizontal area that is considered to be exposed to sound at or above the specified level. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the heterogeneity of the acoustic environment. $R_{95\%}$ excludes the ends of protruding areas or small, isolated acoustic foci not representative of the nominal ensonification zone.



(a) (b)

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

G.6. Model Validation Information

Predictions from JASCO's propagation models (MONM and FWRAM) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Arctic, Canadian and southern United States waters, Greenland, Russia and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modeling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016)..

Appendix H. Acoustic Ranges for Impact Pile Driving

H.1. Single-strike SPL Acoustic Ranges

Table H-1. Distance (in km) to per-strike SPL isopleths for WTG monopile foundation at Site L024-114 at a hammer energy of 4000 kJ for a summer sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting (m-weighting) applied (Southall et al. 2007); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SPL (dB re 1 µPa)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.089	0.089	0.089	0.089	-	-	-	-	0.028	0.028
180	0.5	0.481	0.495	0.472	0.108	0.108	0.072	0.072	0.221	0.215
170	2.184	1.967	2.18	1.945	0.616	0.58	0.393	0.362	1.16	1.075
160	4.107	3.833	4.098	3.825	2.548	2.235	2.125	1.771	3.569	3.282
150	6.433	5.805	6.43	5.794	4.274	4.098	4.108	3.869	5.196	4.696
140	11.851	9.842	11.832	9.828	7.941	7.1	7.357	6.311	9.803	8.685
130	19.551	16.34	19.546	16.31	15.587	12.5	14.156	11.333	18.229	14.776
120	30.35	25.66	30.349	25.635	26.49	21.389	25.177	19.884	28.975	24.007

Dashes indicate that thresholds were not reached

Table H-2. Distance (in km) to per-strike SPL isopleths for WTG monopile foundation at Site L024-114 at a hammer energy of 4000 kJ for a winter sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting (m-weighting) applied (Southall et al. 2007); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SPL (dB re 1 µPa)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.02	0.02	0.02	0.02	-	-	-	-	-	-
190	0.122	0.122	0.12	0.117	0.02	0.02	-	-	0.045	0.045
180	0.728	0.671	0.723	0.662	0.134	0.128	0.082	0.082	0.344	0.328
170	2.96	2.741	2.937	2.724	0.901	0.82	0.625	0.563	1.968	1.713
160	4.601	4.271	4.586	4.26	3.453	3.24	3.046	2.772	3.978	3.785
150	11.732	9.758	11.732	9.741	6.964	6.007	5.38	4.776	9.713	8.222
140	34.632	29.234	34.612	29.177	25.809	20.302	21.022	17.282	31.13	25.93
130	49.469	41.18	49.469	41.18	49.469	41.178	49.469	41.178	49.469	41.18
120	49.469	41.257	49.469	41.257	49.469	41.256	49.469	41.255	49.469	41.257

Dashes indicate that thresholds were not reached

Table H-3. Distance (in km) to per-strike SPL isopleths for OSS monopile foundations at Site OSS2 at a hammer energy of 4000 kJ, computed for a summer sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting (m-weighting) applied (Southall et al. 2007); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SPL (dB re 1 µPa)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.029	0.029	0.029	0.029	0.001	0.001	0.001	0.001	0.001	0.001
190	0.162	0.157	0.157	0.152	0.001	0.001	0.001	0.001	0.045	0.045
180	0.82	0.764	0.801	0.744	0.135	0.128	0.085	0.083	0.306	0.297
170	2.568	2.384	2.556	2.369	0.662	0.621	0.444	0.412	1.482	1.376
160	4.254	4.1	4.247	4.093	2.582	2.379	2.068	1.843	3.76	3.545
150	7.497	6.921	7.479	6.898	4.304	4.162	4.091	3.935	5.809	5.328
140	12.488	11.079	12.476	11.059	8.625	7.857	7.414	6.795	10.831	9.763
130	19.099	15.894	19.072	15.88	14.991	12.871	13.54	11.841	17.315	14.722
120	26.465	20.89	26.448	20.879	22.902	18.487	21.667	17.578	25.25	20.013

Table H-4. Distance (in km) to per-strike SPL isopleths for OSS monopile foundations at Site OSS2 at a hammer energy of 4000 kJ, computed for a winter sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting (m-weighting) applied (Southall et al. 2007); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SPL (dB re 1 µPa)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.029	0.029	0.029	0.029	0.001	0.001	0.001	0.001	0.001	0.001
190	0.181	0.172	0.179	0.17	0.021	0.021	0.001	0.001	0.064	0.063
180	1.005	0.937	0.985	0.924	0.153	0.145	0.1	0.1	0.424	0.397
170	3.214	3.024	3.208	3.005	0.938	0.877	0.581	0.545	1.994	1.836
160	5.12	4.698	5.081	4.671	3.393	3.216	2.853	2.597	4.021	3.838
150	12.252	10.888	12.236	10.864	6.8	6.056	5.064	4.622	10.161	9.028
140	28.829	22.922	28.829	22.892	22.794	18.395	20.832	16.082	27.053	21.174
130	49.47	39.843	49.47	39.844	49.47	39.88	49.47	39.906	49.47	39.853
120	49.47	40.018	49.47	40.018	49.47	40.018	49.47	40.023	49.47	40.017

H.2. Single-strike SEL Acoustic Ranges

Table H-5. Distance (in km) to per-strike SEL isopleths for WTG monopile foundation at Site L024-114 at a hammer energy of 4000 kJ for a summer sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting applied (Southall et al. 2007, NMFS 2018); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SEL (dB re 1 µPa²·s)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	-	-	-	-	-
180	0.117	0.117	0.028	0.028	-	-	-	-	-	-
170	0.597	0.555	0.189	0.184	-	-	-	-	-	-
160	2.472	2.185	0.956	0.882	-	-	-	-	0.108	0.108
150	5.437	4.851	3.369	3.069	0.06	0.06	0.028	0.028	0.668	0.621
140	9.801	8.618	7.383	6.62	0.316	0.297	0.156	0.152	2.797	2.357
130	16.745	14.26	13.534	11.422	2.003	1.547	1.172	1.066	6.586	5.646
120	26.686	22.726	23.849	19.574	4.852	3.827	3.619	2.827	13.132	10.295

Dashes indicate that thresholds were not reached

Table H-6. Distance (in km) to per-strike SEL isopleths for WTG monopile foundation at Site L024-114 at a hammer energy of 4000 kJ for a winter sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting applied (NMFS 2018); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SEL (dB re 1 µPa^2·s)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	-	-	-	-	-	-	-	-	-	-
190	0.028	0.028	-	-	-	-	-	-	-	-
180	0.146	0.144	0.04	0.04	-	-	-	-	-	-
170	0.852	0.8	0.272	0.268	-	-	-	-	0.02	0.02
160	3.507	3.15	1.636	1.409	-	-	-	-	0.134	0.128
150	9.612	7.81	5.723	5.154	0.1	0.1	0.028	0.028	1	0.773
140	25.799	20.453	18.279	15.137	0.481	0.418	0.242	0.206	4.566	3.997
130	49.469	40.87	49.469	40.487	2.478	2.167	1.434	1.124	19.779	14.549
120	49.469	41.239	49.469	41.239	9.091	6.975	5.603	4.326	49.469	41.17

Dashes indicate that thresholds were not reached

Table H-7. Distance (in km) to per-strike SEL isopleths for OSS monopile foundations at Site OSS2 at a hammer energy of 4000 kJ, computed for a summer sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting applied (NMFS 2018); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SEL (dB re 1 µPa^2·s)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.029	0.029	0.029	0.029	0.001	0.001	0.001	0.001	0.001	0.001
190	0.162	0.157	0.157	0.152	0.001	0.001	0.001	0.001	0.045	0.045
180	0.82	0.764	0.801	0.744	0.135	0.128	0.085	0.083	0.306	0.297
170	2.568	2.384	2.556	2.369	0.662	0.621	0.444	0.412	1.482	1.376
160	4.254	4.1	4.247	4.093	2.582	2.379	2.068	1.843	3.76	3.545
150	7.497	6.921	7.479	6.898	4.304	4.162	4.091	3.935	5.809	5.328
140	12.488	11.079	12.476	11.059	8.625	7.857	7.414	6.795	10.831	9.763
130	19.099	15.894	19.072	15.88	14.991	12.871	13.54	11.841	17.315	14.722
120	26.465	20.89	26.448	20.879	22.902	18.487	21.667	17.578	25.25	20.013

Table H-8. Distance (in km) to per-strike SEL isopleths for OSS monopile foundations at Site OSS2 at a hammer energy of 4000 kJ, computed for a winter sound propagation environment. Ranges are reported as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances from the source to modeled broadband (1–25,000 Hz) maximum over depth sound level thresholds, unweighted and with frequency weighting applied (NMFS 2018); LF: low-frequency cetaceans, MF: mid-frequency cetaceans, HF: high-frequency cetaceans.

SEL (dB re 1 µPa²·s)	Unweighted		LF		MF		HF		PPW	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.029	0.029	0.029	0.029	0.001	0.001	0.001	0.001	0.001	0.001
190	0.181	0.172	0.179	0.17	0.021	0.021	0.001	0.001	0.064	0.063
180	1.005	0.937	0.985	0.924	0.153	0.145	0.1	0.1	0.424	0.397
170	3.214	3.024	3.208	3.005	0.938	0.877	0.581	0.545	1.994	1.836
160	5.12	4.698	5.081	4.671	3.393	3.216	2.853	2.597	4.021	3.838
150	12.252	10.888	12.236	10.864	6.8	6.056	5.064	4.622	10.161	9.028
140	28.829	22.922	28.829	22.892	22.794	18.395	20.832	16.082	27.053	21.174
130	49.47	39.843	49.47	39.844	49.47	39.88	49.47	39.906	49.47	39.853
120	49.47	40.018	49.47	40.018	49.47	40.018	49.47	40.023	49.47	40.017

H.3. Single-strike Peak Acoustic Ranges

Table H-9. Distance (in km) to peak pressure level (PK) isopleths at the highest hammer energy for each of the pile types using a summer sound speed profile. All ranges are reported assuming a 10 dB broadband attenuation.

PK	Ranges (km)	
	WTG Monopile Foundation	OSS Monopile Foundation
230	-	-
219	0.005	0.006
218	0.006	0.007
216	0.010	0.011
213	0.018	0.019
210	0.072	0.071
207	0.095	0.090
202	0.178	0.260

Dashes indicate that thresholds were not reached

Table H-10. Distance (in km) to peak pressure level (PK) isopleths at the highest hammer energy for each of the pile types using a winter sound speed profile. All ranges are reported assuming a 10 dB broadband attenuation.

PK	Ranges (km)	
	WTG Monopile Foundation	OSS Monopile Foundation
230	-	-
219	0.005	0.006
218	0.006	0.007
216	0.010	0.010
213	0.018	0.019
210	0.074	0.072
207	0.101	0.095
202	0.200	0.260

Dashes indicate that thresholds were not reached

H.4. Impact Pile Driving per Pile SEL Ranges

H.4.1. Summer

Table H-11. Ranges ($R_{95\%}$ in km) to injury thresholds (NMFS 2018) for marine mammal functional hearing groups due to impact hammering of one WTG 12 m monopile in 24 hours, using an IHC S-4000 hammer with attenuation at two selected modeling locations (L024-002 and L024-114).

Hearing group	Threshold (dB)	L024-002				L024-114			
		Attenuation level (dB)				Attenuation level (dB)			
		0	6	10	15	0	6	10	15
Low-frequency cetaceans	183	9.065	6.27	4.656	2.952	8.458	5.904	4.476	2.868
Mid-frequency cetaceans	185	0.595	0.122	0.08	0.028	0.564	0.146	0.089	0.028
High-frequency cetaceans	155	6.756	4.6	3.42	2.246	6.61	4.532	3.447	2.174
Phocid pinnipeds	185	2.985	1.471	0.81	0.3	3.03	1.601	0.844	0.326
Sea turtles	210	1.598	0.679	0.33	0.161	1.62	0.679	0.354	0.161

Table H-12. Ranges ($R_{95\%}$ in km) to injury thresholds (NMFS 2018) for marine mammal functional hearing groups due to impact hammering of one OSS 15 m monopile in 24 hours, using an IHC S-4000 hammer with attenuation at two selected modeling locations (OSS1 and OSS2).

Hearing group	Threshold (dB)	OSS1				OSS2			
		Attenuation level (dB)				Attenuation level (dB)			
		0	6	10	15	0	6	10	15
Low-frequency cetaceans	183	9.252	6.768	5.324	3.774	10.603	7.835	5.97	4.032
Mid-frequency cetaceans	185	0.605	0.184	0.09	0.029	0.689	0.206	0.09	0.029
High-frequency cetaceans	155	7.08	4.968	3.846	2.517	7.608	5.401	4.048	2.758
Phocid pinnipeds	185	3.542	1.983	1.141	0.604	3.81	2.058	1.154	0.582
Sea turtles	210	2.493	1.329	0.84	0.397	2.585	1.394	0.86	0.397

H.4.2. Winter

Table H-13. Ranges ($R_{95\%}$ in km) to injury thresholds (NMFS 2018) for marine mammal functional hearing groups due to impact hammering of one WTG 12 m monopile in 24 hours, using an IHC S-4000 hammer with attenuation at two selected modeling locations (L024-002 and L024-114).

Hearing group	Threshold (dB)	L024-002				L024-114			
		Attenuation level (dB)				Attenuation level (dB)			
		0	6	10	15	0	6	10	15
Low-frequency cetaceans	183	24.415	13.061	8.663	4.847	28.108	12.369	8.109	4.768
Mid-frequency cetaceans	185	0.511	0.206	0.089	0.028	0.594	0.184	0.102	0.028
High-frequency cetaceans	155	13.885	7.94	5.246	2.709	14.363	8.028	5.404	3.226
Phocid pinnipeds	185	4.907	2.226	1.134	0.428	5.205	2.302	1.165	0.475
Sea turtles	210	2.261	0.955	0.494	0.201	2.35	0.988	0.512	0.224

Table H-14. Ranges ($R_{95\%}$ in km) to injury thresholds (NMFS 2018) for marine mammal functional hearing groups due to impact hammering of one OSS 15 m monopile in 24 hours, using an IHC S-4000 hammer with attenuation at two selected modeling locations (OSS1 and OSS2).

Hearing group	Threshold (dB)	OSS1				OSS2			
		Attenuation level (dB)				Attenuation level (dB)			
		0	6	10	15	0	6	10	15
Low-frequency cetaceans	183	31.061	13.98	9.489	5.948	28.983	16.273	11.121	6.646
Mid-frequency cetaceans	185	0.754	0.241	0.142	0.064	0.72	0.253	0.119	0.063
High-frequency cetaceans	155	15.856	8.88	5.941	3.36	16.353	9.437	6.475	3.706
Phocid pinnipeds	185	6.462	2.7	1.547	0.688	6.72	2.773	1.583	0.698
Sea turtles	210	3.284	1.715	1.024	0.477	3.484	1.767	1.054	0.491

Appendix I. ITAP Comparison

ITAP GmbH is a German agency accredited for measuring and forecasting sound levels produced during impact pile driving for installations such as wind farms (see below/attachment). Sound level predictions were made using ITAP's empirical model to forecast single-strike SEL at 750 m from the pile (results supplied by Ørsted). ITAP's empirical forecasting model was created by compiling and fitting numerous measurements at 750 m for a variety of pile dimensions, hammer types, hammer energy levels, and at several locations (though primarily in the North Sea). The ITAP model is based on the 95th percentile of the single-strike SEL measurement. That is, the SEL value used to generate the model was the level inclusive of 95% of the single-strike measurements at a given hammer energy level (the highest 5% of single-strike SEL measurements were discarded). Because the ITAP model forecasts mean values from aggregated measurements, application to specific pile driving scenarios may be expected to differ to some degree from the forecast.

As a way of validating the acoustic modeling for this study, single-strike SEL received levels at 750 m from the driven pile were determined from the calculated 3-D sound fields (see Appendices F, G, and H) and compared to the ITAP forecast (Tables I-1 and I-2). ITAP's model forecasts the 95th percentile of SEL values while the acoustic modeling in this study results in an estimate of a median value (50th percentile), so the levels calculated for this study at 750 m are expected to be lower than the forecasted levels. All values were rounded to the nearest dB.

Table I-1 shows that the single- strike SEL levels at 750 m predicted in this study compare well with the ITAP forecast. At lower hammer energy levels, this study's predicted received levels are lower than the ITAP forecast, and at higher hammer energy levels, the predicted received levels are greater than the forecast levels. It is likely that the pile penetration depth accounts for this trend. When more of the pile has penetrated into the seabed, the pile as a sound source has a larger radiating area in the water and substrate and produces more sound energy. In this study, lower hammer energy levels were measured at the start of pile driving when little of the pile has penetrated into the substrate. Within the ITAP model, measurements from all hammer energy levels represent a range of pile penetration depths such that measurements of lower hammer energy strikes include piles near full penetration and driven with smaller hammers, which may produce louder sounds.

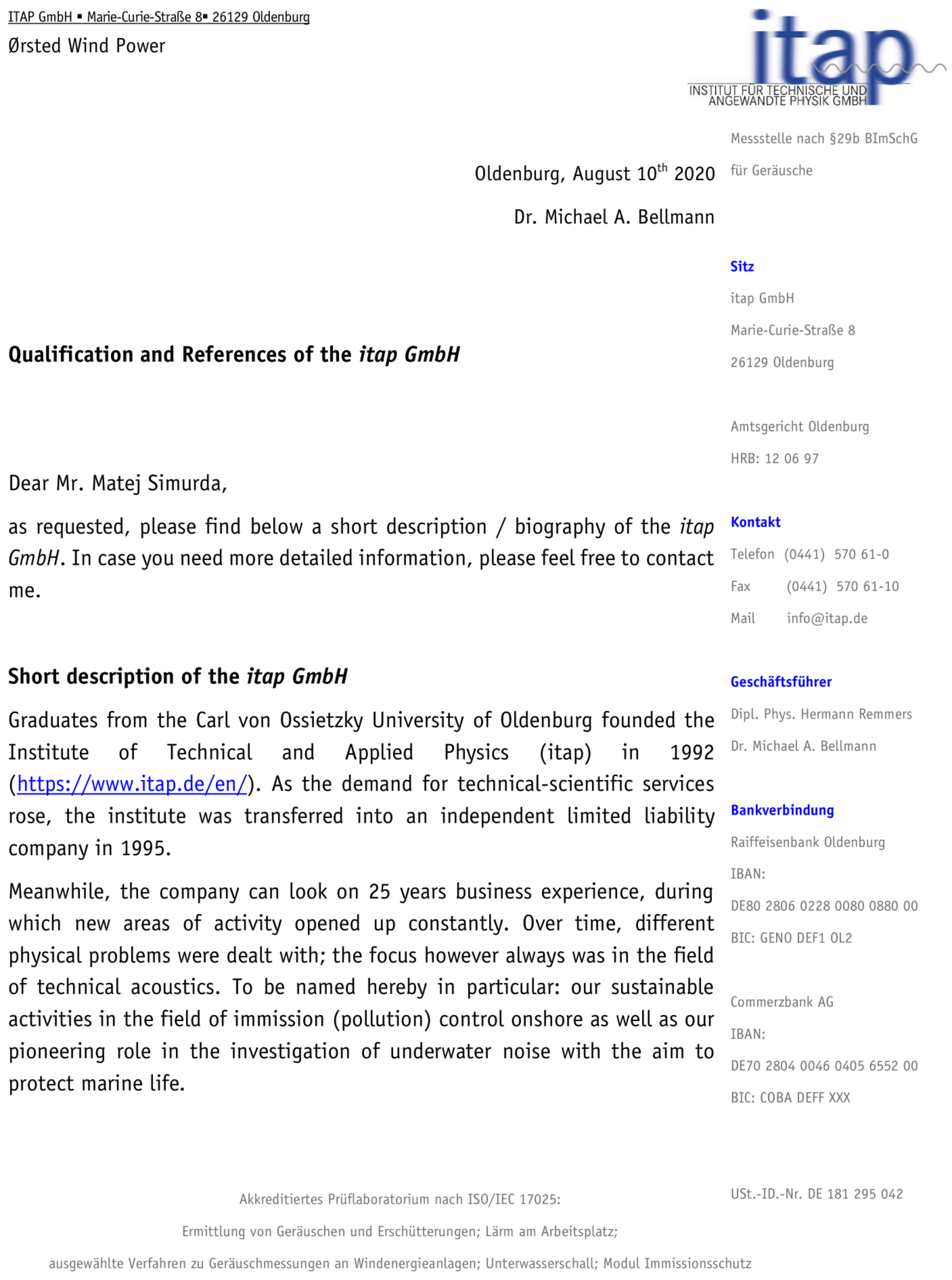
Table I-1. Broadband single-strike SEL (dB re 1 µPa^2·s) comparison of WTG monopile foundation modeled sound field with itap (Bellmann et al. 2020b) at 750 m.

Source location/Season	Hammer energy (kJ			
	1000 kJ	2000 kJ	3000 kJ	4000 kJ
itap (12 m)	*179*	*181*	*183*	*184*
L024-002, Summer	179	181	182	183
L024-114, Summer	181	184	184	185
L024-002, Winter	179	181	182	183
L024-114, Winter	180	184	184	185

Table I-2. Broadband single-strike SEL (dB re 1 µPa^2·s) comparison of OSS monopile modeled sound field with itap (Bellmann et al. 2020b) at 750 m.

Source location/Season	Hammer energy (kJ			
	1000 kJ	2000 kJ	3000 kJ	4000 kJ
itap (15 m)	*180*	*182*	*184*	*185*
OSS1, Summer	181	179	181	184
OSS2, Summer	183	181	183	185
OSS1, Winter	181	179	181	184
OSS2, Winter	183	181	183	185

I.1. itap Description and Qualifications



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Oldenburg, August 10th 2020

Dr. Michael A. Bellmann

Qualification and References of the *itap GmbH*

Dear Mr. Matej Simurda,

as requested, please find below a short description / biography of the *itap GmbH*. In case you need more detailed information, please feel free to contact me.

Short description of the *itap GmbH*

Graduates from the Carl von Ossietzky University of Oldenburg founded the Institute of Technical and Applied Physics (itap) in 1992 (https://www.itap.de/en/). As the demand for technical-scientific services rose, the institute was transferred into an independent limited liability company in 1995.

Meanwhile, the company can look on 25 years business experience, during which new areas of activity opened up constantly. Over time, different physical problems were dealt with; the focus however always was in the field of technical acoustics. To be named hereby in particular: our sustainable activities in the field of immission (pollution) control onshore as well as our pioneering role in the investigation of underwater noise with the aim to protect marine life.

Akkreditiertes Prüflaboratorium nach ISO/IEC 17025:
Ermittlung von Geräuschen und Erschütterungen; Lärm am Arbeitsplatz;
ausgewählte Verfahren zu Geräuschmessungen an Windenergieanlagen; Unterwasserschall; Modul Immissionsschutz

Qualification and certification

The *itap GmbH* is a notified measuring agency in Germany according to §29b BImSchG (Federal Control of Pollution Act) and has an accredited quality management system (QMS) according to the ISO/IEC 17025 for emission and immission (pollution) measurements of sounds and vibrations (accreditation in accordance with the DAkkS – German accreditation body – for measurements and forecasts of underwater noise (impulse and continuous noise), the immission (pollution) protection module sounds and vibrations, as well as noise in the workplace).

Technical references: underwater noise

The itap GmbH was involved in all German Offshore Windfarm (OWF) construction projects since 2008, by predicting the estimated pile-driving noise during construction, consultancy services regarding noise measurements and noise mitigation strategies, as well as measuring ambient and pile-driving noise during the construction phase and operational noise of Offshore Wind Turbine Generators after completion of construction works.

Within a Research and Development (R&D) project the technical information system for underwater noise MarinEARS (Marine Explorer and Registry of Sound https://marinears.bsh.de) was designed in cooperation with the German regulatory authority BSH (Bundesamt für Seeschifffahrt und Hydrographie). All quality checked and post-processed underwater noise measurement data from 2012 till 2020 for German OWF projects within MarinEARS were provided by the *itap GmbH*. The technical field report regarding the experiences with impact pile-driving noise as well as the application of noise mitigation measures of this R&D project is available in German and English version at our homepage: https://www.itap.de/en/news/field-report-pile-driving-noise-published/.

Furthermore, the *itap GmbH* was also involved in OWF construction projects in Belgium, The Netherlands, Denmark, Sweden, United Kingdom and Taiwan, providing underwater noise predictions and consultancy services as well as performing underwater noise measurements.

The *Itap GmbH* has measured underwater noise during use of all available noise mitigation measures (noise mitigation systems as well as noise abatement systems) for offshore constructions worldwide under offshore conditions (offshore reliable and state-of-the-art noise mitigation measures as well as prototypes in accordance to DIN SPEK 45653 (2017)).

Besides the main task domain of underwater noise in connection with OWF construction projects (pile-driving noise), the *itap GmbH* predicts and measures underwater noise of all kinds of maritime activities. Such as for offshore projects like cable or pipe laying activities, cable fault detection, any acoustical surveys (e. g. sonar operations), clearance of unexploded ordnances (UXO), detonations or decommissioning of any offshore constructions, vessel based noise as well as for costal projects (e. g. within harbor facilities).

Services: underwater noise

Consultancy: The *itap GmbH* provides consultancy services related to the full scope of underwater noise predictions and measurements (especially related to Offshore Wind Farms). In recent years, our experience in Europe has expanded and extended beyond Europe to the United States of America, Taiwan and Australia. Due to our pioneering role in this field and the associated 20 years of experience in Europe, we can offer a wide range of consulting services. Such as preparation of noise mitigation concepts, selection of suitable noise mitigation measures, support within approval procedures and contact to local authorities.

Underwater noise prognosis: In recent years, our portfolio of underwater noise prediction services regarding pile driving noise has grown to meet a variety of different local regulatory requirements for various noise mitigation values throughout Europe and Taiwan and to assist the environmental impact assessment by species specific underwater noise modelling like in UK, Australia and the USA. The *itap GmbH* is able to perform underwater noise prognosis for various noise sources regarding impulsiveness and continuous noise according to national guidelines and project-specific requirements of the local approval authorities and respective local environmental conditions.

For underwater noise prognosis we are using our extensive experiences within this domain. Based on this, we have developed two models for underwater noise prediction:

1) Impulsiveness underwater noise model: Our validated pile-driving noise model based on measured values over the last 20 years within more than 35 pcs OWF and more than 30 pcs single foundation projects (empirical approach). With this pile-driving model, mitigated as well as unmitigated pile-driving noise can be predicted (broadband as well as frequency depending).
   This model also contains the empirical approach of Soloway and Dahl (2014) as well as own measured data during UXO clearance activities and detonations.
2) Continuous noise model: *Itap GmbH* also developed a model for continuous noise activities like vessel based construction projects (pipe and cable laying projects as well as operational noise from Offshore Wind Turbine Generator). However, this model will currently be extended to vibro-piling activities based on measured data as well.

<u>Underwater noise measurements:</u> At the beginning of the underwater noise measurements with regard to OWFs in 2000, there was no measurement device commercially available on the market, so the decision was made to develop an own system. The benefit of our own developed and constructed devices is that we can adapt our measurement devices to a variety of special requirements regarding amplitude and frequency range (from ambient noise till noise during UXO clearance from 20 Hz up to 200 kHz). Furthermore, the mooring systems for our measurement devices are self-constructed and can be adapted to the local environmental conditions easily. During the last 20 years we have been able to gain a lot of experience with different measurements under different environmental conditions.

All measurement devices of *itap GmbH* are fulfilling the requirements of national and international standards (e. g. BSH, 2011; ISO 18406) and the calibration is performed in accordance to ISO/IEC 17025 (2018).

<u>Research and Development:</u> Due the special expertise in the field of technical acoustics the *itap GmbH* has participated in various research projects dealing with underwater noise (https://www.itap.de/en/research-projects/). E. g. in the field of underwater sound propagation, further development of noise mitigation measures and the evaluation of the impact of underwater noise on marine mammals.

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Appendix J. Animal Movement and Exposure Modeling

To assess the risk of impacts from anthropogenic sound exposure, an estimate of the received sound levels for individuals of each species known to occur in the Project Area during the assessed activities is required. Both sound sources and animals move. The sound fields may be complex, and the sound received by an animal is a function of where the animal is at any given time. To a reasonable approximation, the locations of the project sound sources are known, and acoustic modeling can be used to predict the individual and aggregate 3-D sound fields of the sources. The location and movement of animals within the sound field, however, is unknown. Realistic animal movement within the sound field can be simulated. Repeated random sampling (Monte Carlo method simulating many animals within the operations area) is used to estimate the sound exposure history of the population of simulated animals (animats) during the operation.

Monte Carlo methods provide a heuristic approach for determining the probability distribution function (PDF) of complex situations, such as animals moving in a sound field. The probability of an event's occurrence is determined by the frequency with which it occurs in the simulation. The greater the number of random samples, in this case the more animats, the better the approximation of the PDF. Animats are randomly placed, or seeded, within the simulation boundary at a specified density (animats/km^2). Higher densities provide a finer PDF estimate resolution but require more computational resources. To ensure good representation of the PDF, the animat density is set as high as practical allowing for computation time. The animat density is much higher than the real-world density to ensure good representation of the PDF. The resulting PDF is scaled using the real-world density.

Several models for marine mammal movement have been developed (Ellison et al. 1999, Frankel et al. 2002, Houser 2006). These models use an underlying Markov chain to transition from one state to another based on probabilities determined from measured swimming behavior. The parameters may represent simple states, such as the speed or heading of the animal, or complex states, such as likelihood of participating in foraging, play, rest, or travel. Attractions and aversions to variables like anthropogenic sounds and different depth distances can be included in the models.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was based on the open-source marine mammal movement and behavior model (3MB; Houser 2006) and used to predict the exposure of animats (virtual marine mammals and sea turtles) to sound arising from sound sources in simulated representative surveys. Inside JASMINE, the sound source location mimics the movement of the source vessel through the proposed survey pattern. Animats are programmed to behave like the marine animals likely to be present in the survey area. The parameters used for forecasting realistic behaviors (e.g., diving, foraging, aversion, surface times, etc.) are determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. An individual animat's modeled sound exposure levels are summed over the total simulation duration, such as 24 hours or the entire simulation, to determine its total received energy, and then compared to the assumed threshold criteria.

JASMINE uses the same animal movement algorithms as the 3MB model (Houser 2006) but has been extended to be directly compatible with MONM and FWRAM acoustic field predictions, for inclusion of source tracks, and importantly for animats to change behavioral states based on time and space dependent modeled variables such as received levels for aversion behavior (Ellison et al. 2016).

J.1. Animal Movement Parameters

JASMINE uses previously measured behavior to forecast behavior in new situations and locations. The parameters used for forecasting realistic behavior are determined (and interpreted) from marine species studies (e.g., tagging studies). Each parameter in the model is described as a probability distribution. When limited or no information is available for a species parameter, a Gaussian or uniform distribution may be chosen for that parameter. For the Gaussian distribution, the user determines the mean and standard deviation of the distribution from which parameter values are drawn. For the uniform distribution, the user determines the maximum and minimum distribution from which parameter values are drawn. When detailed information about the movement and behavior of a species are available, a user-created distribution vector, including cumulative transition probabilities, may be used (referred to here as a vector model; Houser 2006). Different sets of parameters can be defined for different behavior states. The probability of an animat starting out in or transitioning into a given behavior state can in turn be defined in terms of the animat's current behavioral state, depth, and the time of day. In addition, each travel parameter and behavioral state has a termination function that governs how long the parameter value or overall behavioral state persists in simulation.

The parameters used in JASMINE describe animal movement in both the vertical and horizontal planes. A description of parameters relating to travel in these two planes are briefly described below. JASCO maintains species-specific choices of values for the behavioral parameters used in this study. The parameter values are available for limited distribution upon request.

Travel sub-models

- **Direction**–determines an animat's choice of direction in the horizontal plane. Sub-models are available for determining the heading of animats, allowing for movement to distance from strongly biased to undirected. A random walk model can be used for behaviors with no directional preference, such as feeding and playing. In a random walk, all bearings are equally likely at each parameter transition time step. A correlated random walk can be used to smooth the changes in bearing by using the current heading as the mean of the distribution from which to draw the next heading. An additional variant of the correlated random walk is available that includes a directional bias for use in situations where animals have a preferred absolute direction, such as migration. A user-defined vector of directional probabilities can also be input to control animat heading. For more detailed discussion of these parameters, see Houser (2006) and Houser and Cross (1999).
- **Travel rate**–defines an animat's rate of travel in the horizontal plane. When combined with vertical speed and dive depth, the dive profile of the animat is produced.

Dive sub-models

- **Ascent rate**–defines an animat's rate of travel in the vertical plane during the ascent portion of a dive.
- **Descent rate**–defines an animat's rate of travel in the vertical plane during the descent portion of a dive.
- **Depth**–defines an animat's maximum dive depth.
- **Bottom following**–determines whether an animat returns to the surface once reaching the ocean floor, or whether it follows the contours of the bathymetry.
- **Reversals**–determines whether multiple vertical excursions occur once an animat reaches the maximum dive depth. This behavior is used to emulate the foraging behavior of some marine mammal species at depth. Reversal-specific ascent and descent rates may be specified.
- **Surface interval**–determines the duration an animat spends at, or near, the surface before diving again.

J.1.1. Exposure Integration Time

The interval over which acoustic energy (*SEL*) should be integrated and maximal sound pressure (*SPL*) determined is not well defined. Both Southall et al. (2007) and the NMFS (2018) recommend a 24 h baseline accumulation period, but state that there may be situations where this is not appropriate (e.g., a high-level source and confined population). Resetting the integration after 24 h can lead to overestimating the number of individual animals exposed because individuals can be counted multiple times during an operation. The type of animal movement engine used in this study simulates realistic movement using swimming behavior collected over relatively short periods (hours to days) and does not include large-scale movement such as migratory circulation patterns. Therefore, the simulation time should be limited to a few weeks, the approximate scale of the collected data (e.g., marine mammal tag data) (Houser 2006). For this study, one-week simulations (i.e., 7 days) were modeled.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that might be present in the Project Area during sound-producing activities is included. However, there are limits to the simulation area, and computational overhead increases with area. For practical reasons, the simulation area is limited in this analysis to a maximum distance of 38 miles (70 km) from the RWF (see figures in Section J.3). In the simulation, every animat that reaches and leaves a border of the simulation area is replaced by another animat entering at an opposite border—e.g., an animat departing at the northern border of the simulation area is replaced by an animat entering the simulation area at the southern border at the same longitude. When this action places the animat in an inappropriate water depth, the animat is randomly placed on the map at a depth suited to its species definition (Appendix Section J.3). The exposures of all animats (including those leaving the simulation and those entering) are kept for analysis. This approach maintains a consistent animat density and allows for longer integration periods with finite simulation areas.

J.1.2. Aversion

Aversion is a common response of animals to sound, particularly at relatively high sound exposure levels (Ellison et al. 2012). As received sound level generally decreases with distance from a source, this aspect of natural behavior can strongly influence the estimated maximum sound levels an animal is predicted to receive and significantly affects the probability of more pronounced direct or subsequent behavioral effects. Additionally, animals are less likely to respond to sound levels distant from a source, even when those same levels elicit response at closer distances; both proximity and received levels are important factors in aversive responses (Dunlop et al. 2017b). As a supplement to this modeling study for comparison purposes only, parameters determining aversion at specified sound levels were implemented for the North Atlantic right whale, in recognition of its endangered status, and harbor porpoise, a species known to have a strong aversive response to loud sounds.

Aversion is implemented in JASMINE by defining a new behavioral state that an animat may transition into when a received level is exceeded. There is very little data on which aversive behavior can be based. Because of the dearth of information and in order to be consistent within this report, aversion probability is based on the Wood et al. (2012) step function that was used to estimate potential behavioral disruption. Animats will be assumed to avert by changing their headings by a fixed amount away from the source, with greater deflections associated with higher received levels (Figures J-1 and J-2). Aversion thresholds for marine mammals are based on the Wood et al. (2012) step function. Animats remain in the aversive state for a specified amount of time, depending on the level of exposure that triggered aversion (Figures J-3 and J-4). During this time, travel parameters are recalculated periodically as with normal behaviors. At the end of the aversion interval, the animat model parameters are changed (Figures J-5 and J-6), depending on the current level of exposure, and the animat either begins another aversion interval or transitions to a non-aversive behavior. If aversion begins immediately, transition to a regular behavior occurs at the end of the next surface interval, consistent with regular behavior transitions.

Table J-1. North Atlantic right whales: Aversion parameters for the animal movement simulation based on Wood et al. (2012) behavioral response criteria.

Probability of aversion (%)	Received sound level (L_p, dB re 1 µPa)	Change in course (°)	Duration of aversion (s)
10	140	10	300
50	160	20	60
90	180	30	30

Table J-2. Harbor porpoises: Aversion parameters for the animal movement simulation based on Wood et al. (2012) behavioral response criteria.

Probability of aversion (%)	Received sound level (L_p, dB re 1 µPa)	Change in course (°)	Duration of aversion (s)
50	120	20	60
90	140	30	30

J.1.3. Simulation Area: Animat Seeding

The exposure criteria for impulsive sounds were used to determine the number of animats exceeding exposure thresholds. To generate statistically reliable probability density functions, all simulations were seeded with an animat density of 0.5 animats/km^2 over the entire simulation area. Some species have depth preference restrictions, e.g., sperm whales prefer water greater than 1000 m (Aoki et al. 2007), and the simulation location contained a relatively high portion of shallow water areas.

J.2. Animal Movement Modeling Supplemental Results

Supplemental exposure modeling results are included in Appendices J.2.1 - J.2.4 assuming 0, 6, 10, 15, and 20 dB broadband attenuation. The proposed construction schedule is described in Section 1.2.2.

J.2.1. Marine Mammal Exposure Estimates

Table J-3. WTG and OSS monopile foundations: Number of marine mammals predicted to receive sound levels above exposure criteria with sound attenuation for a total of 100 WTG and two OSS monopiles. Construction schedule assumptions are summarized in Section 1.2.2.

Species		Injury										Behavior									
		$L_{E,\,24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	24.95	12.05	6.73	2.72	0.81	0.10	0	0	0	0	27.58	17.81	15.54	10.48	5.55	24.47	15.93	12.64	8.52	5.05
	Minke whale	23.10	12.33	6.80	1.99	0.39	0.08	0.01	0.01	<0.01	0	33.59	24.29	21.28	16.00	9.92	78.92	59.54	49.36	37.80	27.56
	Humpback whale	27.06	13.71	8.04	3.38	0.95	0.09	0.02	0.02	0.02	0	25.29	16.30	14.14	9.67	5.52	22.35	14.54	11.63	7.91	4.77
	North Atlantic right whale[c]	28.66	12.68	6.47	2.47	0.62	0.07	<0.01	<0.01	<0.01	0	29.46	19.34	16.55	11.56	6.36	29.40	19.46	14.39	9.32	5.56
	Sei whale[c]	1.89	0.88	0.46	0.18	0.05	<0.01	<0.01	0	0	0	2.51	1.65	1.43	1.01	0.54	7.21	5.25	4.22	3.12	2.13
MF	Atlantic white sided dolphin	1.23	0.92	0.31	0	0	0	0	0	0	0	945.56	694.14	598.80	432.62	259.12	510.97	345.00	241.23	143.16	91.18
	Short-beaked common dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bottlenose dolphin, coastal	1.55	1.38	0	0	0	0	0	0	0	0	7617.31	4518.53	3401.35	2808.50	2021.88	5852.32	4212.54	2604.95	1347.58	679.22
	Bottlenose dolphin, offshore	0.04	0	0	0	0	0	0	0	0	0	1459.73	1127.89	898.71	566.80	289.29	826.94	520.91	352.53	209.24	139.17
	Risso's dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	0	0	5.58	3.92	3.45	2.54	1.54	3.08	2.10	1.47	0.83	0.55
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	39.04	27.67	24.32	18.60	11.18	21.11	14.65	10.21	5.77	3.59
	Short-finned pilot whale	0.01	0.01	0.01	0	0	0	0	0	0	0	40.69	29.28	25.61	18.91	11.34	21.54	14.87	10.41	6.15	3.84
	Sperm whale[c]	<0.01	0	0	0	0	<0.01	0	0	0	0	3.53	2.47	2.14	1.50	0.80	1.96	1.30	0.85	0.48	0.30
HF	Harbor porpoise	970.04	421.06	238.60	104.09	25.48	68.18	30.65	16.34	3.62	0.59	1200.26	686.93	507.04	412.07	285.00	6484.21	5507.61	4501.20	3974.19	3638.12
PW	Gray seal	542.75	121.76	38.25	5.81	0	0	0	0	0	0	3648.94	1702.78	1036.82	760.18	440.55	4026.11	2826.37	1611.76	798.47	350.89
	Harbor seal	970.35	231.39	79.62	11.81	0	6.23	0	0	0	0	3742.06	1941.83	1329.47	982.69	607.14	4289.02	2938.51	1726.33	879.74	434.69

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

J.2.2. Sea Turtle Exposure Estimates

Table J-4. WTG and OSS monopile foundations: Number of sea turtles predicted to receive sound levels above exposure criteria with sound attenuation for a total of 100 WTG and two OSS monopiles. Construction schedule assumptions are summarized in Section 1.2.2.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	0.06	0.01	<0.01	<0.01	0	0	0	0	0	0	0.25	0.11	0.06	0.02	<0.01
Leatherback turtle[a]	5.92	1.36	0.69	0.13	0	<0.01	<0.01	0	0	0	31.74	14.10	7.52	3.48	1.35
Loggerhead turtle	1.84	0.59	0.16	<0.01	0	0	0	0	0	0	19.98	7.65	3.81	1.40	0.66
Green sea turtle	0.11	0.03	<0.01	<0.01	<0.01	<0.01	0	0	0	0	0.25	0.11	0.06	0.03	0.01

[a] Listed as Endangered under the ESA.

J.2.3. Marine Mammal Exposure Ranges

Table J-5. WTG monopile foundation (7 to 12 m diameter, one pile per day, summer): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\,24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	5.21	3.19	2.15	1.08	0.39	0.02	0	0	0	0	5.81	4.06	3.74	2.98	1.87	5.87	4.08	3.73	2.98	1.86
	Minke whale	4.22	2.39	1.32	0.47	0.20	<0.01	<0.01	<0.01	<0.01	0	5.66	4.07	3.71	2.85	1.73	15.31	11.89	10.09	7.81	5.85
	Humpback whale	5.97	3.78	2.46	1.26	0.46	0.02	<0.01	<0.01	0	0	5.86	4.16	3.75	2.91	1.94	5.93	4.16	3.76	2.92	1.95
	North Atlantic right whale[c]	4.87	2.69	1.85	0.77	0.22	0.06	0	0	0	0	5.56	4.08	3.70	2.83	1.82	5.67	4.12	3.72	2.83	1.82
	Sei whale[c]	4.55	2.52	1.42	0.63	0.09	0.06	<0.01	0	0	0	5.73	4.10	3.66	2.91	1.83	15.61	11.94	10.15	7.80	5.83
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	0	0	5.49	4.07	3.59	2.81	1.71	3.85	2.95	1.96	0.97	0.49
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0	0	0	0	0	0	0	0	0	0	5.60	4.05	3.63	2.85	1.79	3.85	3.02	2.01	1.10	0.52
	Bottlenose dolphin	0.13	0	0	0	0	0	0	0	0	0	5.04	3.63	3.21	2.27	1.51	3.51	2.62	1.64	0.81	0.32
	Risso's dolphin	0	0	0	0	0	0	0	0	0	0	5.77	4.10	3.69	2.91	1.69	4.01	3.07	2.15	0.98	0.47
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	5.66	4.07	3.65	2.84	1.84	3.96	3.00	2.05	0.96	0.46
	Short-finned pilot whale	<0.01	<0.01	<0.01	0	0	0	0	0	0	0	5.74	4.04	3.62	2.82	1.69	3.96	2.97	2.06	0.99	0.43
	Sperm whale[c]	0	0	0	0	0	<0.01	0	0	0	0	5.61	4.04	3.66	2.78	1.67	3.82	3.08	2.10	1.10	0.54
HF	Harbor porpoise	3.71	2.11	1.28	0.49	0.11	0.56	0.28	0.18	0.04	0	5.71	4.06	3.71	2.86	1.75	31.17	23.50	19.13	14.29	11.28
PW	Gray seal	1.76	1.11	0.60	0.13	0	0	0	0	0	0	6.04	4.17	3.78	2.92	1.88	4.60	3.83	3.25	2.01	1.01
	Harbor seal	1.77	0.40	0.21	0.03	0	0.03	0	0	0	0	5.64	4.04	3.66	2.93	1.86	4.53	3.71	3.13	1.99	0.98
	Harp seal	1.54	0.61	0.19	0.01	0.01	0.01	0	0	0	0	5.72	4.06	3.72	2.88	1.83	4.73	3.72	3.12	2.14	0.97

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

Table J-6. WTG monopile foundation (7 to 12 m diameter, two piles per day, summer): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\,24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	5.38	3.38	2.14	1.10	0.35	0.06	0	0	0	0	5.90	4.10	3.73	2.86	1.91	5.95	4.15	3.73	2.87	1.90
	Minke whale	4.23	2.40	1.43	0.47	0.08	0.07	0	0	0	0	5.49	4.07	3.65	2.84	1.77	15.28	11.71	9.92	7.66	5.60
	Humpback whale	6.15	3.98	2.62	1.48	0.50	0.06	<0.01	0	0	0	5.70	4.13	3.70	2.91	1.87	5.78	4.14	3.72	2.94	1.87
	North Atlantic right whale[c]	5.01	2.91	1.83	0.75	0.28	0.03	<0.01	<0.01	0	0	5.61	3.95	3.66	2.84	1.81	5.71	3.99	3.66	2.84	1.81
	Sei whale[c]	4.81	2.87	1.75	0.66	0.16	0.03	<0.01	0	0	0	5.68	4.07	3.68	2.85	1.75	15.84	11.95	9.95	7.72	5.71
MF	Atlantic white sided dolphin	0.01	0.01	0.01	0	0	0	0	0	0	0	5.50	3.97	3.57	2.83	1.65	3.86	3.00	2.01	1.06	0.44
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0.01	0	0	0	0	0	0	0	0	0	5.48	4.01	3.59	2.81	1.75	3.89	3.01	2.05	1.05	0.50
	Bottlenose dolphin	0.02	0	0	0	0	0	0	0	0	0	4.63	3.69	3.22	2.32	1.37	3.59	2.51	1.74	0.77	0.34
	Risso's dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	0	0	5.68	4.10	3.70	2.82	1.80	3.97	3.04	2.01	1.13	0.48
	Long-finned pilot whale	0.01	0.01	0.01	0	0	0	0	0	0	0	5.58	4.01	3.53	2.77	1.78	3.85	2.91	1.96	1.00	0.48
	Short-finned pilot whale	0.02	<0.01	<0.01	0	0	0	0	0	0	0	5.59	4.01	3.62	2.78	1.74	3.85	3.02	2.01	1.00	0.47
	Sperm whale[c]	0	0	0	0	0	0	0	0	0	0	5.60	4.06	3.66	2.89	1.78	3.92	3.08	2.02	1.05	0.45
HF	Harbor porpoise	3.68	2.07	1.38	0.49	0.14	0.59	0.26	0.16	0.06	0.03	5.63	4.03	3.66	2.81	1.78	31.20	23.81	19.05	14.24	11.12
PW	Gray seal	1.91	0.97	0.40	0.10	0	0	0	0	0	0	5.95	4.24	3.73	3.09	1.89	4.72	3.79	3.24	2.13	1.05
	Harbor seal	1.85	0.73	0.18	0.02	0	0.06	0	0	0	0	5.44	4.01	3.57	2.97	1.82	4.60	3.67	3.10	1.91	0.94
	Harp seal	1.61	0.62	0.17	0	0	0.04	0	0	0	0	5.77	4.12	3.75	2.99	1.83	4.52	3.78	3.20	1.96	0.96

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

Table J-7. WTG monopile foundation (8 to 12 m diameter, three piles per day, summer): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\,24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	5.53	3.37	2.23	1.03	0.52	0.07	0	0	0	0	5.68	4.11	3.76	2.92	1.86	5.75	4.11	3.77	2.90	1.86
	Minke whale	4.39	2.40	1.51	0.54	0.06	0.04	<0.01	<0.01	0	0	5.60	4.08	3.63	2.79	1.76	15.28	11.72	9.84	7.60	5.72
	Humpback whale	6.24	4.01	2.66	1.49	0.51	0.04	<0.01	<0.01	<0.01	0	5.73	4.06	3.72	2.89	1.83	5.81	4.10	3.73	2.86	1.83
	North Atlantic right whale[c]	4.88	3.02	1.93	0.84	0.24	0.05	0	0	0	0	5.54	3.98	3.67	2.87	1.80	5.62	4.00	3.67	2.84	1.79
	Sei whale[c]	4.87	2.85	1.81	0.64	0.18	0.03	0	0	0	0	5.70	4.01	3.67	2.88	1.82	15.74	11.90	9.88	7.71	5.75
MF	Atlantic white sided dolphin	0.01	0.01	0.01	0	0	0	0	0	0	0	5.47	4.02	3.63	2.83	1.74	3.88	2.99	2.02	1.09	0.49
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	<0.01	<0.01	0	0	0	0	0	0	0	0	5.42	4.03	3.56	2.77	1.77	3.89	2.97	2.07	1.06	0.51
	Bottlenose dolphin	0	0	0	0	0	0	0	0	0	0	4.70	3.68	3.18	2.21	1.42	3.57	2.53	1.77	0.74	0.37
	Risso's dolphin	<0.01	<0.01	<0.01	0	0	0	0	0	0	0	5.63	4.05	3.67	2.80	1.81	3.91	3.04	2.15	1.10	0.48
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	5.63	4.01	3.55	2.79	1.76	3.88	2.96	1.98	1.04	0.51
	Short-finned pilot whale	0.02	0.02	0.02	0	0	0	0	0	0	0	5.52	4.02	3.57	2.78	1.73	3.92	2.96	2.01	1.03	0.46
	Sperm whale[c]	0	0	0	0	0	<0.01	0	0	0	0	5.59	4.06	3.63	2.83	1.78	3.88	2.99	2.08	1.04	0.44
HF	Harbor porpoise	3.68	2.15	1.34	0.57	0.09	0.54	0.29	0.16	0.07	<0.01	5.58	4.03	3.62	2.84	1.82	31.27	23.61	19.24	14.15	11.04
PW	Gray seal	1.96	0.96	0.44	0.21	0	0	0	0	0	0	5.90	4.20	3.80	3.05	1.95	4.67	3.83	3.29	2.12	1.01
	Harbor seal	1.87	0.67	0.24	0.02	0	0.03	0	0	0	0	5.61	4.04	3.63	2.91	1.89	4.45	3.69	3.13	1.99	0.91
	Harp seal	1.62	0.45	0.26	0	0	0.06	0	0	0	0	5.70	4.09	3.71	2.93	1.82	4.53	3.77	3.17	2.00	0.95

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

Table J-8. WTG monopile foundation (7 to 12 m diameter, one pile per day, winter): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\,24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	11.25	5.64	3.53	1.82	0.58	0.08	0	0	0	0	10.17	5.89	4.05	3.50	2.49	10.21	5.90	4.05	3.51	2.47
	Minke whale	11.33	5.12	3.03	1.20	0.42	<0.01	<0.01	<0.01	<0.01	0	9.89	5.77	4.07	3.33	2.42	41.41	37.59	27.98	15.01	10.04
	Humpback whale	15.39	7.79	4.88	2.43	0.88	0.02	<0.01	<0.01	0	0	10.12	6.10	4.15	3.58	2.66	10.20	6.11	4.16	3.59	2.68
	North Atlantic right whale[c]	12.38	6.07	3.42	1.65	0.47	0.06	0	0	0	0	9.76	5.71	4.06	3.27	2.40	9.91	5.78	4.07	3.28	2.40
	Sei whale[c]	10.72	5.09	2.82	1.06	0.45	0.06	<0.01	0	0	0	10.05	5.80	4.11	3.31	2.50	41.37	39.08	28.48	15.27	10.11
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	0	0	9.54	5.59	4.01	3.37	2.36	5.74	3.57	3.00	1.71	0.68
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0	0	0	0	0	0	0	0	0	0	9.73	5.61	4.06	3.36	2.42	5.78	3.56	3.02	1.64	0.73
	Bottlenose dolphin	0.24	0	0	0	0	0	0	0	0	0	8.72	5.15	3.62	3.13	2.15	5.27	3.30	2.64	1.41	0.49
	Risso's dolphin	0	0	0	0	0	0	0	0	0	0	9.98	5.89	4.07	3.35	2.48	6.07	3.61	3.00	1.64	0.62
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	9.86	5.67	4.05	3.35	2.51	5.66	3.55	2.95	1.69	0.68
	Short-finned pilot whale	<0.01	<0.01	<0.01	0	0	0	0	0	0	0	9.61	5.76	4.02	3.43	2.60	5.82	3.51	2.98	1.66	0.74
	Sperm whale[c]	0.05	0	0	0	0	<0.01	0	0	0	0	9.81	5.72	4.03	3.48	2.43	5.73	3.64	3.01	1.54	0.60
HF	Harbor porpoise	7.27	3.72	2.29	0.92	0.28	0.62	0.28	0.18	0.04	0	9.93	5.73	4.00	3.40	2.54	45.55	44.11	42.38	41.66	40.98
PW	Gray seal	3.42	1.44	0.73	0.23	0	0	0	0	0	0	10.40	6.17	4.21	3.54	2.72	8.55	4.50	3.73	2.96	1.56
	Harbor seal	3.16	1.20	0.31	0.05	0	0.06	0	0	0	0	9.95	5.73	4.10	3.39	2.56	8.31	4.36	3.58	2.95	1.53
	Harp seal	2.65	1.06	0.21	0.01	0.01	0.01	0	0	0	0	10.01	5.85	4.07	3.35	2.57	8.45	4.48	3.50	2.88	1.55

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

Table J-9. WTG monopile foundation (7 to 12 m diameter, two piles per day, winter): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\,24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	14.63	6.75	4.05	1.83	0.75	0.06	0	0	0	0	9.99	6.00	4.10	3.49	2.58	10.11	6.03	4.11	3.48	2.58
	Minke whale	13.72	5.85	3.26	1.33	0.33	0.07	0	0	0	0	9.64	5.61	4.03	3.35	2.47	41.45	38.46	27.54	14.68	9.79
	Humpback whale	20.52	9.28	5.59	2.72	0.99	0.07	<0.01	0	0	0	9.81	5.85	4.13	3.45	2.59	9.94	5.88	4.14	3.44	2.58
	North Atlantic right whale[c]	15.14	6.94	3.80	1.73	0.55	0.03	<0.01	<0.01	0	0	9.58	5.69	3.93	3.40	2.55	9.70	5.71	3.95	3.40	2.50
	Sei whale[c]	13.10	5.98	3.44	1.38	0.32	0.03	<0.01	0	0	0	9.80	5.84	4.07	3.40	2.42	41.62	39.49	29.08	15.18	9.90
MF	Atlantic white sided dolphin	0.01	0.01	0.01	0.01	0	0	0	0	0	0	9.37	5.59	3.94	3.35	2.42	5.74	3.54	3.01	1.65	0.73
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0.01	0	0	0	0	0	0	0	0	0	9.44	5.56	3.99	3.37	2.51	5.66	3.54	3.01	1.69	0.74
	Bottlenose dolphin	0.20	0	0	0	0	0	0	0	0	0	8.39	4.67	3.70	3.03	2.08	4.81	3.36	2.58	1.38	0.47
	Risso's dolphin	0.04	<0.01	<0.01	0	0	0	0	0	0	0	9.77	5.71	4.10	3.42	2.51	5.87	3.62	3.03	1.78	0.76
	Long-finned pilot whale	0.01	0.01	0.01	0	0	0	0	0	0	0	9.56	5.67	3.99	3.27	2.42	5.71	3.44	2.93	1.67	0.67
	Short-finned pilot whale	0.02	<0.01	<0.01	0	0	0	0	0	0	0	9.48	5.69	4.00	3.32	2.36	5.70	3.52	2.98	1.64	0.66
	Sperm whale[c]	0.08	0	0	0	0	0	0	0	0	0	9.65	5.69	4.03	3.35	2.50	5.75	3.59	3.02	1.68	0.62
HF	Harbor porpoise	8.01	3.98	2.36	1.04	0.33	0.62	0.23	0.17	0.07	0.01	9.73	5.73	3.97	3.36	2.50	46.29	44.28	42.26	41.48	40.69
PW	Gray seal	3.61	1.53	0.82	0.27	0	0	0	0	0	0	10.10	6.09	4.26	3.58	2.75	8.47	4.57	3.67	2.99	1.65
	Harbor seal	3.69	1.25	0.45	0.10	0	0.06	0	0	0	0	9.63	5.58	4.00	3.29	2.64	8.04	4.34	3.47	2.96	1.62
	Harp seal	3.22	1.07	0.51	0	0	0.04	0	0	0	0	9.79	5.84	4.09	3.46	2.52	8.24	4.33	3.60	3.01	1.56

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

Table J-10. WTG monopile foundation (7 to 12 m diameter, three piles per day, winter): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,24h}$					L_{PK}					L_p[a]					L_p[b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	16.96	7.49	4.38	2.09	0.81	0.07	0	0	0	0	9.84	5.78	4.09	3.43	2.63	9.99	5.85	4.11	3.42	2.63
	Minke whale	15.59	6.45	3.45	1.46	0.41	0.04	<0.01	<0.01	0	0	9.41	5.70	4.07	3.34	2.48	41.24	38.44	27.42	14.89	9.64
	Humpback whale	23.46	10.34	6.29	3.00	1.13	0.04	<0.01	<0.01	<0.01	0	9.69	5.86	4.11	3.50	2.54	9.80	5.90	4.11	3.49	2.53
	North Atlantic right whale[c]	17.12	7.44	3.97	1.90	0.61	0.05	0	0	0	0	9.55	5.68	3.95	3.31	2.54	9.70	5.73	3.98	3.30	2.51
	Sei whale[c]	15.03	6.62	3.67	1.65	0.54	0.05	0	0	0	0	9.69	5.78	4.02	3.42	2.53	41.24	39.82	29.09	15.09	9.80
MF	Atlantic white sided dolphin	0.01	0.01	0.01	0	0	0	0	0	0	0	9.32	5.57	3.99	3.38	2.40	5.69	3.57	3.03	1.64	0.70
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	<0.01	<0.01	0	0	0	0	0	0	0	0	9.31	5.52	4.04	3.31	2.45	5.69	3.52	2.98	1.72	0.70
	Bottlenose dolphin	0.09	0	0	0	0	0	0	0	0	0	8.33	4.85	3.65	2.98	1.99	5.01	3.30	2.54	1.25	0.57
	Risso's dolphin	0.02	<0.01	<0.01	0	0	0	0	0	0	0	9.55	5.66	4.05	3.41	2.51	5.78	3.62	3.03	1.74	0.73
	Long-finned pilot whale	0.01	0	0	0	0	0	0	0	0	0	9.44	5.70	3.97	3.26	2.44	5.69	3.52	2.96	1.65	0.73
	Short-finned pilot whale	0.06	0.02	0.02	0	0	0	0	0	0	0	9.31	5.62	3.99	3.31	2.40	5.65	3.50	2.96	1.65	0.73
	Sperm whale[c]	0.05	0	0	0	0	<0.01	0	0	0	0	9.57	5.68	4.03	3.41	2.48	5.65	3.55	2.99	1.66	0.70
HF	Harbor porpoise	8.29	4.07	2.33	1.16	0.29	0.62	0.28	0.16	0.07	<0.01	9.54	5.70	4.03	3.39	2.51	46.73	44.59	42.41	41.52	40.76
PW	Gray seal	3.62	1.57	0.81	0.32	0	0	0	0	0	0	10.08	6.09	4.23	3.53	2.68	8.45	4.49	3.71	3.03	1.61
	Harbor seal	4.35	1.32	0.50	0.05	0	0.03	0	0	0	0	9.22	5.68	3.99	3.32	2.47	7.88	4.28	3.55	2.86	1.49
	Harp seal	3.48	1.11	0.39	0.06	0	0.06	0	0	0	0	9.78	5.86	4.13	3.44	2.65	8.18	4.35	3.67	2.95	1.58

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

Table J-11. OSS monopile foundation (7 to 15 m diameter, one pile per day, summer): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\ 24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	4.53	2.68	1.57	0.64	0.11	0.06	0	0	0	0	5.54	4.04	3.62	2.97	1.68	5.59	4.05	3.62	2.97	1.74
	Minke whale	3.53	1.70	0.94	0.45	0.06	0	0	0	0	0	5.35	4.01	3.56	2.71	1.64	13.69	11.00	9.44	7.30	5.46
	Humpback whale	5.12	3.22	1.79	1.13	0.38	0.02	0.01	0	0	0	5.47	4.06	3.61	2.95	1.69	5.58	4.07	3.61	2.93	1.69
	North Atlantic right whale[c]	3.95	2.40	1.25	0.63	0.07	<0.01	<0.01	<0.01	<0.01	0	5.37	3.93	3.51	2.80	1.61	5.45	3.94	3.51	2.80	1.61
	Sei whale[c]	3.85	2.04	1.22	0.55	0.19	0.02	0	0	0	0	5.50	3.99	3.58	2.85	1.79	14.13	11.09	9.47	7.42	5.56
MF	Atlantic white sided dolphin	0	0	0	0	0	0	0	0	0	0	5.25	3.88	3.46	2.64	1.55	3.61	2.53	1.54	0.83	0.41
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0.01	0.01	0	0	0	0	0	0	0	0	5.37	3.93	3.49	2.55	1.77	3.61	2.47	1.78	0.79	0.44
	Bottlenose dolphin	0	0	0	0	0	0	0	0	0	0	4.51	3.72	3.00	1.93	1.37	3.17	1.81	1.33	0.63	0.41
	Risso's dolphin	<0.01	0	0	0	0	0	0	0	0	0	5.36	3.91	3.59	2.68	1.79	3.66	2.57	1.79	0.73	0.35
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	5.22	3.94	3.38	2.54	1.66	3.53	2.31	1.75	0.77	0.33
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	5.32	3.93	3.39	2.69	1.62	3.56	2.56	1.59	0.85	0.45
	Sperm whale[c]	0.34	0	0	0	0	<0.01	0	0	0	0	5.34	3.98	3.63	2.71	1.76	3.74	2.62	1.81	0.70	0.29
HF	Harbor porpoise	2.85	1.46	0.83	0.32	0.04	0.48	0.28	0.11	0.06	0	5.25	3.96	3.50	2.78	1.69	22.93	18.28	15.76	12.82	9.97
PW	Gray seal	1.48	0.63	0.37	0	0	0	0	0	0	0	5.96	4.18	3.75	3.03	1.92	4.41	3.71	3.10	1.93	0.83
	Harbor seal	1.20	0.22	0.01	0	0	0.01	0	0	0	0	5.59	3.94	3.54	2.88	1.64	4.31	3.46	2.95	1.65	0.91
	Harp seal	0.93	0.44	0.03	0	0	0.03	0	0	0	0	5.50	4.05	3.52	2.79	1.63	4.28	3.52	2.91	1.67	1.00

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

Table J-12. OSS monopile foundation (7 to 15 m diameter, two piles per day, summer): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\ 24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	4.61	2.81	1.80	0.82	0.30	0.05	<0.01	0	0	0	5.55	4.04	3.66	2.89	1.82	5.66	4.05	3.67	2.87	1.81
	Minke whale	3.46	1.74	0.89	0.41	0.05	0.05	0	0	0	0	5.23	3.97	3.47	2.80	1.72	13.78	10.80	9.11	7.27	5.38
	Humpback whale	5.33	3.25	2.14	1.01	0.38	0.01	0.01	<0.01	0	0	5.50	4.02	3.57	2.87	1.84	5.59	4.05	3.57	2.85	1.83
	North Atlantic right whale[c]	4.18	2.35	1.40	0.67	0.15	0.04	0	0	0	0	5.29	3.96	3.47	2.75	1.74	5.43	3.99	3.47	2.75	1.73
	Sei whale[c]	3.90	2.22	1.31	0.54	0.21	0.02	<0.01	<0.01	0	0	5.39	3.91	3.61	2.79	1.73	14.02	11.16	9.43	7.46	5.45
MF	Atlantic white sided dolphin	0	0	0	0	0	<0.01	0	0	0	0	5.22	3.91	3.48	2.70	1.65	3.58	2.51	1.65	0.83	0.38
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0.01	0	0	0	0	<0.01	0	0	0	0	5.24	3.91	3.46	2.69	1.69	3.55	2.51	1.68	0.84	0.46
	Bottlenose dolphin	0.03	0	0	0	0	0	0	0	0	0	4.51	3.48	2.98	2.11	1.28	3.15	1.97	1.26	0.63	0.28
	Risso's dolphin	0.01	0	0	0	0	0	0	0	0	0	5.38	3.96	3.46	2.78	1.78	3.60	2.66	1.79	0.75	0.35
	Long-finned pilot whale	0.01	0	0	0	0	0	0	0	0	0	5.08	3.88	3.38	2.53	1.68	3.58	2.41	1.69	0.77	0.44
	Short-finned pilot whale	<0.01	0	0	0	0	0	0	0	0	0	5.23	3.89	3.45	2.65	1.56	3.51	2.53	1.54	0.87	0.42
	Sperm whale[c]	0	0	0	0	0	<0.01	0	0	0	0	5.24	3.92	3.57	2.75	1.59	3.71	2.57	1.52	0.79	0.31
HF	Harbor porpoise	2.86	1.46	0.90	0.34	0.06	0.48	0.27	0.15	0.06	0.02	5.20	3.94	3.45	2.79	1.67	22.62	18.10	15.49	12.72	9.82
PW	Gray seal	1.65	0.82	0.43	0	0	0	0	0	0	0	5.89	4.18	3.65	3.03	1.97	4.43	3.65	3.06	1.97	0.96
	Harbor seal	1.20	0.46	0.04	0	0	0	0	0	0	0	5.33	4.00	3.55	2.77	1.84	4.35	3.51	2.89	1.86	0.95
	Harp seal	0.93	0.29	0.10	0	0	0.04	0	0	0	0	5.35	4.04	3.56	2.89	1.71	4.27	3.51	2.91	1.73	0.89

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

Table J-13. OSS monopile foundation (7 to 15 m diameter, one pile per day, winter): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

	Species	Injury										Behavior									
		$L_{E,24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	8.53	4.48	2.68	1.16	0.41	0.06	0	0	0	0	8.60	5.20	3.88	3.26	2.39	8.63	5.21	3.89	3.28	2.41
	Minke whale	7.86	3.73	1.81	0.71	0.34	0	0	0	0	0	8.18	4.95	3.84	3.23	2.15	39.37	26.73	18.39	12.43	8.28
	Humpback whale	11.77	6.09	3.56	1.74	0.72	0.02	0.01	0	0	0	8.60	5.23	3.87	3.24	2.26	8.67	5.24	3.88	3.25	2.26
	North Atlantic right whale[c]	8.84	4.26	2.66	1.09	0.34	<0.01	<0.01	<0.01	<0.01	0	8.29	4.85	3.75	3.26	2.27	8.41	4.91	3.79	3.26	2.25
	Sei whale[c]	7.72	3.75	2.05	0.84	0.20	0.02	0	0	0	0	8.30	5.17	3.92	3.18	2.31	40.34	27.44	18.76	12.73	8.37
MF	Atlantic white sided dolphin	0.01	0	0	0	0	0	0	0	0	0	8.08	4.80	3.71	3.09	2.00	4.06	3.21	2.38	1.11	0.57
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0.01	0.01	0	0	0	0	0	0	0	0	7.99	4.92	3.74	3.20	2.08	4.13	3.28	2.40	1.18	0.57
	Bottlenose dolphin	0	0	0	0	0	0	0	0	0	0	7.47	4.23	3.54	2.63	1.61	3.91	2.75	1.75	0.85	0.42
	Risso's dolphin	<0.01	0	0	0	0	0	0	0	0	0	8.22	5.04	3.78	3.27	2.25	4.39	3.32	2.39	1.23	0.51
	Long-finned pilot whale	0	0	0	0	0	0	0	0	0	0	7.95	4.71	3.73	3.12	2.03	4.14	3.18	2.18	1.26	0.60
	Short-finned pilot whale	0	0	0	0	0	0	0	0	0	0	7.94	4.88	3.76	3.02	2.13	4.17	3.11	2.47	1.16	0.59
	Sperm whale[c]	<0.01	<0.01	0	0	0	<0.01	0	0	0	0	8.24	5.04	3.81	3.19	2.23	4.37	3.28	2.51	1.21	0.45
HF	Harbor porpoise	5.04	2.32	1.25	0.41	0.12	0.52	0.28	0.08	0.06	0	8.20	4.92	3.79	3.21	2.13	46.24	42.27	41.56	40.44	36.46
PW	Gray seal	1.96	0.78	0.37	0	0	0	0	0	0	0	8.99	5.51	4.02	3.31	2.42	7.15	4.11	3.35	2.54	1.46
	Harbor seal	1.87	0.43	0.11	0	0	0.01	0	0	0	0	8.44	5.12	3.72	3.10	2.21	6.64	3.75	3.34	2.55	1.20
	Harp seal	1.45	0.44	0.13	0.01	0	0.03	0	0	0	0	8.58	5.14	3.87	3.19	2.22	6.74	3.95	3.43	2.44	1.26

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

Table J-14. OSS monopile foundation (7 to 15 m diameter, two piles per day, winter): Exposure ranges (ER95%) in km to marine mammal threshold criteria with sound attenuation.

Species		Injury										Behavior									
		$L_{E,\ 24h}$					L_{PK}					L_p [a]					L_p [b]				
		Attenuation (dB)										Attenuation (dB)									
		0	6	10	15	20	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
LF	Fin whale[c]	10.19	5.21	3.21	1.36	0.55	0.06	<0.01	0	0	0	8.58	5.15	3.87	3.31	2.33	8.64	5.17	3.90	3.33	2.33
	Minke whale	9.11	4.06	2.12	0.72	0.37	0.05	0	0	0	0	8.07	4.94	3.84	3.17	2.19	39.73	26.24	18.16	12.26	8.24
	Humpback whale	13.83	6.85	4.13	1.89	0.69	0.01	0.01	<0.01	0	0	8.49	5.21	3.84	3.30	2.27	8.57	5.24	3.87	3.30	2.27
	North Atlantic right whale[c]	10.41	4.68	2.68	1.16	0.47	0.04	0	0	0	0	8.08	4.91	3.75	3.16	2.22	8.25	4.98	3.78	3.17	2.20
	Sei whale[c]	9.10	4.21	2.33	0.94	0.26	0.02	<0.01	<0.01	0	0	8.40	5.12	3.86	3.19	2.27	40.64	27.04	18.42	12.53	8.55
MF	Atlantic white sided dolphin	0.01	0	0	0	0	<0.01	0	0	0	0	8.01	4.76	3.72	3.08	2.13	4.15	3.15	2.43	1.12	0.54
	Atlantic spotted dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Short-beaked common dolphin	0.01	0	0	0	0	<0.01	0	0	0	0	7.99	4.85	3.72	3.16	2.15	4.14	3.26	2.41	1.23	0.56
	Bottlenose dolphin	0.03	0	0	0	0	0	0	0	0	0	7.29	4.16	3.31	2.64	1.70	3.75	2.78	1.92	0.88	0.43
	Risso's dolphin	0.01	0.01	0	0	0	0	0	0	0	0	8.22	4.88	3.74	3.16	2.27	4.35	3.21	2.41	1.15	0.51
	Long-finned pilot whale	0.01	0.01	0	0	0	0	0	0	0	0	7.85	4.69	3.70	3.08	2.05	4.18	3.10	2.21	1.22	0.58
	Short-finned pilot whale	<0.01	0	0	0	0	0	0	0	0	0	7.92	4.88	3.74	3.09	2.06	4.18	3.21	2.37	1.16	0.54
	Sperm whale[c]	0	0	0	0	0	<0.01	0	0	0	0	8.21	4.81	3.80	3.15	2.21	4.32	3.27	2.46	1.07	0.47
HF	Harbor porpoise	5.55	2.42	1.32	0.44	0.09	0.49	0.25	0.15	0.06	0.02	8.14	4.89	3.76	3.14	2.17	46.92	42.97	42.01	41.00	36.39
PW	Gray seal	2.89	0.94	0.59	0	0	0	0	0	0	0	8.94	5.45	4.04	3.29	2.43	7.15	4.09	3.53	2.53	1.46
	Harbor seal	2.25	0.58	0.11	0	0	0	0	0	0	0	8.32	5.00	3.83	3.22	2.33	6.69	3.91	3.34	2.44	1.28
	Harp seal	1.84	0.59	0.17	0	0	0.06	0	0	0	0	8.36	5.11	3.86	3.17	2.32	6.84	3.90	3.34	2.55	1.23

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

J.2.4. Sea Turtle Exposure Ranges

Table J-15. WTG monopile foundation (7 to 12 m diameter, one pile per day, summer): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.01	0.23	0.04	0.02	0	0	0	0	0	0	2.79	1.47	0.90	0.42	0.08
Leatherback turtle[a]	1.10	0.07	<0.01	0	0	<0.01	<0.01	0	0	0	2.44	1.23	0.61	0.30	0.11
Loggerhead turtle	0.49	0.02	0.02	0	0	0	0	0	0	0	2.18	1.04	0.57	0.47	0.08
Green sea turtle	1.32	0.57	0.20	0	0	0	0	0	0	0	2.89	1.43	0.94	0.32	0.13

[a] Listed as Endangered under the ESA.

Table J-16. WTG monopile foundation (7 to 12 m diameter, two piles per day, summer): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.03	0.27	0.05	<0.01	0	<0.01	<0.01	0	0	0	2.64	1.56	0.84	0.40	0.11
Leatherback turtle[a]	1.10	0.54	0.03	<0.01	0	0	0	0	0	0	2.66	1.23	0.63	0.36	0.09
Loggerhead turtle	0.53	0.23	0.01	0	0	0	0	0	0	0	2.30	1.06	0.50	0.32	0.16
Green sea turtle	1.64	0.51	0.20	0.02	0.02	0	0	0	0	0	2.95	1.61	0.87	0.30	0.21

[a] Listed as Endangered under the ESA.

Table J-17. WTG monopile foundation (7 to 12 m diameter, three piles per day, summer): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	0.98	0.23	0.12	0.02	0	0	0	0	0	0	2.71	1.59	0.88	0.35	0.17
Leatherback turtle[a]	0.86	0.42	0.12	0.03	0	0	0	0	0	0	2.45	1.48	0.62	0.32	0.09
Loggerhead turtle	0.51	0.06	0.03	0	0	0	0	0	0	0	2.40	1.30	0.58	0.29	0.06
Green sea turtle	1.63	0.55	0.21	<0.01	<0.01	<0.01	0	0	0	0	2.91	1.61	0.89	0.37	0.17

[a] Listed as Endangered under the ESA.

Table J-18. WTG monopile foundation (7 to 12 m diameter, one pile per day, winter): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.55	0.42	0.04	0.02	0	0	0	0	0	0	3.32	2.19	1.08	0.45	0.26
Leatherback turtle[a]	1.51	0.38	0.07	<0.01	0	<0.01	<0.01	0	0	0	3.20	1.90	1.13	0.48	0.22
Loggerhead turtle	0.65	0.09	0.02	0	0	0	0	0	0	0	3.17	1.55	0.82	0.52	0.09
Green sea turtle	2.43	0.91	0.36	0	0	0	0	0	0	0	3.46	2.27	1.27	0.60	0.21

[a] Listed as Endangered under the ESA.

Table J-19. WTG monopile foundation (7 to 12 m diameter, two piles per day, winter): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.86	0.63	0.09	<0.01	<0.01	<0.01	0	0	0	0	3.31	2.12	1.23	0.59	0.18
Leatherback turtle[a]	2.18	0.61	0.21	0.03	0	0	0	0	0	0	3.21	1.93	1.19	0.47	0.27
Loggerhead turtle	0.91	0.32	0.01	0	0	0	0	0	0	0	3.02	1.81	0.90	0.49	0.22
Green sea turtle	2.84	0.94	0.45	0.02	0.02	0	0	0	0	0	3.44	2.34	1.48	0.54	0.25

[a] Listed as Endangered under the ESA.

Table J-20. WTG monopile foundation (7 to 12 m diameter, three piles per day, winter): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.98	0.60	0.13	0.03	0	0	0	0	0	0	3.38	2.21	1.29	0.58	0.22
Leatherback turtle[a]	2.57	0.66	0.29	0.03	0	0	0	0	0	0	3.19	1.99	1.14	0.43	0.18
Loggerhead turtle	1.10	0.12	0.03	0	0	0	0	0	0	0	3.03	1.90	1.07	0.45	0.06
Green sea turtle	3.12	1.03	0.37	0.06	<0.01	<0.01	0	0	0	0	3.43	2.31	1.41	0.64	0.18

[a] Listed as Endangered under the ESA.

Table J-21. OSS monopile foundation (7 to 15 m diameter, one pile per day, summer): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.12	0.27	0.05	0.01	0	0	0	0	0	0	2.70	1.40	0.97	0.31	0.16
Leatherback turtle[a]	0.84	0.51	0	0	0	0	0	0	0	0	2.50	1.19	0.72	0.36	0.19
Loggerhead turtle	0.51	0.11	0.04	<0.01	0	0	0	0	0	0	2.18	1.23	0.76	0.12	0.04
Green sea turtle	1.72	0.77	0.25	0.06	0	0	0	0	0	0	2.74	1.51	0.82	0.49	0.08

[a] Listed as Endangered under the ESA.

Table J-22. OSS monopile foundation (7 to 15 m diameter, two piles per day, summer): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	0.98	0.40	0.11	0.01	0	0	0	0	0	0	2.65	1.57	0.89	0.36	0.21
Leatherback turtle[a]	0.90	0.62	0.12	<0.01	0	0	0	0	0	0	2.57	1.43	0.70	0.47	0.12
Loggerhead turtle	0.58	0.10	0.04	0	0	0	0	0	0	0	2.13	1.16	0.59	0.22	0.04
Green sea turtle	1.79	0.75	0.36	0.06	0	0	0	0	0	0	2.79	1.67	0.82	0.43	0.18

[a] Listed as Endangered under the ESA.

Table J-23. OSS monopile foundation (7 to 15 m diameter, one pile per day, winter): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.67	0.63	0.23	0.01	0	0	0	0	0	0	3.23	1.84	1.14	0.42	0.21
Leatherback turtle[a]	1.96	0.57	0.26	0	0	0	0	0	0	0	2.94	1.62	0.94	0.57	0.22
Loggerhead turtle	0.87	0.39	0.11	<0.01	<0.01	0	0	0	0	0	2.74	1.70	1.10	0.42	0.11
Green sea turtle	2.48	0.83	0.28	0.06	0	0	0	0	0	0	3.22	2.19	1.33	0.64	0.09

[a] Listed as Endangered under the ESA.

Table J-24. OSS monopile foundation (7 to 15 m diameter, two piles per day, winter): Exposure ranges (ER95%) in km to sea turtle threshold criteria with sound attenuation.

Species	Injury										Behavior				
	$L_{E,\,24h}$					L_{PK}					L_p				
	Attenuation (dB)										Attenuation (dB)				
	0	6	10	15	20	0	6	10	15	20	0	6	10	15	20
Kemp's ridley turtle[a]	1.91	0.87	0.32	0.01	0.01	0	0	0	0	0	3.20	1.80	1.11	0.61	0.22
Leatherback turtle[a]	2.33	0.65	0.28	0.12	0	0	0	0	0	0	3.12	1.70	0.91	0.61	0.21
Loggerhead turtle	1.08	0.55	0.10	0	0	0	0	0	0	0	2.63	1.38	1.06	0.57	0.05
Green sea turtle	2.93	1.13	0.47	0.13	0	0	0	0	0	0	3.21	2.03	1.34	0.67	0.17

[a] Listed as Endangered under the ESA.

J.3. Animat Seeding Area

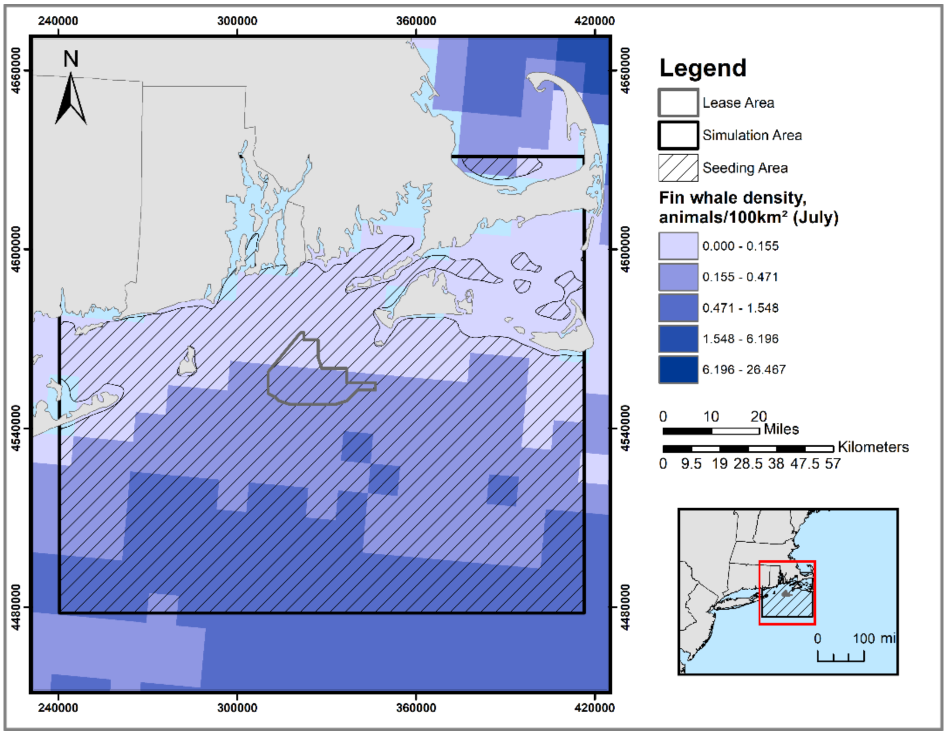

Figure J-1. Map of fin whale animat seeding range for July, the month with the highest density.

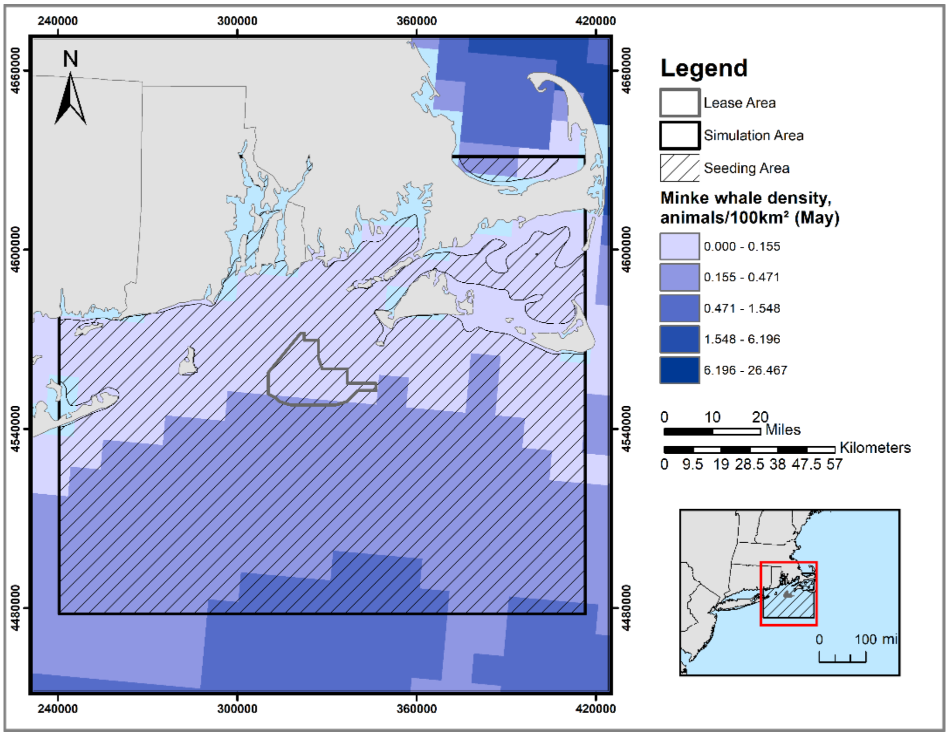

Figure J-2. Map of minke whale animat seeding range for May, the month with the highest density.

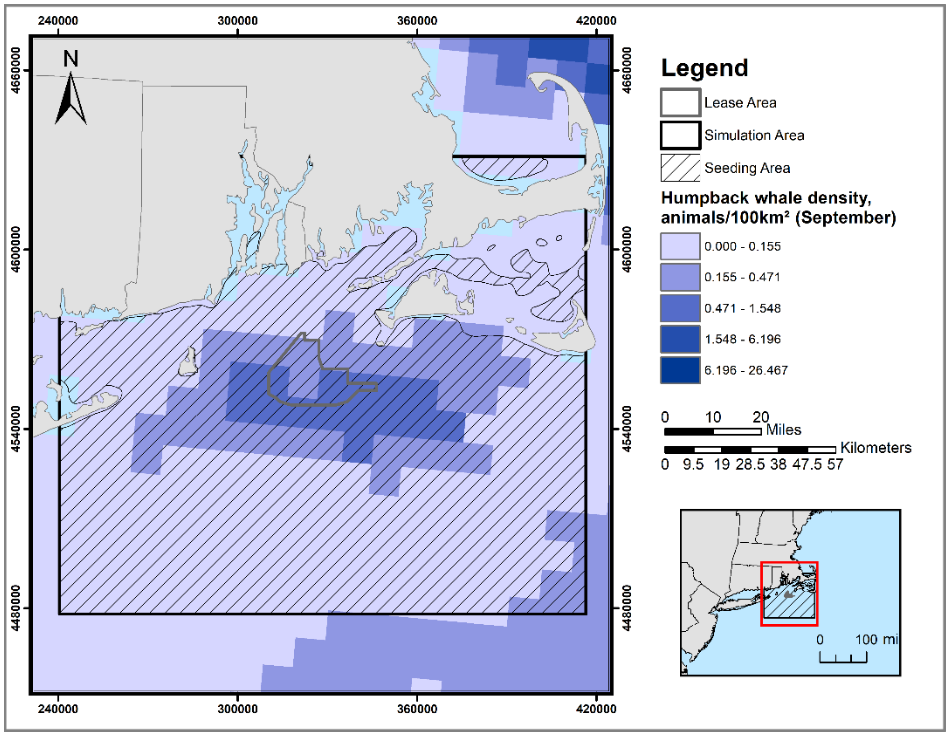

Figure J-3. Map of humpback whale animat seeding range for September, the month with the highest density.

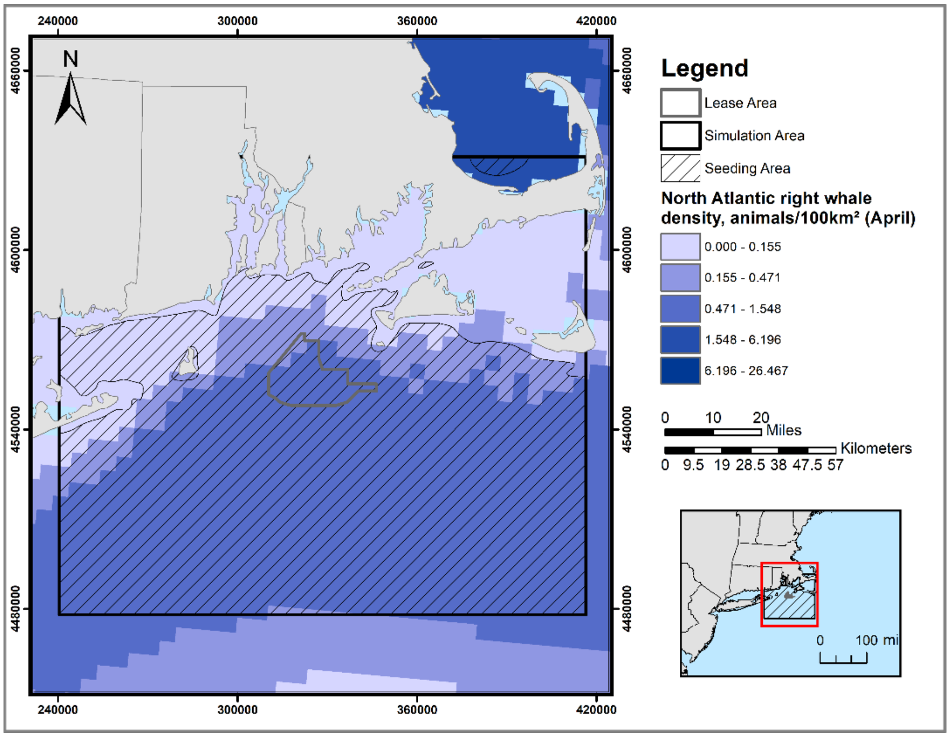

Figure J-4. Map of NARW animat seeding range for April, the month with the highest density.

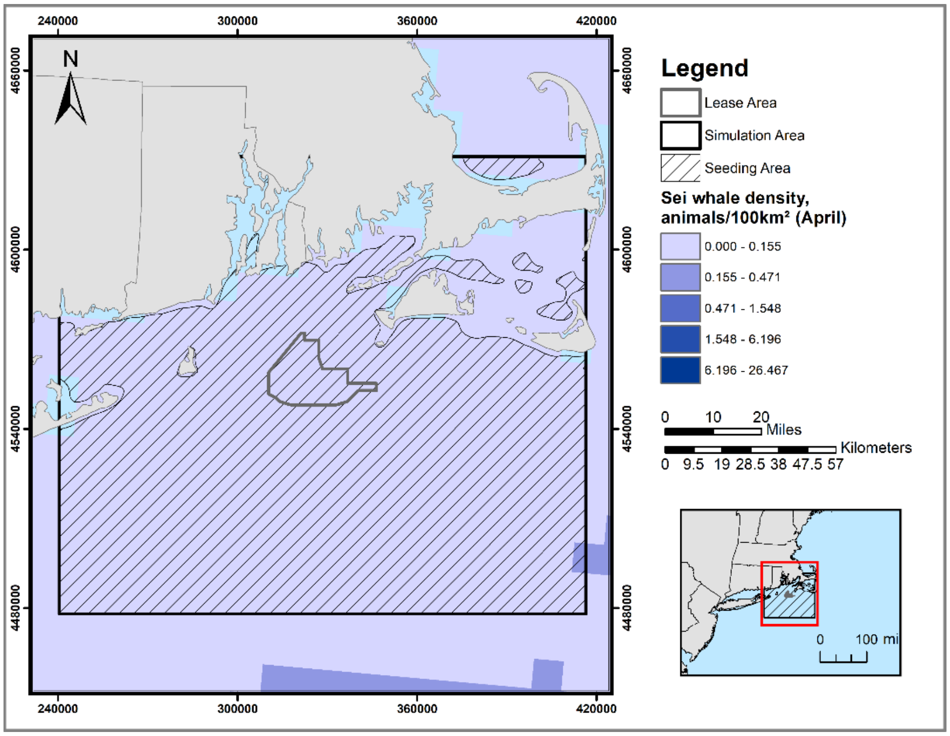

Figure J-5. Map of sei animat seeding range for April, the month with the highest density.

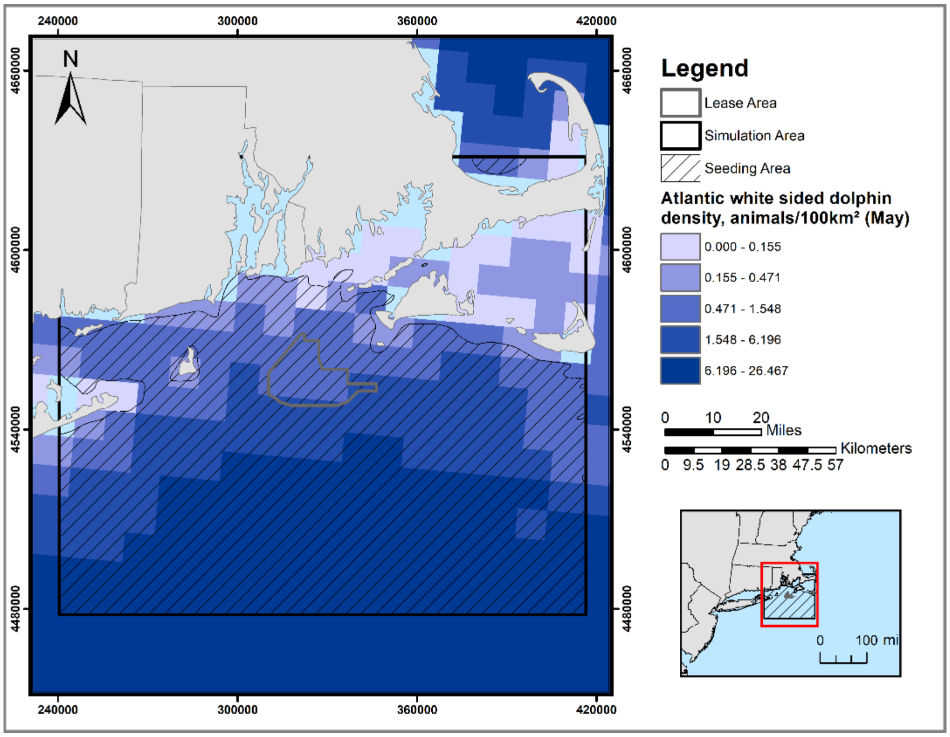

Figure J-6. Map of Atlantic white sided dolphin animat seeding range for May, the month with the highest density.

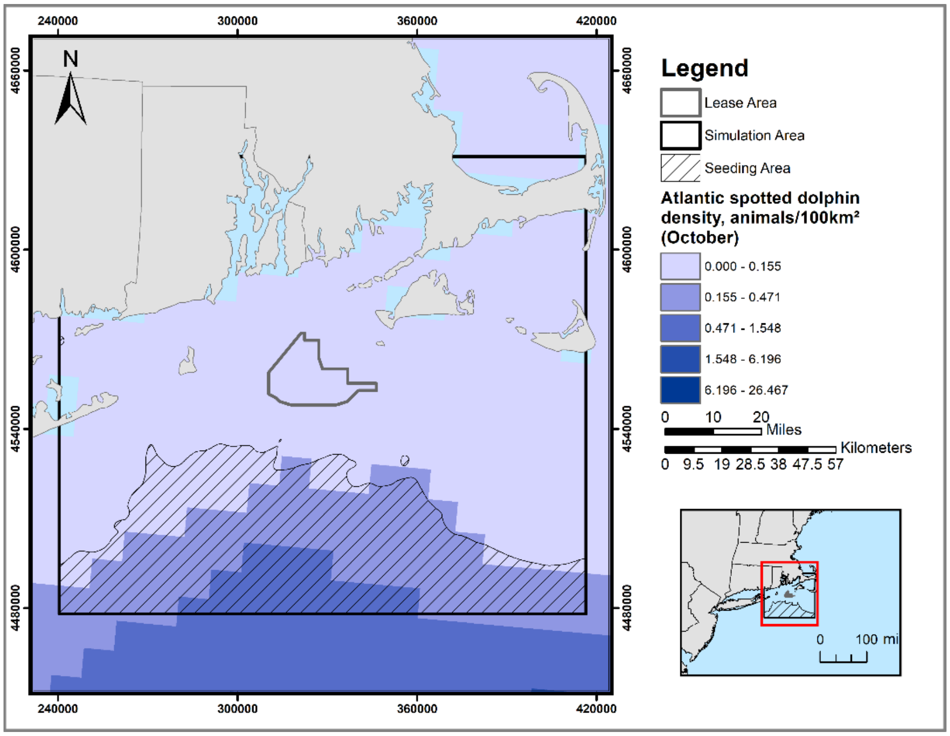

Figure J-7. Map of Atlantic spotted dolphin animat seeding range for October, the month with the highest density.

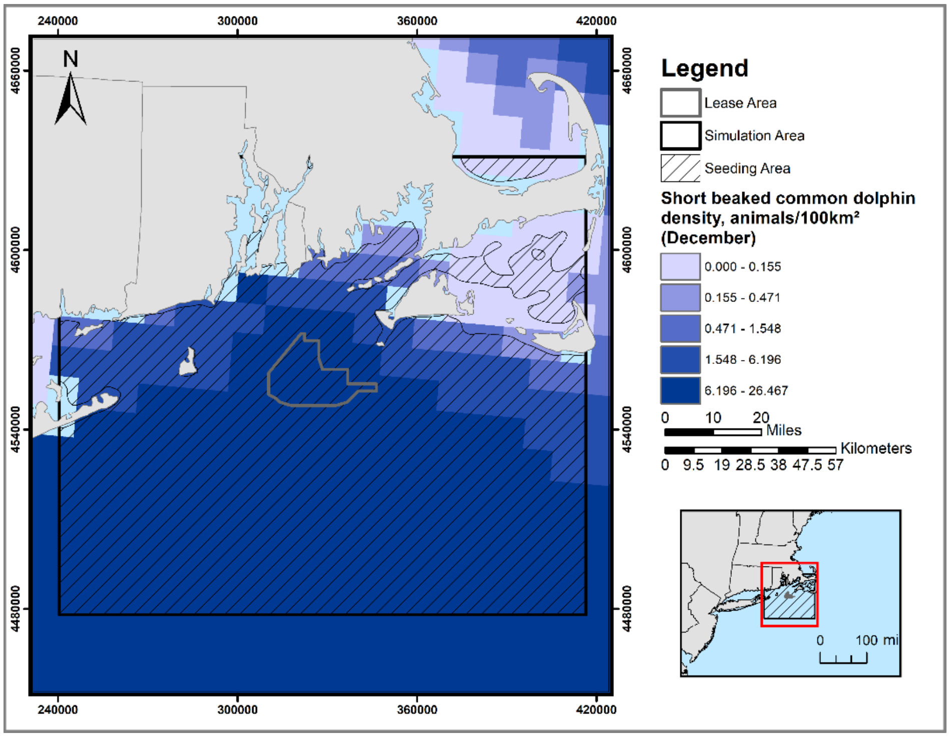

Figure J-8. Map of short-beaked common dolphin animat seeding range for December, the month with the highest density.

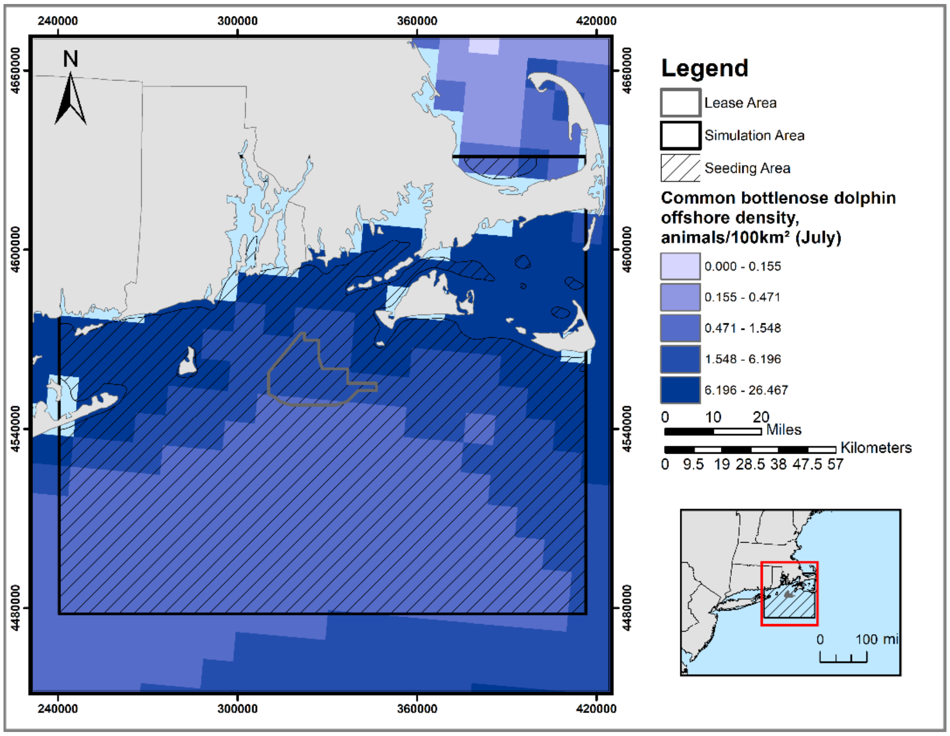

Figure J-9. Map of bottlenose dolphin animat seeding range for July, the month with the highest density.

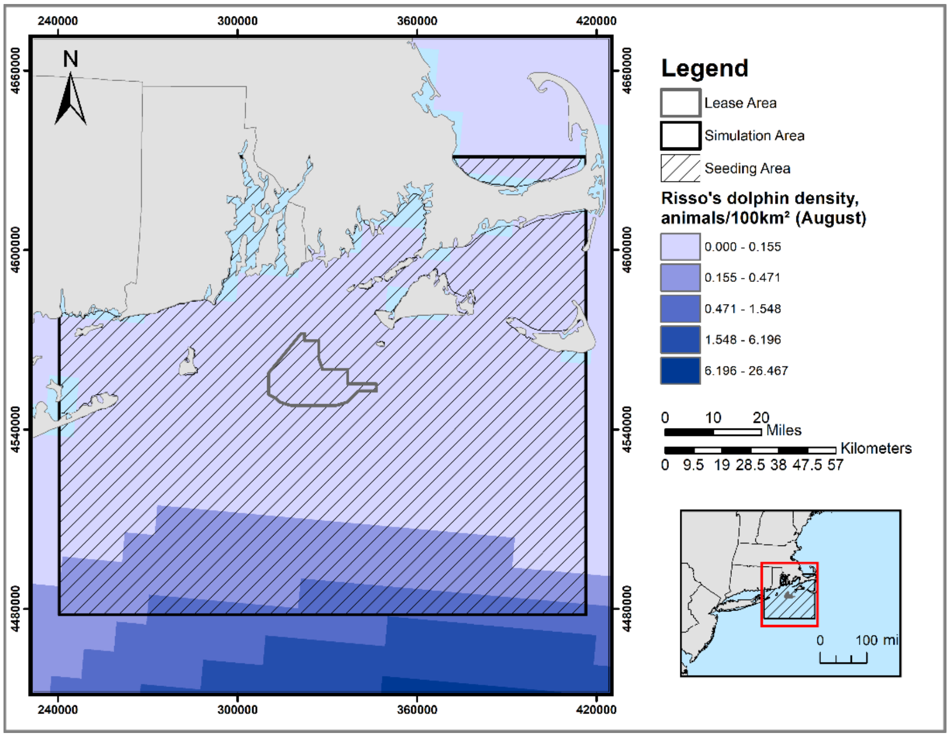

Figure J-10. Map of Risso's dolphin animat seeding range for August, the month with the highest density.

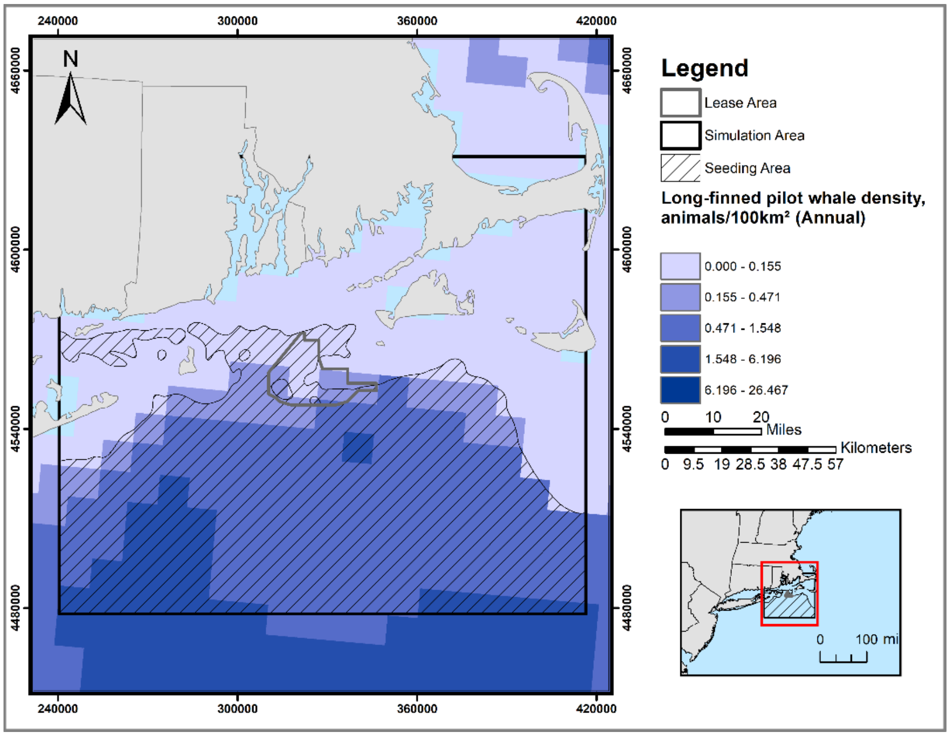

Figure J-11. Map of long-finned pilot whale animat seeding range.

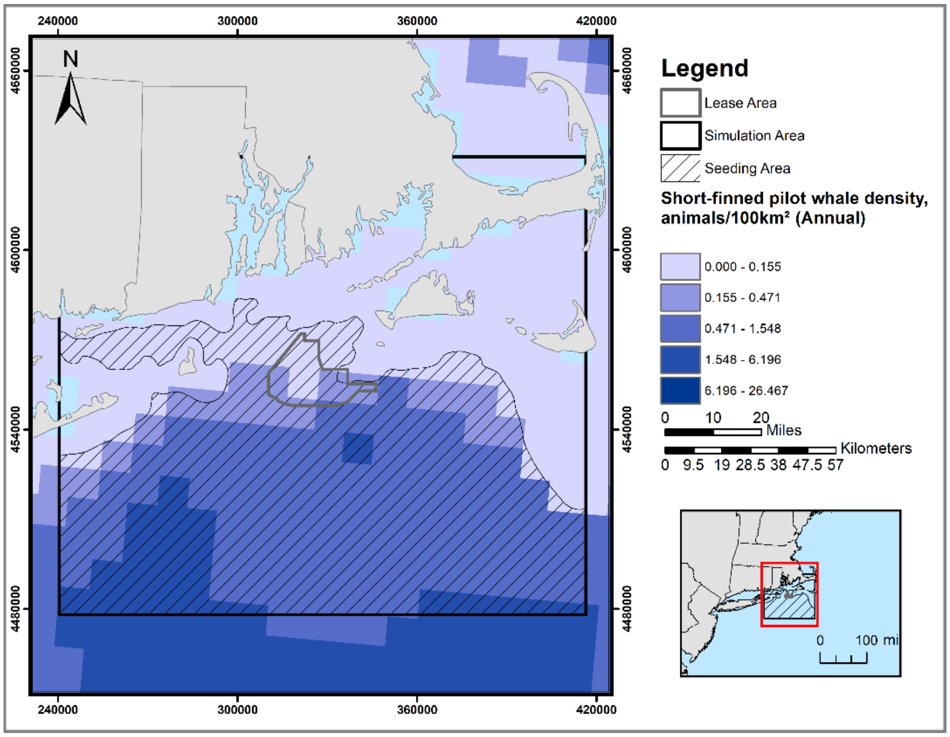

Figure J-12. Map of short-finned pilot whale animat seeding range.

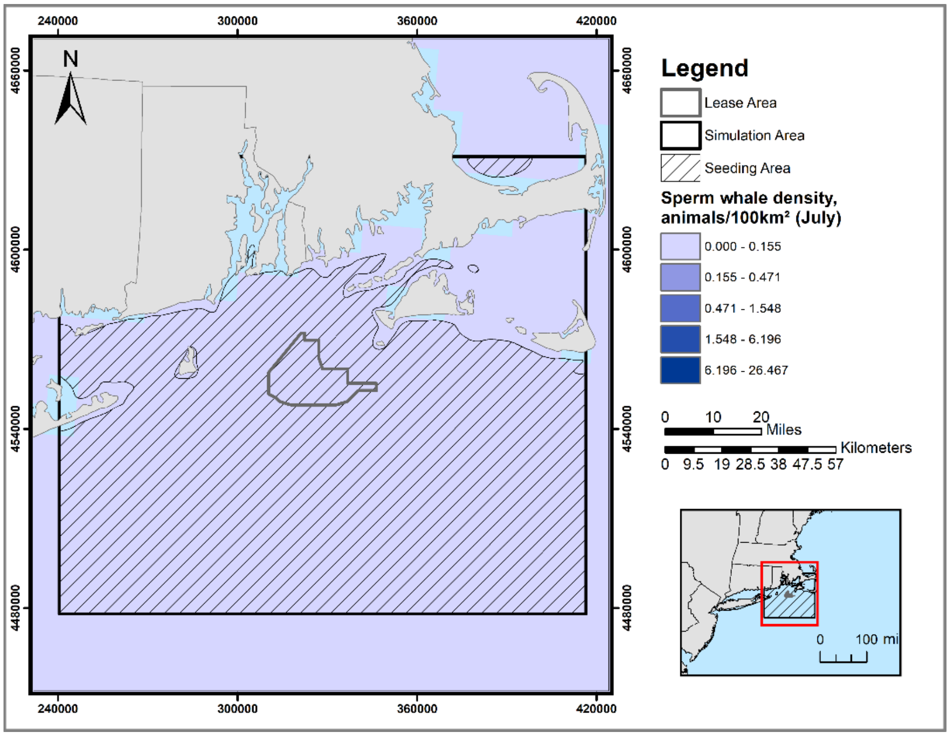

Figure J-13. Map of sperm whale animat seeding range for July, the month with the highest density.

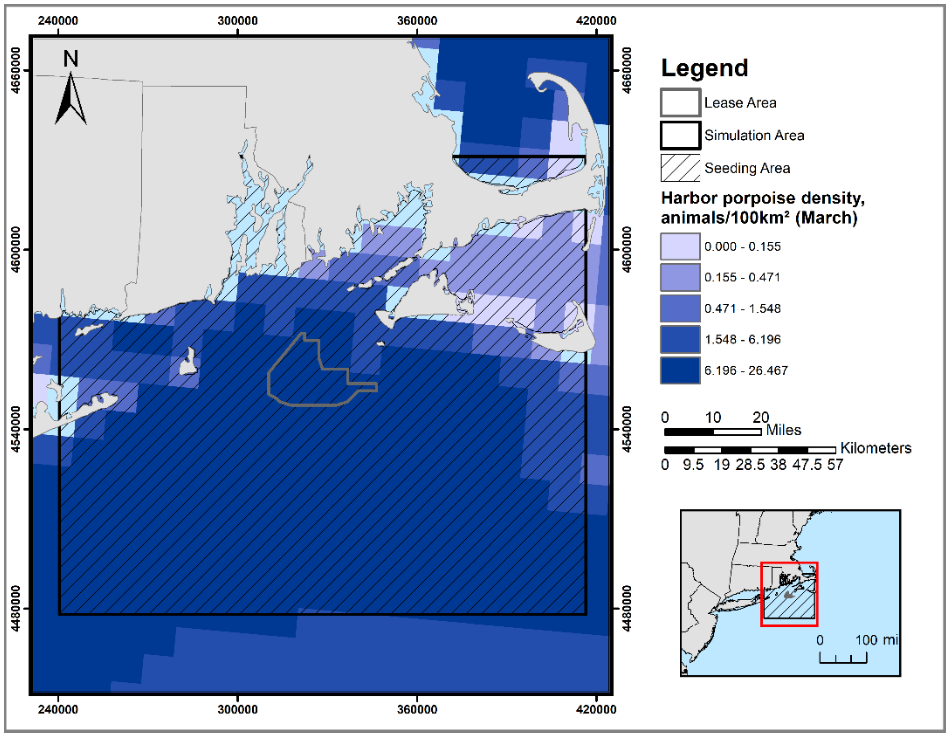

Figure J-14. Map of harbor porpoise animat seeding range for March, the month with the highest density.

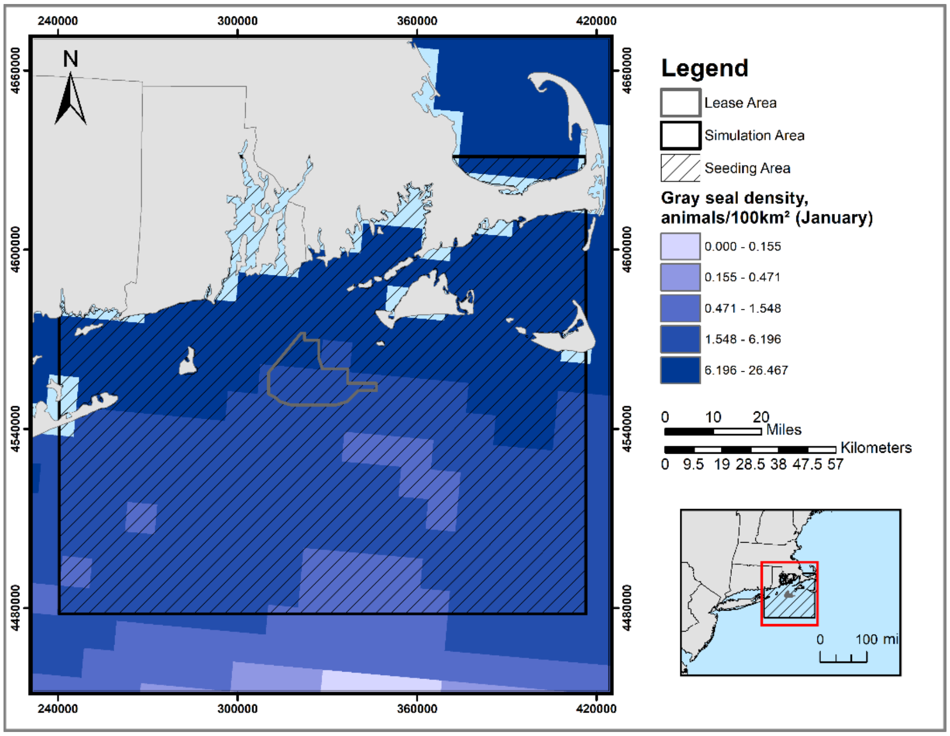

Figure J-15. Map of gray seal animat seeding range for January, the month with the highest density.

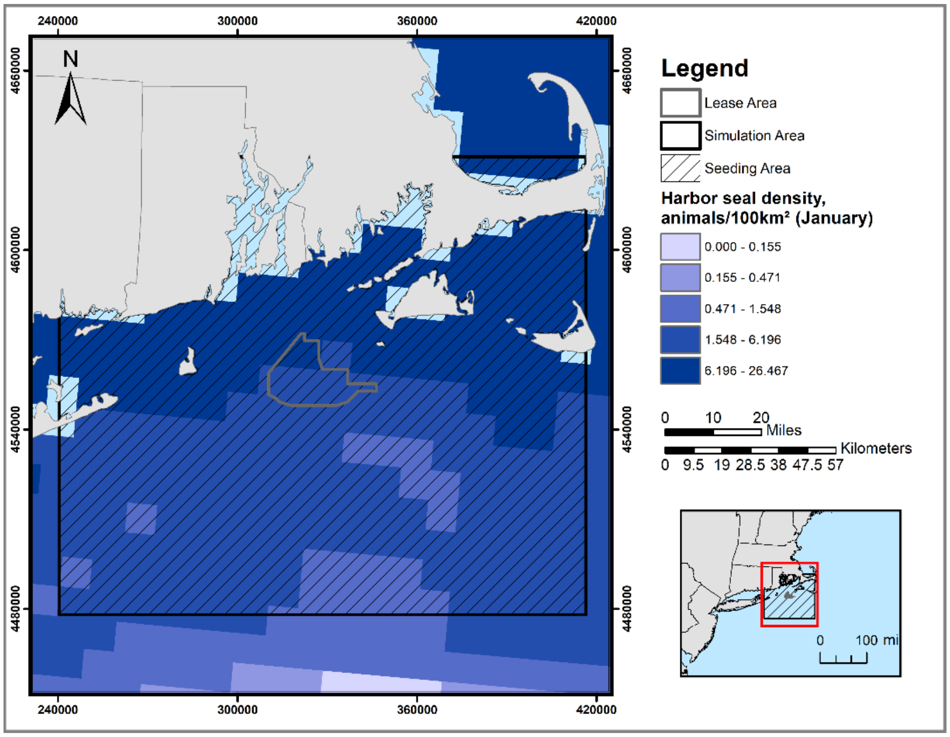

Figure -J-16. Map of harbor seal animat seeding range for January, the month with the highest density.

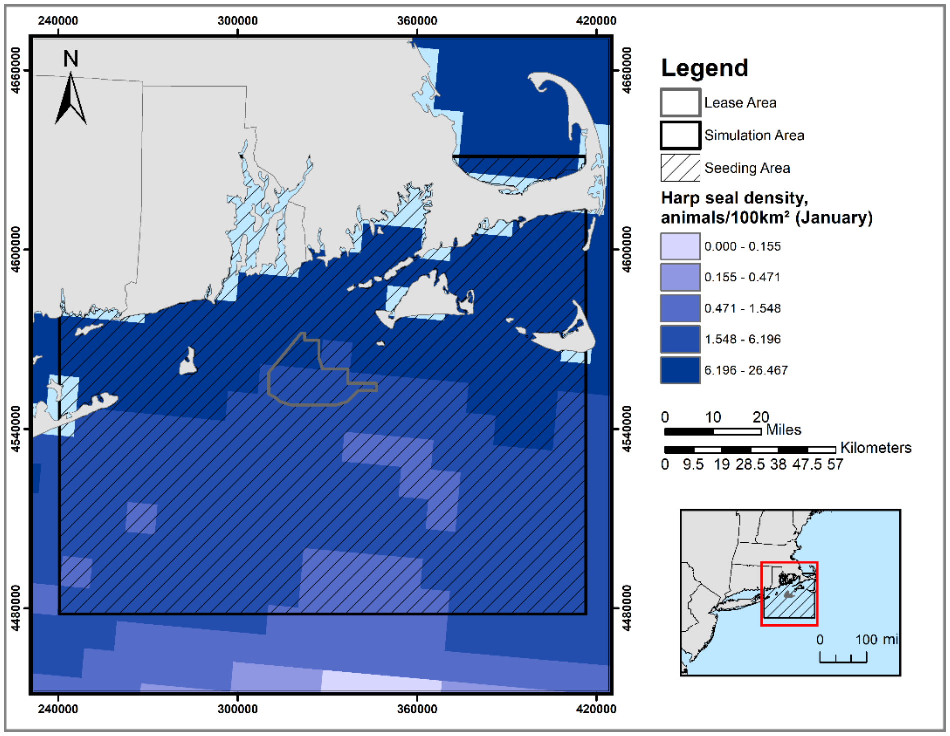

Figure J-17. Map of harp seal animat seeding range for January, the month with the highest density.

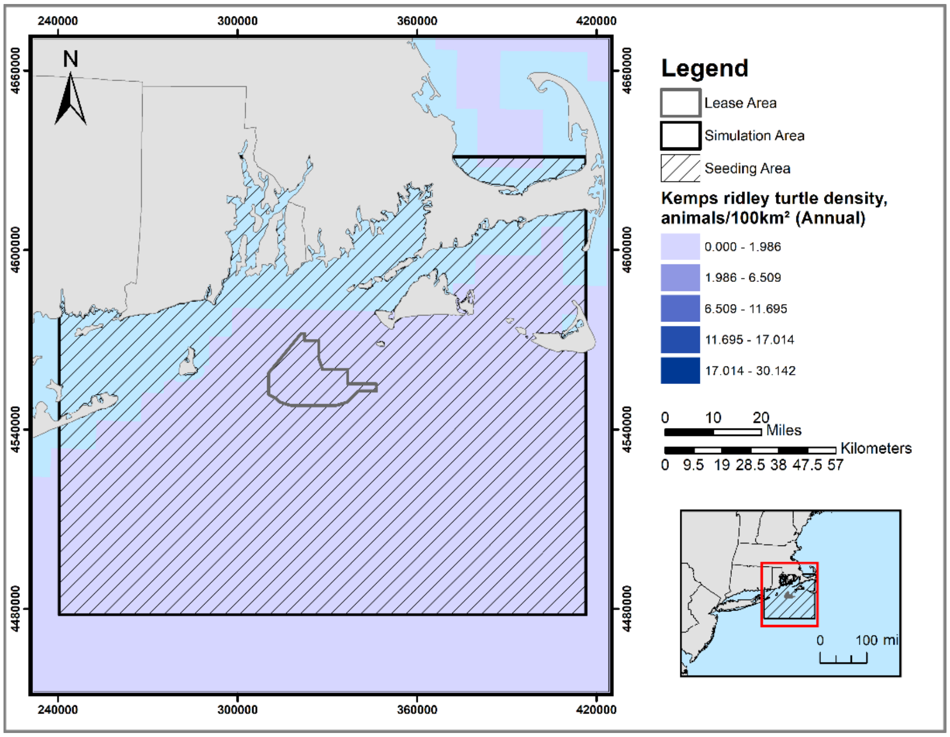

Figure J-18. Map of Kemp's ridley sea turtle with annual density from DoN (2017).

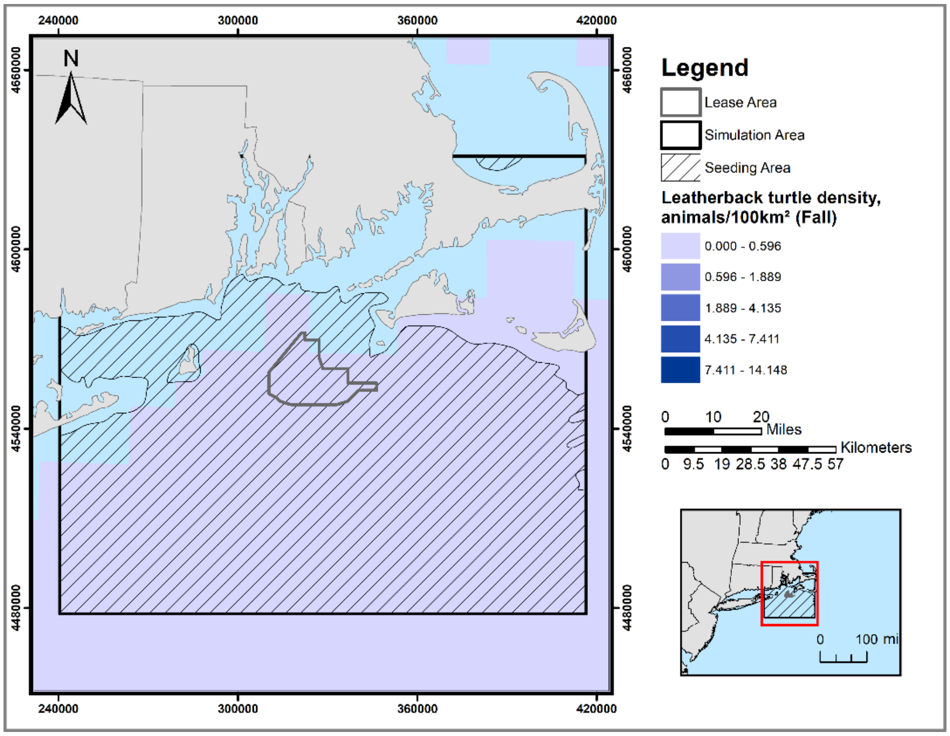

Figure J-19. Map of leatherback turtle with density from DoN (2017) for fall, the season with the highest density. Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

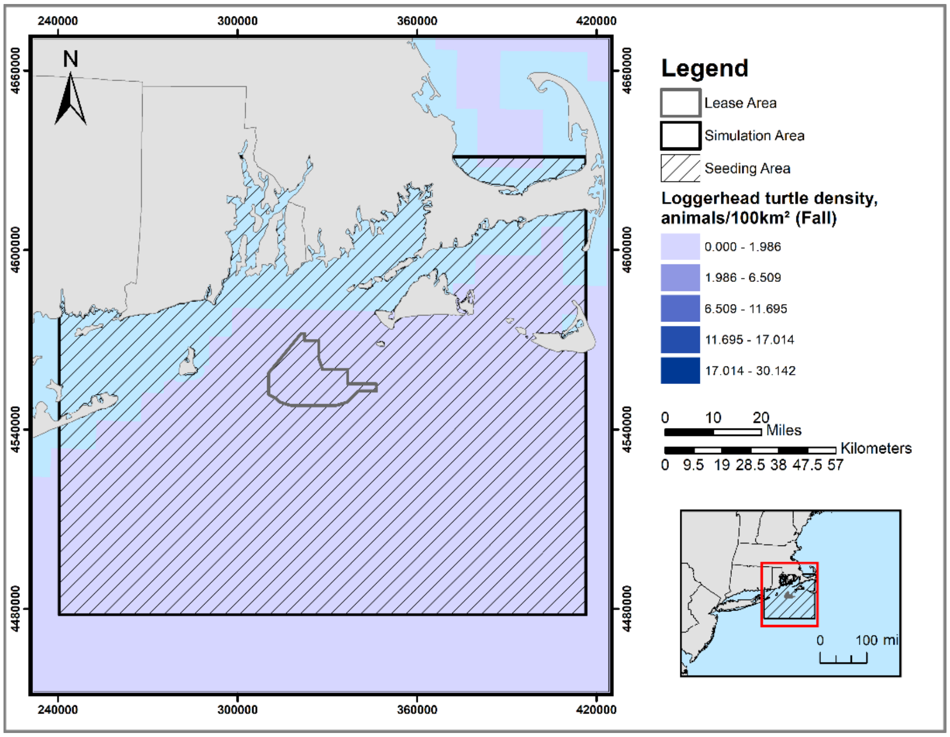

Figure J-20. Map of loggerhead turtle with density from DoN (2017) for fall, the season with the highest density. Exposure estimates are calculated using average seasonal density from Kraus et al. (2016) for summer and fall.

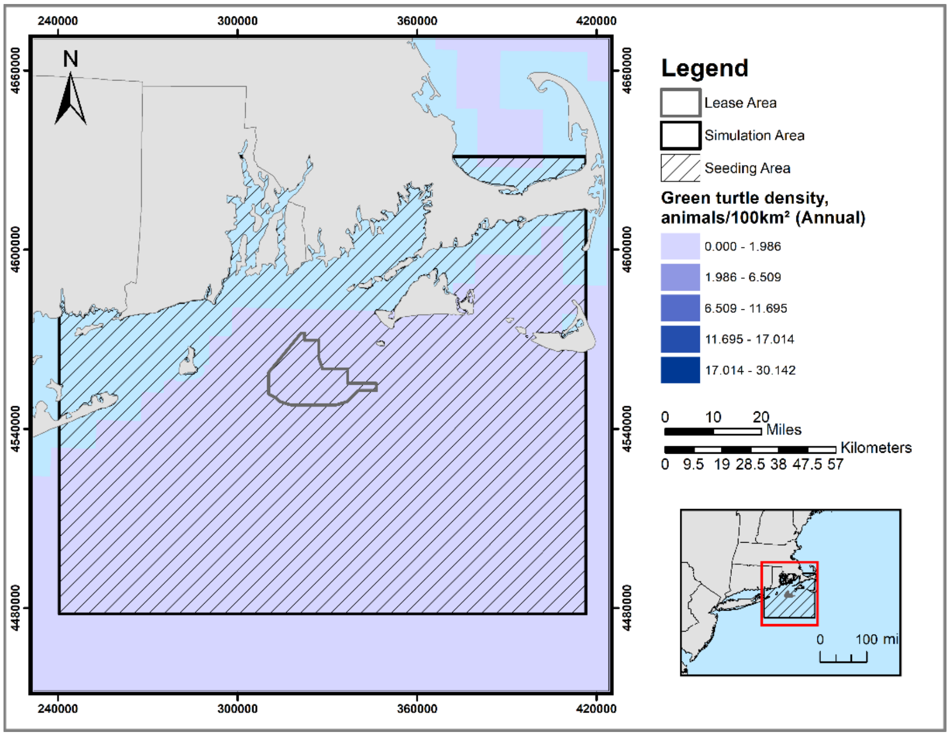

Figure J-21. Map of Green sea turtle, showing Kemp's ridley sea turtle annual density from DoN (2017) as an estimate.

Underwater Acoustic Modeling of Detonations of Unexploded Ordnance (UXO) for Orsted Wind Farm Construction, US East Coast

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Contents

1. Introduction

Orsted's offshore wind projects along the eastern US seaboard may encounter unexploded ordinances (UXO) on the seabed in the wind farm lease areas and along export cable routes. While non-explosive methods may be employed to lift and move these objects, some may need to be removed by explosive detonation. Underwater detonation explosions generate sound waves with high pressure levels that could cause disturbance and/or injury to marine fauna. Mitigation measures will likely be required to avoid Level-A (injurious) takes of animals, and Level-B (behavior) takes will need to be accounted for in the project letter of authorization (LOA) or incidental harassment authorization (IHA). The study described in this report has modeled acoustic source and sound propagation to estimate the sizes of Level-A and Level-B take zones for several species and for a selection of charge weights spanning the expected UXO types that may be encountered. The results provided here do not directly predict numbers of takes but they are intended for that purpose. Takes can be computed using approaches such as multiplication of zone areas by the corresponding animal densities (number of animals per unit area).

Most UXO assessment work in the US has been performed by or for the US Navy, who have worked closely with National Marine Fisheries Service (NMFS) to choose and define appropriate criteria for effects based on best available science. We have evaluated effects thresholds based on three key sound pressure metrics considered by the Navy and NMFS as indicators of injury and behavioral disturbance: unweighted peak compressional pressure level ($L_{\mathrm{pk,c}}$ and abbreviated here L_{pk}), frequency weighted sound exposure level (SEL or $L_{E,w}$), and acoustic impulse (J_p). A fourth metric, sound pressure level (SPL or L_p), which is often used for other impulsive sound assessments, has not been evaluated here because it is not presently used by NMFS as an assessment criterion for sounds from explosive detonations. The names and symbols used for the above metrics follow the terminology of International Organization of Standards (ISO) 18405 (ISO 2017), except where tables and equations have been copied from previous regulatory documents.

The thresholds applied here for each of the acoustic metrics have been obtained from three primary sources:

1.) *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III), June 2017* (Navy, 2017). This report provides thresholds for gastrointestinal and lung injury, and mortality to marine mammals, sea turtles and fish due to explosive pressure based on impulse and peak pressure.

2.) *Marine Mammal Acoustic Technical Guidance (2018 Revision to Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing*), Office of Protected Resources, NOAA Technical Memorandum NMFS-OPR-59, April 2018 (NMFS, 2018). This technical memorandum incorporates the report by J.J. Finneran (2016) that provides auditory weighting functions for SEL calculations and provides thresholds for hearing-related effects.

3.) *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. ASA S3/SC1.4 TR-2014 (Popper et al., 2014). This report provides peak pressure thresholds for injury and mortality to fish.

The acoustic metrics and thresholds for effects depend on species and in some cases animal size and submersion depth. Specialized acoustic models and semiempirical formulae are applied to evaluate the threshold exceedance distances from explosive charges detonated on the seabed and exposed directly to seawater. The theory underlying these models is provided in the technical discussion sections of this report.

This assessment considers acoustic effects to marine mammals, sea turtles and fish from five possible charge sizes at sites with four water depths near Orsted's Revolution Wind project areas. The results are also relevant for sites with similar water depths at Orsted's Ocean Wind 1 project, Orsted's Sunrise Wind project, and possibly other wind farm sites with similar depths and seabed sediment properties. An unmitigated and mitigated scenario are considered at each site, with mitigation considering a 10 decibel (dB) reduction to L_{pk}, $J_{p,}$ and L_{E}, that might be obtained using an air bubble curtain or similar system. The results for unmitigated and mitigated UXO detonations are provided in Sections 8 and 9 respectively.

Because of the large number of result tables, the Summary (Section 10) provides cross-references for effects assessment criteria to the relevant tables for both unmitigated and mitigated scenarios.

A key assumption of the model predictions presented in this report is that the full weights of UXO explosive charges are detonated together with their donor charges. A recent review of UXO explosive removals in the North Sea indicates that in most cases the UXO charge weights either did not detonate or only partly detonated, with the result being that the pressure waves generated were produced by the donor charge and only a small fraction of the UXO charge (Bellman, 2021). As such, it is likely that the full UXO charge will not detonate in all cases and the results presented herein assume full UXO charge detonation and therefore should be considered the worst case.

2. UXO Charge Sizes

The UXO charges considered here are characterized by their equivalent trinitrotoluene (TNT) weight. Five charge weight "bins" were defined, with each bin representing a group of similar weapons using a categorization defined by the US Navy. The modeling performed here considered the largest charge weight for the corresponding bin. The final set of bins are listed in Table 1. We note that the effect of the donor charges used to detonate the UXO are assumed to be included in the TNT equivalent weight for the respective bin.

Table 1. Navy "bins" and corresponding maximum UXO charge weights (Maximum equivalent weight TNT) to be modeled.

Navy bin	Maximum equivalent weight TNT	
	(kg)	(lbs)
E4	2.3	5
E6	9.1	20
E8	45.5	100
E10	227	500
E12	454	1000

3. Modeling Locations and Depths

Sound propagation away from UXO detonations is affected by acoustic reflections from the sea surface and seabed. Water depth and seabed properties, which are site-dependent, will influence the sound exposure levels and sound pressure levels at distance from detonations. However, when water depths and seabed conditions are similar, the predictions from one site can be used to approximate the acoustic levels at other sites. The influence of the seabed and water depth on sound propagation away from the detonation site is complex but it can be predicted accurately by acoustic models.

Orsted's recent projects under development in the US include the Revolution Wind project off Massachusetts, the Sunrise Wind project located just south of Revolution Wind, and the Ocean Wind 1 project on the Avalon Shoal off New Jersey. Each project is located in relative shallow waters of 20-54 meter (m) depth, and have sandy seabeds. The results of the present study are relevant for all three projects even though the specific locations modeled here were chosen inside the Revolution Wind project area. The key influencing parameter for these results is water depth; however, small variances of water depth (<10 m) are not expected to generate significant differences to the sound fields, so the propagation results will be relevant for each project area at sites with similar water depth as the sites modeled. The only possible exception is the shallowest site, located in a constrained channel of Narragansett Bay with nearby islands blocking sounds propagating in some directions. Maximum distances to specific sound level thresholds will be similar when islands are not nearby, but the area ensonified above the thresholds could be larger.

Four specific sites (S1 to S4) were chosen for this modeling assessment; two are along the export cable route and two are inside the wind lease area of the Revolution Wind project. The sites are shown on the map of Figure 1 and include:

In shallow waters along export cable route:

- Site S1: In the channel within Narragansett Bay in 12 m depth.
- Site S2: Intermediate waters outside of the Bay in 20 m depth.

Inside the lease area:

- Site S3: Shallower waters in southern portion of Hazard Zone 2 area, in 30 m depth.
- Site S4: Deeper waters in northern portion of Hazard Zone 2 area, in 45 m depth.

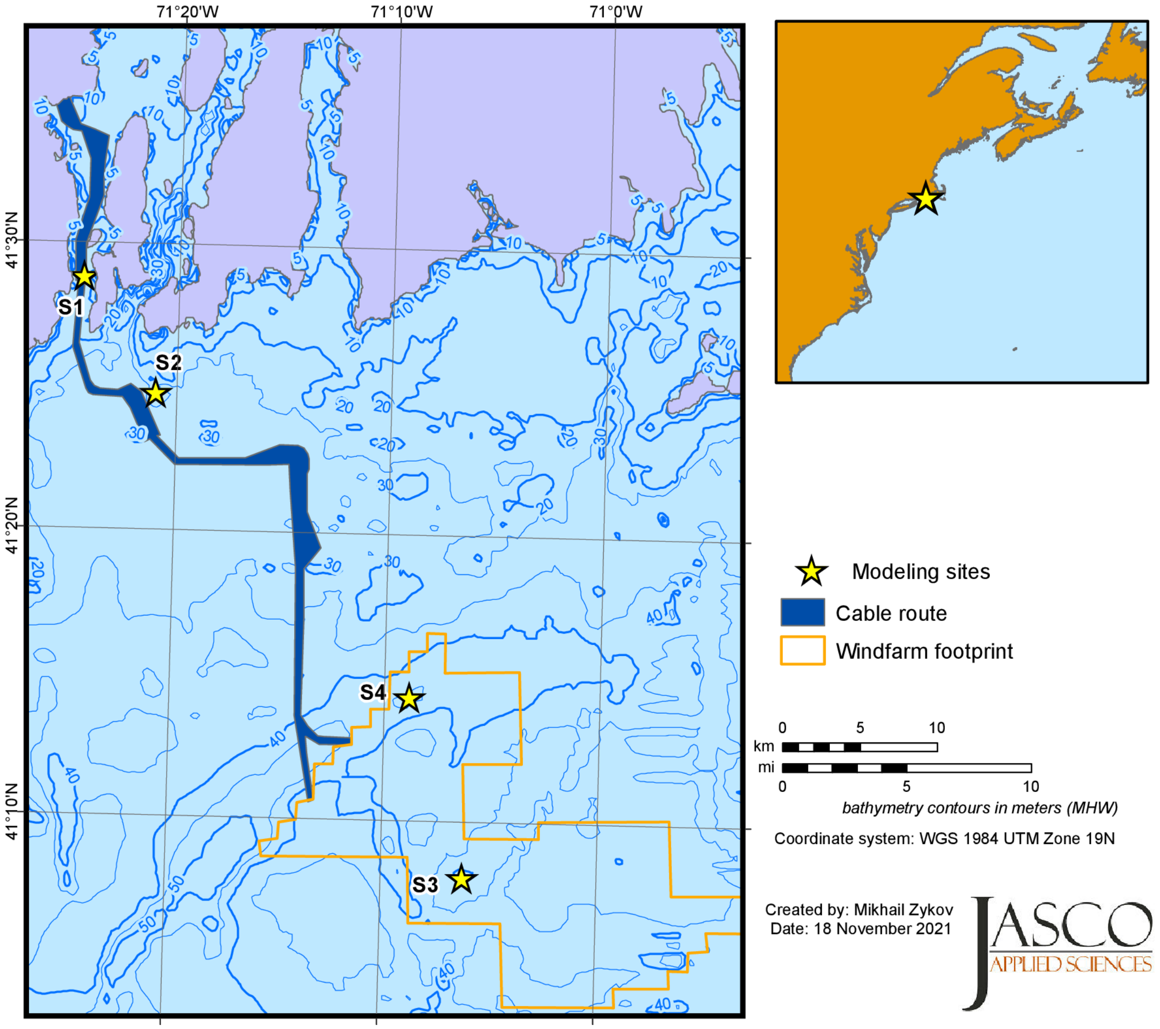


Figure 1. Map showing locations of the four modeling sites.

4. Blast Mitigation

Predictions of exceedance distances for effects to marine mammals were performed for unmitigated and mitigated scenarios, where the mitigated results were obtained by reducing the detonation source levels by 10 dB at all sound frequencies. The 10 dB reduction was applied to L_{pk} and decidecade band L_{E} and $L_{\mathrm{E,w}}$. The corresponding reduction to J_{p} was applied using a multiplicative factor of $10^{-1/2}$. This amount of acoustic reduction is expected to be achievable by deploying an air bubble curtain or similar system around the detonation site. A review of the expected attenuation for modern bubble curtain systems is provided below.

There is a little published information available on direct measurements of bubble curtain effectiveness for reducing peak pressure, SEL and impulse produced by underwater explosives detonations. One measurement of a small bubble curtain showed good performance for 1 kilogram (kg) charges, providing approximately 16 dB attenuation at all frequencies greater than 1 kilohertz (kHz) using small curtains of less than 11.5 m diameter (Schmidke et al., 2009). The same study evaluated another relatively small bubble curtain (diameter 22 m in 20 m water depth) surrounding 300 kg mines. That bubble curtain configuration produced smaller attenuations of approximately 2 dB at 100 hertz (Hz) to 6 dB at 10 kHz. These values are substantially smaller than observed attenuations at corresponding frequencies for modern bubble curtains applied to mitigate sounds from large pile installations. The smaller attenuation values observed by Schmidke et al are likely due to use of a small bubble curtain for a relatively large detonation charge size, even though the air flow rate per unit curtain length was similar. Modern curtains also apply bubble size optimization to maximize the frequency-dependent attenuation characteristics, but it is not clear if that was performed for the bubble curtains used in the Schmidke et al study.

A recent review of bubble curtain effectiveness for pile driving noise mitigation by Bellman et al (2020) found the attenuation performance of modern bubble curtains increases with sound frequency from about 20 Hz to 1.5 kHz, and then decreases slowly with further increase in frequency. They tabulated attenuation results for a Big Bubble Curtain (BBC) that indicated attenuations of at least 10 dB at 32 Hz, increasing to approximately 35 dB near 1 kHz. A follow-up report indicates first results for attenuation of UXO acoustic levels by BBC of 11 dB for broadband L_E and up to 18 dB for L_{pk}, although particulars of the charge sizes and water depths in the study were not provided (Bellman, 2021).

The spectral energy distribution of the pressure waveforms of explosives detonated in water will differ from the spectral distribution of pile driving sounds. Nevertheless, the frequency-dependent attenuations are expected to be similar if the bubble curtain radius is large enough to avoid nearfield effects of the explosive detonations. The spectra of smaller charges contain relatively more high-frequency energy than the spectra of larger charges after accounting for the higher overall energy of the larger charges. This spectral shape dependence on charge size is discussed in detail in Section 7.2.1. The maximum spectral levels of all charge sizes considered in this report occur at less than 10 Hz, but their spectral roll-off is small so their maximum decidecade L_E band levels occur above a few hundred Hz. Pile driving spectra have maximum band levels at lower frequencies, which suggests bubble curtain performance for explosive charges should in general produce greater broadband attenuation than for pile driving. The minimum modern bubble curtain attenuation effectiveness for the frequency bands dominating explosive detonation L_E in shallow waters is well above 10 dB. Therefore, the choice of 10 dB as a broadband L_E attenuation is expected to be conservative.

The very rapid onset of the shock pulse, within a few microseconds (μs), and its rapid decay constant of less than 2 ms for the largest charge size considered (454 kg), suggests the shock pulse peak pressure is dominated by high frequencies that are likely much higher than 500 Hz. The results compiled by Bellman et al (2020) indicate the peak pressure attenuation at those frequencies by modern bubble curtains should be greater than 10 dB. As mentioned above, the first results that applied the use of BBC for UXO produced attenuations slightly larger than 10 dB.

As a final note regarding UXO removal detonation pressures: Bellman (2021) noted that many UXO charges are situated slightly below the seafloor elevation after removal of overlying sedimentation. These charges then lie slightly below the seafloor grade and are then partly shielded by surrounding sediments. The generated pressure waves propagating away in the horizontal direction must pass through the sediments, which have higher absorption characteristics than seawater. Bellman found that propagation loss coefficients were higher for these partially buried charges than for charges detonated in seawater. In this study we assumed no such shielding by sediments.

5. Environmental Parameters

5.1. Seafloor Geoacoustic Parameters

Sound propagation in the shallow water environments of Orsted's wind projects is influenced by the properties of the seafloor substrate. A general profile for the area has been used for all four modeling sites. The surficial sediments are primarily sand as described for the seabed at the adjacent South Fork Wind site (Denes et al. 2018). Table 2 shows the sediment layer geoacoustic property profile used for acoustic modeling of SEL in this study. These properties are based on the sediment type and generic porosity-depth profile using a sediment grain-shearing model (Buckingham 2005). This general profile should be relevant for sites throughout the Sunrise Wind, Ocean Wind, and Revolution Wind lease areas.

Table 2. Estimated geoacoustic properties used for modeling at all sites, as a function of depth. Within each depth range, the parameter varies linearly within the stated range.

Depth below seafloor (m)	Material	Density (g/cm^3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–5	Sand	1.87	1,650–1,690	0.74–1.0	300	3.65
5–10		1.87–2.04	1,690–1,830	1.0		
10–100		2.04	1,830–2,140	1.0–1.67		
>100			2,140	1.67		

5.2. Ocean Sound Speed Profile

The gradients of the speed of sound in seawater affect acoustic refraction during sound propagation. The sound speed is a function of water temperature, salinity, and pressure (i.e., depth) (Coppens 1981). Monthly average sound speed profiles near the proposed construction areas, for the months of April to November, were obtained from the US Navy's Generalized Digital Environmental Model (GDEM; NAVO 2003) and are plotted in Figure 2. The sound speed profiles change little with depth, so these environments do not have strong seasonal dependence. The propagation modeling was performed using a sound speed profile representative of September, which is slightly downward refracting and represents the most likely time of year for UXO removal activities.

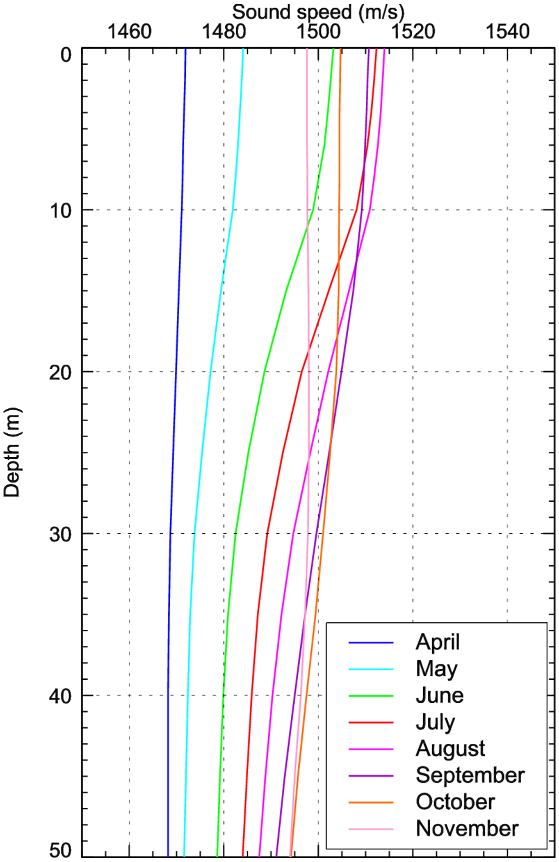


Figure 2. Monthly average sound speed profiles in proposed construction area (excluding winter season) (source: GDEM (NAVO 2003)).

6. Acoustic Thresholds for Mitigation Zones and Take Estimates

6.1. Marine Mammals and Sea Turtles: Auditory Injury (PTS)

The injury zones surrounding explosives detonations are of key importance for developing mitigation designed to minimize takes. Two injury mechanisms are assessed for marine mammals: auditory injury and non-auditory injury. We follow the US Navy approach for assessing both types of effects (Navy, 2017). Auditory injury (onset of permanent threshold shift (PTS)) is assessed using a dual criteria of L_{pk} and frequency-weighted SEL ($L_{E,w}$), where the frequency weighting functions are dependent on the species group (NMFS, 2018). The Navy follows NMFS's guidelines for assessing PTS and temporary threshold shift (TTS) using metrics L_{pk} and $L_{E,w}$ for marine mammals. These thresholds and additional thresholds for sea turtles are provided (Table 3). Note the TTS thresholds also listed in that table are used for Level-B take assessments (see Section 6.3). The Group column in Table 3 represents species groups from top to bottom: low-frequency cetaceans (LF), mid-frequency cetaceans (MF), high-frequency cetaceans (HF), sirenians (SI), otariids in water (OW), pinnipeds in water (PW), and sea turtles (TU).

Table 3. US Navy peak (2017) pressure and frequency-weighted sound exposure thresholds for onset of PTS and TTS. See text for a description of the Group abbreviations.

Group	Hearing threshold at f_0	TTS threshold		PTS threshold	
	SPL (dB SPL)	SEL (weighted) (dB SEL)	peak SPL (dB SPL)	SEL (weighted) (dB SEL)	peak SPL (dB SPL)
LF	54	168	213	183	219
MF	54	170	224	185	230
HF	48	140	196	155	202
SI	61	175	220	190	226
OW	67	188	226	203	232
PW	53	170	212	185	218
TU	95	189	226	204	232

Note: the term “peak SPL” used in column 6 represents the peak pressure level (L_{pk}) metric as defined in ISO 18405. Peak pressure is not truly an SPL, as SPL is now defined as a root-mean-square pressure level.

6.2. Marine Mammals and Sea Turtles: Non-Auditory Injury and Mortality

Non-auditory injury and mortality mitigation zones are calculated using metrics representing onset of injury to animal’s lungs and gastrointestinal tracts from compression of enclosed air volumes or bubbles. The relevant metrics are L_{pk} and J_p of the blast shock pulse. The peak pressure threshold for injury to gastrointestinal tract is provided in Table 6 as L_{pk} = 237 dB re µPa and this is independent of animal mass. The impulse calculation for lung injury and mortality integrates pressure through the time of the shock pulse, with the integration period limited by the arrival of the surface-reflected path or 20% of the animal’s lung oscillation period – whichever is smaller. These integration time limits are applied because the arrival of the phase-inverted surface reflection signal reduces or truncates the positive phase of the shock pulse, and because the excitation of lung compression is reduced if the impulse duration is greater than 20% of the lung’s oscillation period. The lung oscillation limiting times are straightforward to calculate using the Goertner formulas (Goertner 1982) but they depend on animal mass and submersion depth. The surface reflection arrival time is determined by the geometry of the source and receiving animal relative to each other and the sea surface.

The Navy’s impulse criteria for onset of lung injury and mortality are based on measurements of blast effects on a variety of mammals experimentally exposed to detonation pressures (Yelverton 1973). The Navy has published two sets of equations for effects thresholds for impulse that depend on animal mass and submersion depth. The first set of equations (Table 5) produces thresholds based on effects observed in 50% of exposed animals. The second set of equations (Table 6) represent thresholds for onset of effects, based on observed effects in 1% of the exposed animals. NMFS has asked that the more conservative (onset of effects) values also be used for take assessments for Orsted’s projects if the distances exceed those of other take criteria.

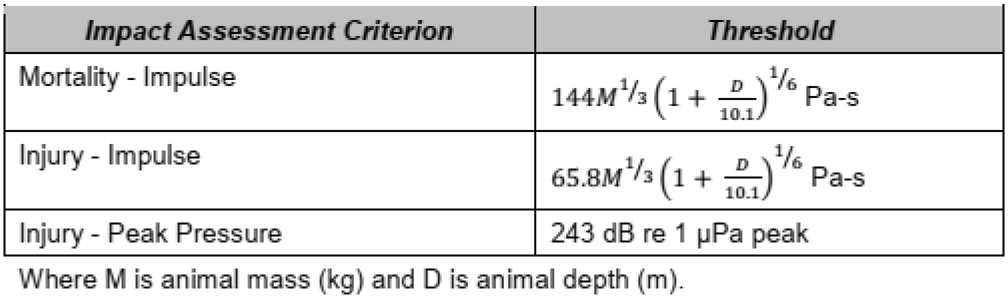
The impulse thresholds for lung injury and mortality to marine mammals and sea turtles depend on the animal lung volume, which is dependent on animal mass and submersion depth. To be conservative, maximum horizontal distances for threshold exceedances were calculated in 1 m submersion depth increments from the surface to seabed at the respective assessment location. The maximum distance over these depths was listed as the representative exceedance distance.

The animal masses used for exceedance calculations were obtained from a tabulation of animal masses (Table C.9, Navy, 2017). The Navy table provides conservative calf/pup and adult masses for all marine mammal species. The adult mass is the smallest mass from the range of adult masses for the respective species. Five animal groups are defined in Table 4 that represent and comprise similar-mass species to those that may be encountered at the project sites, including rare species for those areas. For each group, a representative species with the smallest calf and adult masses are used as conservative values for the entire animal group. Sperm whales were grouped with larger baleen whales due to their similar adult masses, but the sei whale calf mass was used for this group due to their smaller mass. The smallest animals of dolphin, kogia, pinniped, and sea turtle families had very similar mass to harbor seals. Harbor seal calf and adult masses were therefore used as the representative species for that animal group for conservatism. Table 4 lists the defined animal groups and the corresponding calf/pup and adult masses of representative species used for impulse threshold calculations. Table 7 and Table 8 provide the corresponding thresholds for onset of lung injury and onset of mortality, respectively, for all relevant animal masses at a selection of submersion depths.

Table 4. Representative calf/pup and adult mass estimates for the animal groups defined for this assessment. These mass values are based on the smallest expected animals for the species that might be present within project areas. Masses listed here are used for assessing impulse-based onset of lung injury and mortality threshold exceedance distances.

Impulse Animal Group	Representative Species	Calf/Pup Mass (kg)	Adult Mass (kg)
Baleen whales and Sperm whale	Sei whale calf (*Balaenoptera borealis*) Sperm whale adult (*Physeter macrocephalus*)	650	16,000
Pilot and Minke whales	Minke whale (*Balaenoptera acutorostrata*)	200	4,000
Beaked whales	Gervais' beaked whale (*Mesoplodon europaeus*)	49	366
Dolphins, Kogia, Pinnipeds, and Sea Turtles	Harbor Seal (*Phoca vitulina*)	8	60
Porpoises	Harbor Porpoise (*Phocoena phocoena*)	5	40

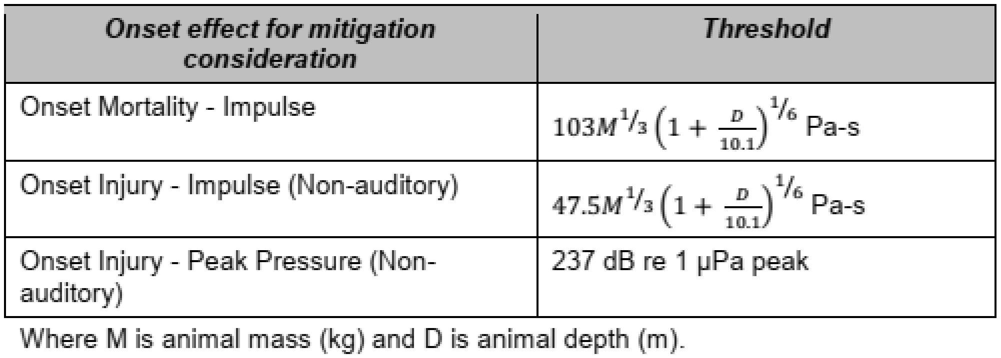
Table 5. US Navy impulse and peak pressure threshold equations for onset lung injury in marine mammals and sea turtles due to explosive detonations (Department of the Navy 2017). These thresholds are based on observed effects to 50% of exposed animals. Note that this table is provided primarily for information purposes. The threshold formula in Table 6 are used for most of the results in this assessment.



Impact Assessment Criterion	*Threshold*
Mortality - Impulse	$144M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Injury - Impulse	$65.8M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Injury - Peak Pressure	243 dB re 1 μPa peak

Where M is animal mass (kg) and D is animal depth (m).

Table 6. US Navy impulse and peak pressure threshold equations for onset of lung injury in marine mammals and sea turtles due to explosive detonations (Department of the Navy 2017). These thresholds are based on observed effects to 1% of exposed animals.



Onset effect for mitigation consideration	*Threshold*
Onset Mortality - Impulse	$103M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Onset Injury - Impulse (Non-auditory)	$47.5M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Onset Injury - Peak Pressure (Non-auditory)	237 dB re 1 µPa peak

Where M is animal mass (kg) and D is animal depth (m).

Table 7. Impulse thresholds (units of Pa·s) for Onset Injury from equation in Table 6 for all animal masses in Table 4, for selected submersion depths between 1 and 60 m.

Submersion Depth (m)	Animal mass (kg) / Impulse Thresholds for Onset Lung Injury (Pa s)									
	5 kg	8 kg	40 kg	49 kg	60 kg	200 kg	366 kg	680 kg	4,000 kg	16,000 kg
1	165	82.5	188.9	96.5	345.2	176.6	766	282.2	1215.9	424.3
10	182.2	91.1	208.6	106.5	381.1	194.9	845.7	311.5	1342.4	468.5
20	194.9	97.4	223.1	114	407.6	208.5	904.5	333.2	1435.8	501.1
30	204.4	102.2	234	119.5	427.6	218.7	948.8	349.5	1506.2	525.6
40	212.1	106.1	242.8	124.1	443.7	227	984.7	362.8	1563.1	545.5
50	218.7	109.3	250.3	127.9	457.4	234	1015	373.9	1611.2	562.3
60	224.4	112.2	256.8	131.2	469.3	240.1	1041.4	383.7	1653.1	576.9

Table 8. Impulse thresholds (units of Pa·s) for Onset Mortality from equation in Table 6 for all animal masses in Table 4, for selected submersion depths between 1 and 60 m.

Submersion Depth (m)	Animal mass (kg) / Impulse Thresholds for Onset Mortality (Pa s)									
	5 kg	8 kg	40 kg	49 kg	60 kg	200 kg	366 kg	680 kg	4,000 kg	16,000 kg
1	357.8	178.9	409.6	209.3	748.5	382.9	1661	611.9	2636.6	920.1
10	395.1	197.5	452.2	231	826.3	422.7	1833.7	675.6	2910.9	1015.8
20	422.6	211.3	483.7	247.1	883.8	452.1	1961.4	722.6	3113.5	1086.5
30	443.3	221.6	507.4	259.2	927.1	474.3	2057.4	758	3266	1139.8
40	460	230	526.6	269	962.2	492.2	2135.2	786.6	3389.5	1182.8
50	474.2	237.1	542.8	277.3	991.8	507.4	2201	810.8	3493.8	1219.3
60	486.5	243.3	556.9	284.5	1017.6	520.6	2258.2	831.9	3584.6	1250.9

6.3. Marine Mammals and Sea Turtles: Level-B takes and Disturbance

The acoustic criteria relevant for Level-B takes include L_{pk} and $L_{\mathrm{E,w}}$ thresholds. All SEL modeling in this study assumes a single detonation per day as the assessment criteria and thresholds are different when more than one detonation occurs in a 24-hour period, as discussed below.

Single blast events within a 24-hour period are not presently considered by NMFS to produce behavior effects if received levels are below the onset of TTS thresholds for $L_{\mathrm{E,w}}$ and L_{pk} (Table 3). When multiple blast events occur within a 24-hour period, the US Navy approach applies a disturbance threshold of TTS $L_{\mathrm{E,w}}$ minus 5 dB. Thus, the effective Level-B take threshold for single events in each 24-hour period is the $L_{E,w}$ for TTS onset, and for multiple events it is the $L_{E,w}$ for TTS – 5 dB.

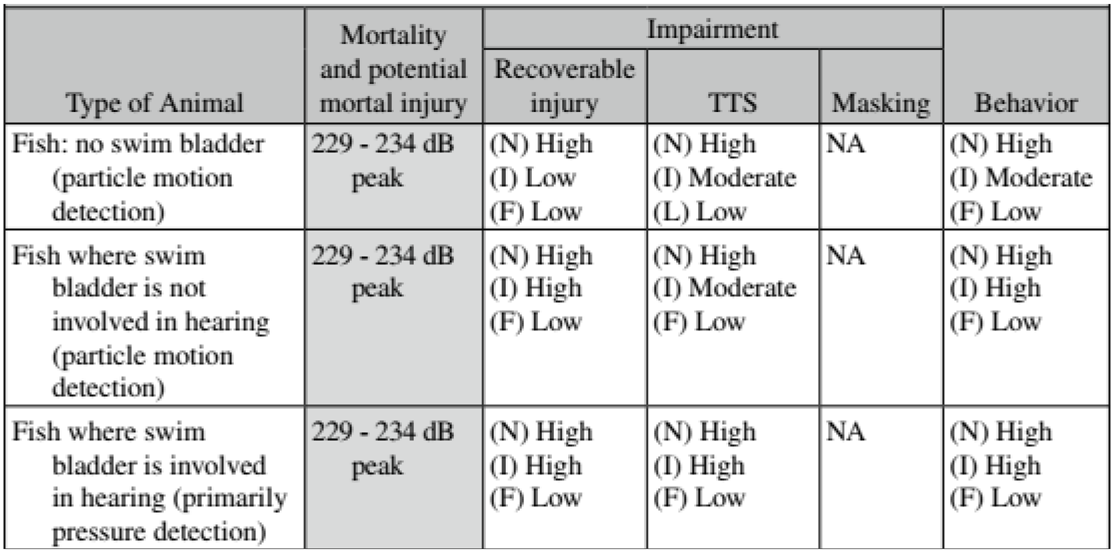
The calculation of TTS onset and behavioural effects (TTS – 5 dB) is more difficult when multiple blasts occur within a 24-hour period. In this case marine mammals and sea turtles could receive partial doses of SEL from multiple detonations. The individual event doses depend on the charge sizes, relative detonation timing, animal locations, and geoacoustic environment parameters along paths between the detonation and the exposed animals, most of which are not known in advance of the UXO detonations. If the parameters other than animal locations were known, then animal movement models could be used to provide exposure and take estimates. However, since Orsted plans on only one charge detonation per day, a single event SEL model scenario is sufficient to calculate an $L_{\mathrm{E,w}}$ map around each charge, and the TTS zones can be evaluated using the TTS criteria from Table 3.

Note: For multiple blast events an SPL-based disturbance threshold of L_p = 175 dB re 1 μPa^2 would be relevant. Here we are considering only a single blast event per day, so we have not considered that threshold. The approach for calculating L_p is defined in ISO 18405, but that metric is not currently applied by the Bureau of Ocean Energy Management (BOEM) or NMFS for explosives effects assessment of single blast events. Modeling of SPL requires using full wave source and propagation models that are not required for SEL-based assessments. That has not been done here, but it could be added later if required.

6.4. Fish Injury

Injury to fish from exposures to blast pressure waves is attributed to compressive damage to tissue surrounding the swim bladder and gastrointestinal tract, which may contain small gas bubbles. Effects of detonation pressure exposures to fish have been assessed according to the L_{pk} limits for onset of mortality or injury leading to mortality due to explosives, as recommended by the American National Standards Institute (ANSI) expert working group (Popper et al. 2014) and provided in Table 9. The injurious effects thresholds for all fish species groups are the same: L_{pk} = 229–234 dB re 1 μPa. The present assessment has applied the lower range value of L_{pk} = 229 dB re 1 μPa for potential mortal injury and mortality.

Table 9. Recommended Fish Injury thresholds for explosives from Popper et al. (2014).



Type of Animal	Mortality and potential mortal injury	Impairment			Behavior
		Recoverable injury	TTS	Masking	
Fish: no swim bladder (particle motion detection)	229 - 234 dB peak	(N) High (I) Low (F) Low	(N) High (I) Moderate (L) Low	NA	(N) High (I) Moderate (F) Low
Fish where swim bladder is not involved in hearing (particle motion detection)	229 - 234 dB peak	(N) High (I) High (F) Low	(N) High (I) Moderate (F) Low	NA	(N) High (I) High (F) Low
Fish where swim bladder is involved in hearing (primarily pressure detection)	229 - 234 dB peak	(N) High (I) High (F) Low	(N) High (I) High (F) Low	NA	(N) High (I) High (F) Low

6.5. Fish Disturbance

This assessment has not quantitatively assessed zones of non-injurious effects to fish from explosive detonations because the Popper et al. (2014) guidelines (see Table 9) are qualitative and vague on that subject. For fish species that use swim bladders for hearing, Popper et al suggest a high likelihood of TTS and recoverable injury at near and intermediate distances, where near refers to within a few tens of meters and intermediate refers to a few hundreds of meters. For fish species with swim bladders not used for hearing, the guidelines indicate high likelihood of recoverable impairment at near and intermediate distances but low levels of TTS at intermediate distances. For fish without swim bladders the guidelines indicate low likelihood of recoverable injury at intermediate distances and moderate likelihood of TTS at intermediate distances and low levels of both effects at far distances of a few kilometers.

7. Acoustic Modeling

7.1. Peak Pressure and Impulse

7.1.1. Shock Pulse Source Function

Modeling of acoustic fields generated by UXO detonations is performed using a combination of semi-empirical and physics-based computational models. The source pressure function used for estimating L_{pk} and J_p metrics is calculated using a semiempirical model that approximates the rapid conversion (within approximately 1 μs for high explosive) of solid explosive to gaseous form in a small gas bubble under high pressure, followed by an exponential pressure decay as that bubble expands outwards from the charge detonation location. This behavior imparts an initial pressure "shock pulse" into the water that is represented well by an instantaneous rise to peak pressure P_0 followed by an exponentially decaying pressure function of the form:

$$P(t) = P_0 e^{-t/\tau} \qquad 1$$

The shape and amplitude of the pressure versus time signature of the shock pulse changes with distance from the detonation location due to non-linear propagation effects caused by its high L_{pk}. Arons and Yennie (1949) made measurements of the detonations of a range of charge sizes in Vineyard Sound, coincidentally just a few miles from Orsted's wind leases, and derived empirical formulae for P_0 in Pascals, and exponential time constant τ in seconds as functions of equivalent TNT charge weight W in kilograms, and distance from the detonation r in meters (note the original equations used different weight and distance units and are converted to metric system units in the formulae presented here.

$$P_0 = 5.24 \times 10^7 \left(\frac{W^{\frac{1}{3}}}{r}\right)^{1.13} \quad \text{Pa} \qquad 2$$

$$\tau = 9.25 \times 10^{-5} W^{\frac{1}{3}} \left(\frac{W^{\frac{1}{3}}}{r}\right)^{-0.22} \quad \text{s} \qquad 3$$

7.1.2. Shock Pulse Pressure Range Dependence

The shock pulse source function variation with distance described above is valid only close to the source. Beyond a certain distance R_0, the functional dependence of P_0 and τ on W and r are better-described by weak shock theory (Rogers 1977). The transition distance was defined by Gaspin (1983) as $R_0 = 4.76\, W^{1/3}$ meters. For example, R_0 is 47.6 m for a 1000 kg charge. At distances greater than R_0, the L_{pk} and time constant are obtained by modified formulae (Rogers 1977):

$$P_0(r > R_0) = \frac{P_0(R_0)\left\{\left[1 + \frac{2R_0}{L_0}\ln\frac{r}{R_0}\right]^{\frac{1}{2}} - 1\right\}}{\left(\frac{r}{L_0}\right)\ln\frac{r}{R_0}} \quad \text{Pa} \qquad 4$$

$$\tau(r > R_0) = \tau(R_0)\left[1 + 2\left(\frac{R_0}{L_0}\right)\ln\frac{r}{R_0}\right]^{\frac{1}{2}} \quad \text{s} \qquad 5$$

where $L_0 = (\rho_0 {c_0}^3 \tau(R_0))/(\beta P_0(R_0)$.

In Eq. 5, water density ρ_0=1026 kg/m^3, water sound speed c_0 = 1500 m/s, and β=3.5. These equations lead to a pressure decay with range r that transitions to spherical spreading at long distances. The time constant also increases as the higher frequencies of the shock pulse, responsible for its sharp peak, are preferentially attenuated by absorptive loss. The pressure calculations were performed for the charge sizes of Table 1 and these results are graphed as a function of distance from the charges in Figure 3. The corresponding shock pulse time constant versus distance from Eqs. 3 and 5 is plotted in Figure 4.

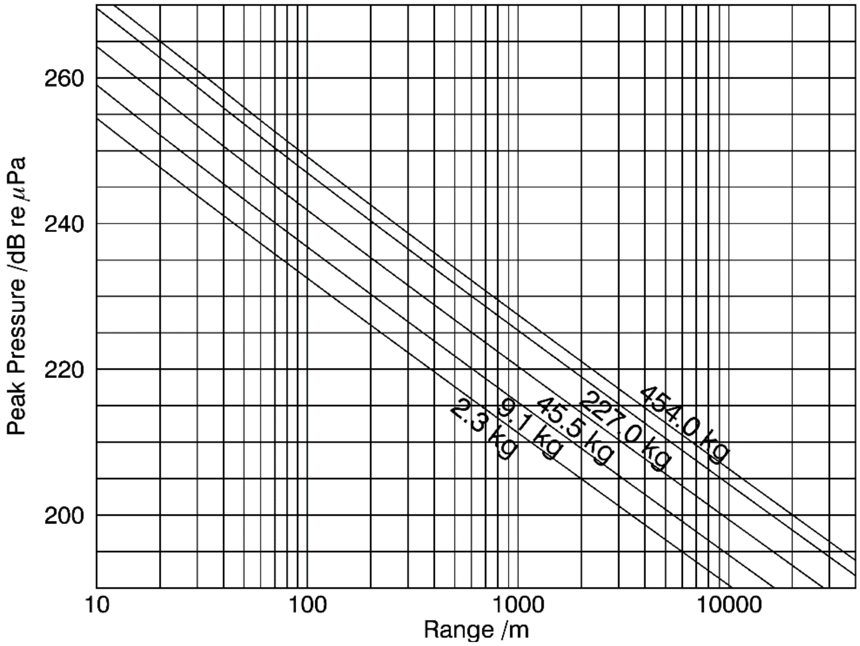


Figure 3. Peak pressures versus distance from detonations of the charge weights listed in Table 1, calculated with Eqs. 2 and 4.

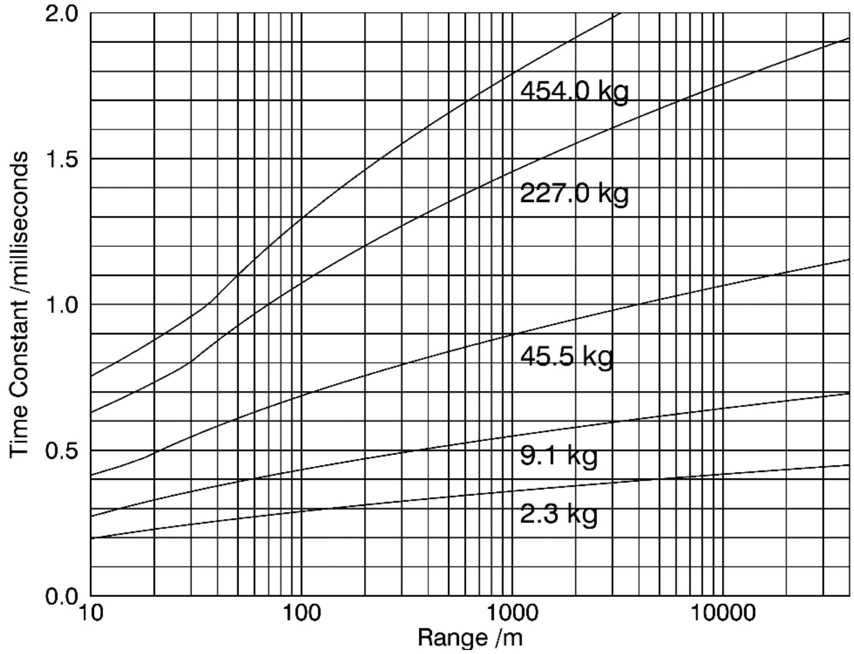


Figure 4. Time constants calculated with Eqs. 3 and 5 and converted to milliseconds for the exponential decay approximation of the shock pulse, for each of the charge weights listed in Table 1.

7.1.3. Impulse

Acoustic impulse is defined as the integral of pressure through time. Assuming the onset of the pressure signal of the direct acoustic path starts at $t = 0$ and ends at $t = T$, the impulse is given by:

$$J_p = \int_0^T P(t)\,dt \tag{6}$$

If the integration end time T is within the part of the shock pulse pressure waveform approximated well by the exponential function (Eq. 1) then Eq. 6 can be expressed:

$$J_p(r) = P_0(r)\tau(r)\left(1 - e^{-T/\tau(r)}\right) \tag{7}$$

In practice, this approximation is accurate for integration times much larger than the time constant because most of the contribution to impulse occurs near the shock pulse onset and the right bracketed term in Eq. 7 approaches 1.0 as the integration time exceeds a few time constants (e.g., see Figure 4).

The US Navy applies an integration time window starting at the onset of the shock pulse and ending at the lesser of the arrival time of the surface reflection and 20% of the oscillation period of an exposed animal's lung, i.e., T = *minimum*(T_{surf}, 0.2 T_{lung}). The arrival time of the surface-reflected path relative to the direct path can be calculated from the depths of the source charge z_s and the exposed animal z_r, their horizontal separation x and the water sound speed c_0:

$$T_{surf} = \left(\sqrt{x^2 + (z_s + z_r)^2} - \sqrt{x^2 + (z_s - z_r)^2}\right)/c_0 \tag{8}$$

The lung oscillation period can be approximated by the oscillation period of a gas sphere of the same volume. The lung volume of animals at atmospheric pressure is approximately proportional to the animal's mass M in kilograms, and this volume decreases with animal submersion depth z_r due to compression by hydrostatic pressure. Goertner (1982) provides the following approximation for lung volume V and equivalent volume fundamental oscillation period t_{osc} for a submerged animal:

$$V = 3.5 \times 10^{-5}\, M \frac{p_{atm}}{(\rho_0 g z_r + p_{atm})} \quad \mathrm{m}^3 \tag{9}$$

$$t_{osc} = 97.1\ (V4\pi/3)^{\frac{1}{3}}/\sqrt{\rho_0 g z_r + p_{atm}} \quad \mathrm{s} \tag{10}$$

where $g = 9.81\ m/s^2$ is the gravitational acceleration and p_{atm} is the atmospheric pressure in pascals at the sea surface. Figure 5 shows lung fundamental oscillation periods calculated from Eq. 10 for four animal masses, versus submersion depth.

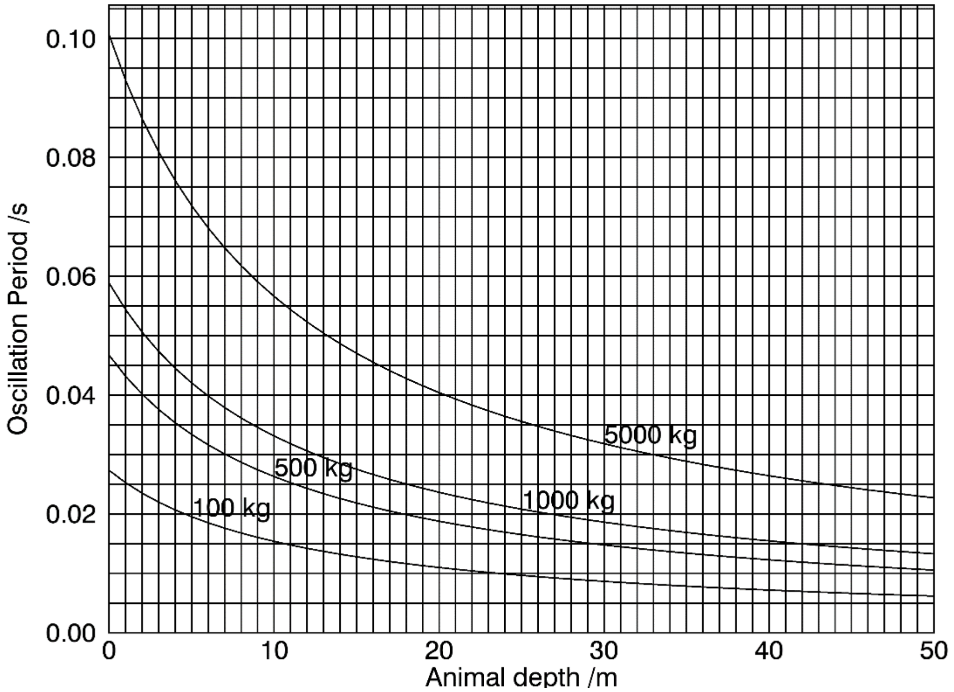


Figure 5. Lung oscillation periods for animal masses of 100 kg, 500 kg, 1000 kg, and 5000 kg versus submersion depth, calculated using Eq. 10.

7.2. Sound Exposure Level Model

SEL and SPL calculations for blast pressure waveforms depend on the characteristics of the initial shock pulse, as described above, and the subsequent oscillation of the detonation gas bubble. The oscillations lead to a series of alternating negative and positive pressure phases trailing the initial positive pressure shock pulse (Figure 6). The positive pressures (relative to hydrostatic pressure) occur when the bubble volume is small, and the negative pressures occur when the bubble volume is large. The shape of the resulting pressure waveform can be calculated using an explosive waveform model (e.g., Wakeley 1977) that includes the shock pulse model of Eq. 1 and extends the pressure prediction in time through several oscillations of the bubble. The negative phase pressure troughs and bubble pulse peaks following the shock pulse are responsible for most of the low frequency energy of the overall blast waveform.

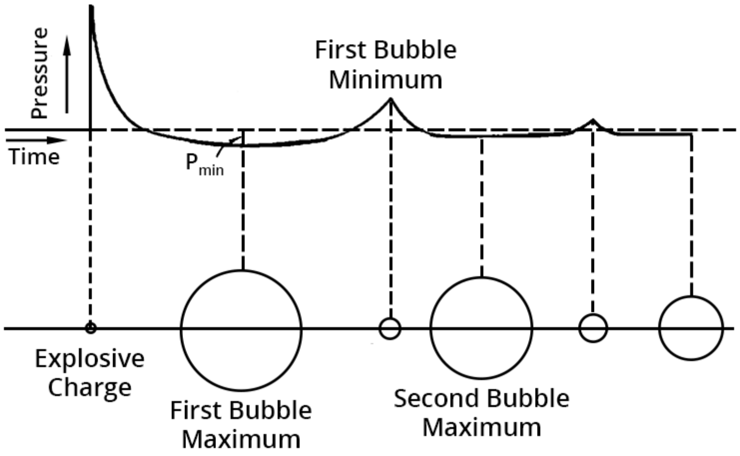


Figure 6. Pictorial representation of the relationship between the radiated pressure signal and the volume of the gas bubble as it oscillates in size after the detonation. This figure is reproduced from Discovery of Sound in the Sea (DOSITS) website https://dosits.org/galleries/technology-gallery/basic-technology/explosive-sound-sources.

The SEL thresholds for PTS and TTS occur at distances of several water depths in the relatively shallow waters of Orsted's Sunrise Wind, Ocean Wind, and Revolution Wind's wind farm environments. The sound field at becomes increasingly influenced by the contributions of sound energy reflected from the sea surface and sea bottom multiple times. In many instances the reflected paths become dominant over the direct acoustic path at horizontal distances greater than a few water depths. Some acoustic energy is also transmitted into the seafloor on each reflection and that energy can propagate partly through the seafloor before re-emerging into the water column and interacting in a complex way with waterborne energy. We apply acoustic propagation models to account for the effects of multiple reflections and sound propagation partly in the seabed. The modeling of SEL does not require use of a full waveform signature model. Nevertheless, the rate of decay of L_E with distance from the detonation varies in a complex way with sound frequency, so a source model that accounts for frequency dependence is necessary. The modeling of $L_{E,w}$ performed here was carried out by first modeling L_E in decidecade frequency bands using the marine operations noise model (MONM, JASCO Applied Sciences). This model uses an energy source level model, described in the next section, and then calculates acoustic propagation loss using parabolic equation (PE) approach for frequencies below 4 kHz, and a Gaussian beam ray trace model at higher frequencies. The PE model applied here also accounts for shear wave conversion losses from reflections at layer interfaces.

7.2.1. Energy Source Levels in Decidecade Frequency Bands

A key input for the MONM model is the energy source level (ESL), which quantifies the acoustic energy (SEL) and its distribution across different frequency bands for each of the charges considered. The distribution depends on the charge weight and detonation depth. The ESL is calculated using an approach described by Urick (1971 and 1983). A series of energy source level spectral density curves for normalized underwater explosion events at various depths (Figure 7) are defined in terms of frequency relative to the frequency of the first bubble pulse. The first bubble pulse frequency is calculated using an equation provided by Chapman (1985):

$$f_{b1} = (2.11 W^{\frac{1}{3}} z_0^{-5/6})^{-1}, \qquad 11$$

where W is the weight of the charge in kg of equivalent TNT and z_0 is the hydrostatic depth of the charge ($z_0 \ = z_s + 10.1 \text{ meters}$).

The energy source level scaling factor for charge weight is calculated as:

$$\Delta \mathrm{ESL} = 13.3 \log W. \tag{12}$$

The ESL in decidecade bands is calculated as follows:

1. The appropriate energy source level spectral density (ESLSD) curve is selected from the chart (Figure 7) based on the charge depth;
2. The first bubble pulse frequency f_{b1} is calculated using Equation 11 and absolute frequencies for the ESLSD curve are obtained by scaling their normalized frequency by multiplying by f_{b1};
3. The spectral levels are adjusted for the charge weight using Equation 12;
4. The ESLs are calculated by integrating the corrected ESLSD spectral function through the bandwidth of each decidecade band.

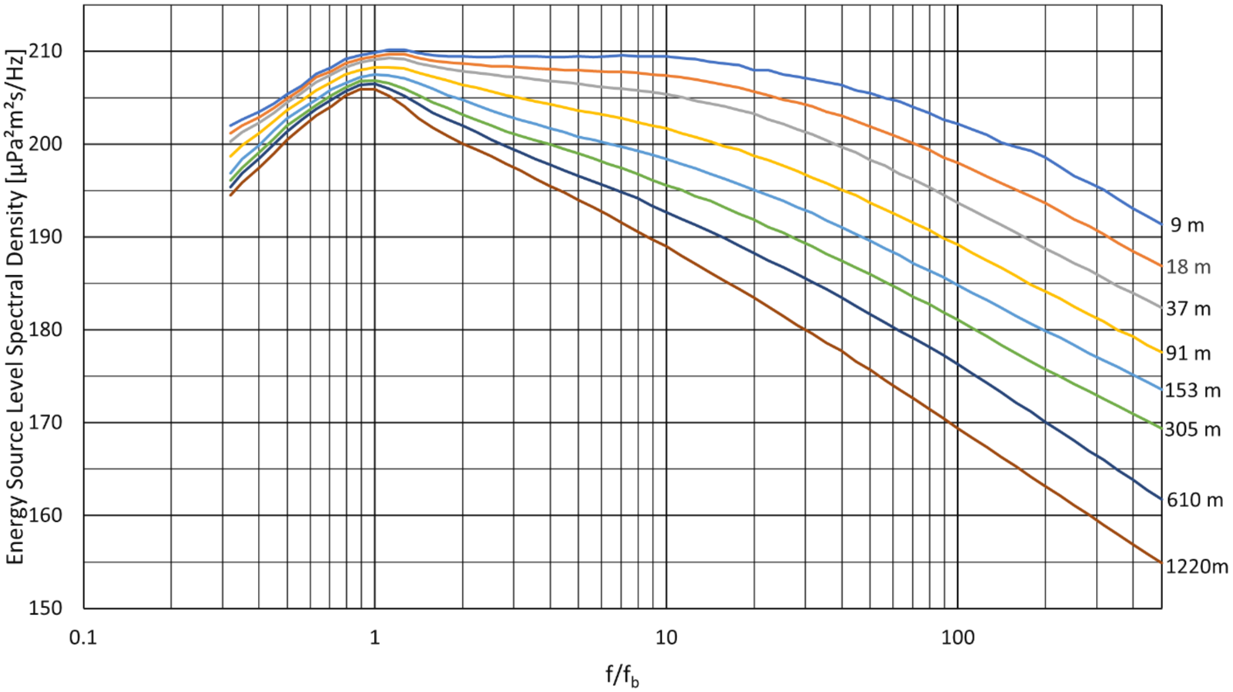


Figure 7. Energy source level spectral density curves for underwater explosion events at various depths expressed in normalized frequency, relative to the frequency f_{b1} of the first bubble pulse (after Urick 1983).

8. Exceedance Distance Results (Unmitigated)

8.1. Marine Mammals and Sea Turtles TTS and PTS by Peak Pressure Distances

Peak pressure exceedance distances are not dependent on water depth or seabed properties, so the results of Table 10 are relevant for all sites.

Table 10. Marine mammals and sea turtles PTS and TTS maximum exceedance distances for peak pressure for various UXO charge sizes for all sites.

Marine mammal group	TTS / PTS L_{pk} threshold (dB re 1 µPa)	Maximum distances (meters) to TTS and PTS thresholds for peak pressure									
		E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		TTS	PTS	TTS	PTS	TTS	PTS	TTS	PTS	TTS	PTS
Low-frequency cetaceans	213 / 219	826	426	1306	678	2233	1162	3817	1982	4813	2497
Mid-frequency cetaceans	224 / 230	246	130	394	206	674	350	1150	602	1450	758
High-frequency cetaceans	196 / 202	5357	2761	8476	4373	14490	7476	24764	12775	31202	16098
Phocid pinnipeds	212 / 218	922	478	1458	754	2493	1294	4261	2213	5369	2785
Otariid pinnipeds and sea turtles	226 / 232	198	102	314	166	542	282	926	486	1170	610

8.2. Marine Mammals and Sea Turtles Gastrointestinal Injury by Peak Pressure Distances

The threshold exceedances in Table 11 are for Onset Gastrointestinal Injury (effects observed in 1% of exposed animals) and Gastrointestinal Injury (effects observed in 50% of exposed animals).

Table 11. Maximum exceedance distances for Gastrointestinal Injury (1% and 50% of exposed animals) due to peak pressure exposures for five UXO charge sizes. The peak pressure thresholds applied here are from Table 5 and Table 6.

Effect	L_{pk} Threshold (dB re 1 µPa)	All sites: Maximum distance to L_{pk} threshold exceedance (m)				
		E4 (2.3 kg)	E6 (9.1 kg)	E8 (45.5 kg)	E10 (227 kg)	E12 (454 kg)
Onset Gastrointestinal Injury (1% of exposed animals)	237	61 m	97 m	167 m	285 m	359 m
Gastrointestinal Injury (50% of exposed animals)	243	32 m	51 m	88 m	151 m	190 m

8.3. Marine Mammals and Sea Turtles Onset Lung Injury by Impulse Distances

The exceedance distances in this section represent the onset of lung injury based on the threshold formula in Table 6. These thresholds represent effects observed in 1% of exposed animals.

Impulse levels and thresholds are depth-dependent, so maximum exceedance distances vary between sites with different depths. The results for the four sites evaluated are presented in Table 12 through Table 15.

Table 12. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse at Site S1 (12 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 1: 12 m depth – Impulse threshold exceedance distances for onset lung injury (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	24	7	62	19	150	59	247	129	291	160
Minke whales	38	12	93	33	199	93	310	174	361	210
Beaked whales	63	30	144	76	268	174	399	277	461	325
Dolphins, Kogia, Pinnipeds and Sea Turtles	114	58	234	136	383	257	548	385	628	446
Porpoises	132	67	261	153	418	280	594	413	680	478

Table 13. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse at Site S2 (20 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion-depth and based on the threshold formula in Table 6.

Marine mammal group	Site 2: 20 m depth – Impulse threshold exceedance distances for onset lung injury (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	22	6	62	18	172	60	352	161	431	219
Minke whales	36	11	96	31	249	97	455	234	546	300
Beaked whales	62	28	152	78	362	208	599	402	707	487
Dolphins, Kogia, Pinnipeds and Sea Turtles	117	58	263	142	541	344	839	576	975	681
Porpoises	137	67	297	162	591	380	913	623	1059	733

Table 14. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse at Site S3 (30 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 3: 30 m depth – Impulse threshold exceedance distances for onset lung injury (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	21	6	60	17	177	58	432	168	563	251
Minke whales	33	10	96	29	261	98	583	260	730	369
Beaked whales	59	26	155	77	392	216	775	505	966	644
Dolphins, Kogia, Pinnipeds and Sea Turtles	118	54	274	145	589	371	1044	747	1289	929
Porpoises	138	65	312	166	644	412	1110	804	1364	1004

Table 15. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury to Lung – Impulse at Site S4 (45 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 4: 45 m depth – Impulse threshold exceedance distances for onset lung injury (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	19	6	52	16	181	51	463	172	648	262
Minke whales	31	10	92	27	270	95	631	270	843	402
Beaked whales	51	25	156	71	412	222	846	546	1084	746
Dolphins, Kogia, Pinnipeds and Sea Turtles	115	47	283	145	630	389	1148	815	1421	1052
Porpoises	137	57	324	167	695	435	1228	878	1518	1127

8.4. Marine Mammals and Sea Turtles Onset of Mortality by Impulse Distances

The exceedance distances in this section represent the onset of mortality based on the threshold formula in Table 6. These thresholds represent effects observed in 1% of exposed animals.

Impulse levels and thresholds are depth-dependent, so maximum exceedance distances vary between sites with different depths. The results for the four sites evaluated are presented in Table 16 through Table 19.

Table 16. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S1 (12 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 1: 12 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	9	5	27	7	78	26	155	72	189	97
Pilot and Minke whales	15	5	43	13	113	43	199	104	238	132
Beaked whales	27	12	69	34	161	95	261	177	307	213
Dolphins, Kogia, Pinnipeds and Sea Turtles	52	25	123	64	242	154	364	252	422	296
Porpoises	62	29	140	74	266	169	396	271	458	319

Table 17. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S2 (20 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion-depth and based on the threshold formula in Table 6.

Marine mammal group	Site 2: 20 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	9	5	25	7	81	24	203	76	266	116
Pilot and Minke whales	14	5	41	12	121	42	275	120	346	173
Beaked whales	25	11	70	32	186	99	376	238	458	305
Dolphins, Kogia, Pinnipeds and Sea Turtles	52	23	128	65	293	176	534	360	644	441
Porpoises	61	27	147	75	319	197	573	393	702	477

Table 18. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S3 (30 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 3: 30 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	8	5	23	7	80	22	219	77	316	120
Pilot and Minke whales	14	5	37	12	123	38	308	124	421	188
Beaked whales	23	11	68	30	194	100	425	262	552	367
Dolphins, Kogia, Pinnipeds and Sea Turtles	47	22	130	63	310	183	586	406	736	536
Porpoises	58	25	150	73	343	206	633	440	786	575

Table 19. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S4 (45 m water depth) for five UXO charge sizes. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 4: 45 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	8	5	22	6	76	21	227	72	334	121
Pilot and Minke whales	13	5	34	11	123	36	325	125	453	194
Beaked whales	22	10	61	28	199	98	455	275	602	392
Dolphins, Kogia, Pinnipeds and Sea Turtles	39	20	129	55	328	186	637	434	814	580
Porpoises	49	23	152	67	361	212	690	477	868	628

8.5. Fish Injury by Peak Pressure Distances

Table 20. Maximum exceedance distances for Onset of Injury for fish without and with a swim bladder due to peak pressure exposures for various UXO charge sizes. The threshold of 229 dB re 1 µPa is the minimum of the threshold range from Popper et al. (2014).

Fish Hearing Group	Onset Injury L_{pk} (dB re 1 µPa)	All sites: Maximum distance to L_{pk} onset injury threshold exceedance (m)				
		E4 (2.3 kg)	E6 (9.1 kg)	E8 (45.5 kg)	E10 (227 kg)	E12 (454 kg)
All fish hearing groups	229	145	230	393	671	847

8.6. Marine Mammals and Sea Turtles: PTS by SEL Distances

The methods discussed in Section 7.2 were applied to calculate SEL, at receiver depths from the surface to the seabed, versus distance and direction from each charge detonation. The maxima of these results were extracted over depth to create noise maps of the type shown in Figure 8. This map and similar maps for the other sites modeled for the 2.3 kg and 454 kg charge sizes are provided in Appendix A.

Exceedance distances to each of the marine mammal, sea turtle, and fish SEL PTS thresholds listed in Table 3, were obtained from these maps in two ways:

- R_{max}: represents the maximum distance in any direction that the threshold was exceeded. This metric is often overly conservative for take estimates because it reflects the influence of coherent constructive interference effects, produced by most propagation loss models, due to model approximations of highly uniform environments. In practice, these coherent effects are almost always disrupted by rough interfaces and ocean inhomogeneities.
- $R_{95\%}$: represents the radius of a circle that encompasses 95% of the area predicted by the model to exceed the threshold. The circle radius is typically larger than the maximum distances in most directions, but it cuts off "fingers" of ensonification that protrude in a small number of directions. This metric is typically also conservative, but less so than the R_{max} distance.

The SEL effects thresholds are not dependent on animal depth, but SEL exposure levels generally do depend on depth. The PTS threshold exceedance distances provided in Tables 21 to 24 are maxima over depth.

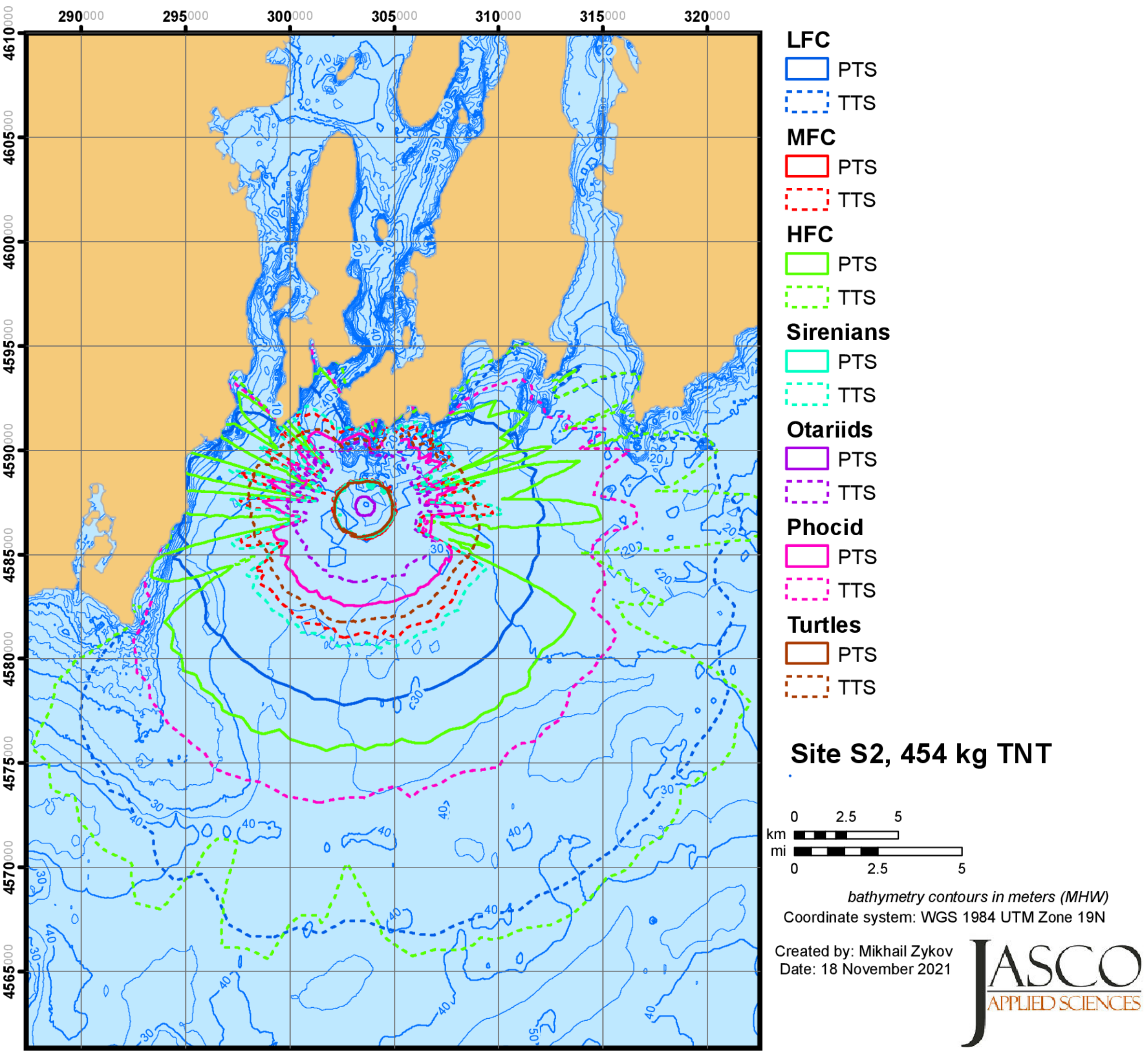


Figure 8. Frequency-weighted SEL PTS and TTS exceedance zone maps for the 454 kg charge size at Site S2, for each species group.

Table 21. SEL-based criteria ranges to PTS-onset at Site S1 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 µPa²s)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	183	2010	1710	3060	2640	4710	4140	7280	6460	8490	7640
Mid-frequency cetaceans	185	252	214	455	385	822	714	1500	1220	1840	1540
High-frequency cetaceans	155	4930	4250	6500	5700	8590	7610	11100	10200	12200	11300
Phocid pinnipeds	185	970	804	1520	1310	2530	2190	4040	3580	4990	4340
Otariid pinnipeds	203	59	56	119	106	240	221	539	466	720	615
Sea turtles	204	110	104	259	241	637	545	1180	946	1370	1150

Table 22. SEL-based criteria ranges to PTS-onset at Site S2 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 µPa²s)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	183	1820	1590	3110	2810	5460	4880	8170	7520	9580	8800
Mid-frequency cetaceans	185	148	139	372	332	761	633	1300	1130	1590	1450
High-frequency cetaceans	155	4760	4290	6280	5750	8510	7810	10900	10000	12000	11000
Phocid pinnipeds	185	741	644	1380	1210	2500	2190	4190	3660	4900	4500
Otariid pinnipeds	203	<50	<50	66	62	165	155	377	346	508	456
Sea turtles	204	76	76	190	182	535	473	1160	1030	1580	1390

Table 23. SEL-based criteria ranges to PTS-onset at Site S3 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 µPa²s)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	183	1630	1540	2890	2720	5080	4750	7810	7270	9130	8440
Mid-frequency cetaceans	185	181	161	388	358	734	636	1290	1140	1630	1480
High-frequency cetaceans	155	4790	4300	6390	5750	8510	7710	10700	9760	12100	10700
Phocid pinnipeds	185	653	592	1230	1120	2370	2170	3930	3620	4900	4450
Otariid pinnipeds	203	<50	<50	60	57	134	128	333	313	501	462
Sea turtles	204	<50	<50	184	181	444	416	980	931	1400	1220

Table 24. SEL-based criteria ranges to PTS-onset at Site S4 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 µPa²s)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	183	1620	1470	2870	2610	5090	4640	8060	7280	9510	8540
Mid-frequency cetaceans	185	108	89	362	272	749	684	1260	1120	1640	1410
High-frequency cetaceans	155	4650	4170	6400	5660	8520	7670	11100	9890	12300	10900
Phocid pinnipeds	185	666	607	1140	1010	2360	2140	4100	3740	4970	4520
Otariid pinnipeds	203	<50	<50	<50	<50	89	89	233	221	400	372
Sea turtles	204	<50	<50	144	141	350	340	884	852	1330	1260

8.7. Marine Mammals and Sea Turtles: TTS by SEL Distances

The SEL distances thresholds are not dependent on animal depth, but the SEL exposure levels are. The TTS threshold exceedance distances provided in Tables 25 to 28 are maxima over depth.

Table 25. SEL-based criteria ranges to TTS-onset at Site S1 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 $\mu Pa^2 s$)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	7600	6830	10700	9780	14300	13100	18000	16700	19900	18300
Mid-frequency cetaceans	170	1820	1520	2660	2290	3760	3340	5650	4970	6660	5860
High-frequency cetaceans	140	12100	11200	14600	13400	17400	16000	20600	19100	21900	20200
Phocid pinnipeds	170	4780	4120	6840	6080	9630	8750	13000	11900	14500	13300
Otariid pinnipeds	188	681	569	1230	965	1930	1670	3210	2760	3830	3400
Sea turtles	189	822	708	1380	1160	2290	1920	3180	2750	3810	3220

Table 26. SEL-based criteria ranges to TTS-onset at Site S2 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 $\mu Pa^2 s$)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	8000	7340	11200	10300	15200	13900	19500	17500	21300	19200
Mid-frequency cetaceans	170	1590	1430	2520	2160	4030	3460	5510	5020	6380	5850
High-frequency cetaceans	140	12000	11000	14200	13100	17500	15900	20800	18800	22200	20200
Phocid pinnipeds	170	4630	4200	6730	6200	9760	9060	13000	11800	14500	13200
Otariid pinnipeds	188	444	406	926	788	1790	1560	3120	2720	3950	3440
Sea turtles	189	706	639	1540	1350	2780	2520	4660	4340	5670	5260

Table 27. SEL-based criteria ranges to TTS-onset at Site S3 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 $\mu Pa^2 s$)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	7610	7000	10600	9790	14700	13400	19100	17400	21100	19300
Mid-frequency cetaceans	170	1600	1450	2510	2210	3890	3490	5590	5020	6500	5840
High-frequency cetaceans	140	12000	10700	14200	12700	17500	15600	20800	18700	22400	20200
Phocid pinnipeds	170	4420	4070	6690	6070	9700	8780	12800	11500	14400	12800
Otariid pinnipeds	188	412	394	796	756	1720	1600	3000	2730	3750	3400
Sea turtles	189	605	581	1340	1200	2550	2340	4440	4150	5500	5070

Table 28. SEL-based criteria ranges to TTS-onset at Site S4 for various UXO charge sizes: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	**Threshold** (dB re 1 µPa²s)	**E4 (2.3 kg)**		**E6 (9.1 kg)**		**E8 (45.5 kg)**		**E10 (227 kg)**		**E12 (454 kg)**	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	7650	6950	11100	9850	15600	13600	20600	17400	22500	19000
Mid-frequency cetaceans	170	1580	1350	2400	2160	3760	3420	5710	5040	6540	5810
High-frequency cetaceans	140	12100	10700	14900	13000	18400	15800	22300	18700	23700	20000
Phocid pinnipeds	170	4260	3940	6680	6010	10000	8850	13800	12000	15300	13300
Otariid pinnipeds	188	283	261	782	725	1640	1470	3100	2810	3820	3460
Sea turtles	189	495	480	1290	1190	2480	2340	4320	4030	5220	4870

9. Exceedance Distance Results with 10 dB Mitigation

This section provides exceedance distances assuming 10 dB reduction to the exposure pressures and SEL achieved via mitigation measures (e.g., bubble curtain or similar system).

9.1. Marine Mammals and Sea Turtles TTS and PTS by Peak Pressure Distances with 10 dB mitigation

L_{pk} exceedance distances are not dependent on water depth or seabed properties, so Table 29 is relevant for all sites.

Table 29. Marine mammals and sea turtles PTS and TTS maximum exceedance distances for peak pressure for maximum charge weights for various UXO charge sizes with 10 dB mitigation, relevant for all sites.

Marine mammal group	**TTS / PTS threshold (dB re 1 µPa)**	**Maximum distances (meters) to TTS and PTS thresholds for peak pressure**									
		E4 (2.3 kg)		**E6 (9.1 kg)**		**E8 (45.5 kg)**		**E10 (227 kg)**		**E12 (454 kg)**	
		TTS	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**
Low-frequency cetaceans	213 / 219	278	142	438	230	750	390	1282	670	1618	846
Mid-frequency cetaceans	224 / 230	82	42	134	70	226	118	390	206	494	258
High-frequency cetaceans	196 / 202	1778	922	2813	1458	4813	2493	8228	4261	10367	5369
Phocid pinnipeds	212 / 218	310	158	490	254	838	438	1430	746	1802	942
Otariid pinnipeds and sea turtles	226 / 232	66	34	106	54	182	98	314	166	398	210

9.2. Marine Mammals and Sea Turtles Gastrointestinal Injury by Peak Pressure Distances with 10 dB mitigation

The threshold exceedances in Table 30 are for Onset Gastrointestinal Injury (effects observed in 1% of exposed animals) and Gastrointestinal Injury (effects observed in 50% of exposed animals).

Table 30. Maximum exceedance distances for Gastrointestinal Injury (1% and 50% exposed animals) due to peak pressure exposures for five UXO charge sizes with 10 dB mitigation. The peak pressure thresholds applied here are from Table 5 and Table 6.

Effect	**L_{pk} Threshold (dB re 1 µPa)**	**All sites: Maximum distance to L_{pk} threshold exceedance (m)**				
		E4 (2.3 kg)	**E6 (9.1 kg)**	**E8 (45.5 kg)**	**E10 (227 kg)**	**E12 (454 kg)**
Onset Gastrointestinal Injury (1% of exposed animals)	237	21 m	34 m	58 m	99 m	125 m
Gastrointestinal Injury (50% of exposed animals)	243	11 m	18 m	31 m	53 m	67 m

9.3. Marine Mammals and Sea Turtles Onset of Lung Injury Distances for Impulse with 10 dB mitigation

Impulse thresholds are depth-dependent, so maximum exceedance distances could vary between sites with different depths with 10 dB mitigation. The results for each of the sites evaluated are presented in Table 31 through Table 34.

Table 31. Mitigated Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury – Impulse at Site S1 (12 m water depth) for various UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion depth and based on the formula in Table 6.

Marine mammal group	Site 1: 12 m depth - Maximum distances to Impulse threshold exceedance (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	6	5	17	5	54	16	121	50	151	73
Pilot and Minke whales	10	5	28	8	80	28	158	77	192	103
Beaked whales	17	8	47	22	121	66	210	139	250	171
Dolphins, Kogia, Pinnipeds and Sea Turtles	35	16	86	44	189	115	297	202	347	241
Porpoises	42	19	99	50	210	128	323	219	377	260

Table 32. Mitigated Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury – Impulse at Site S2 (20 m water depth) for various UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion depth and based on the formula in Table 6.

Marine mammal group	Site 2: 20 m depth - Maximum distances to Impulse threshold exceedance (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	6	5	16	5	54	15	147	51	204	80
Pilot and Minke whales	9	5	26	8	83	26	208	83	272	126
Beaked whales	16	7	46	20	131	68	290	176	366	237
Dolphins, Kogia, Pinnipeds and Sea Turtles	32	15	88	42	211	123	404	277	508	351
Porpoises	39	17	102	50	235	139	433	303	541	381

Table 33. Mitigated Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury – Impulse at Site S3 (30 m water depth) for various UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion depth and based on the formula in Table 6.

Marine mammal group	Site 3: 30 m depth - Maximum distances to Impulse threshold exceedance (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	5	5	15	5	51	14	153	49	226	81
Pilot and Minke whales	9	5	24	7	83	25	221	84	310	131
Beaked whales	15	7	41	19	135	66	310	186	413	267
Dolphins, Kogia, Pinnipeds and Sea Turtles	29	14	88	38	223	126	441	298	557	400
Porpoises	34	16	103	46	248	144	471	325	594	429

Table 34. Mitigated Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset Injury – Impulse at Site S4 (45 m water depth) for various UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion depth and based on the formula in Table 6.

Marine mammal group	Site 4: 45 m depth - Maximum distances to Impulse threshold exceedance (meters)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	5	5	14	5	45	13	156	44	237	78
Pilot and Minke whales	8	5	22	7	79	23	230	81	330	132
Beaked whales	14	6	37	18	135	59	331	192	448	282
Dolphins, Kogia, Pinnipeds and Sea Turtles	26	13	83	34	231	126	471	315	606	429
Porpoises	29	15	100	39	261	145	512	347	648	465

9.4. Marine Mammals and Sea Turtles Onset of Mortality Distances by Impulse with 10 dB mitigation

The exceedance distances in this section represent the onset of mortality based on the threshold formula in Table 6 and assuming 10 dB of sound level reduction is obtained through a noise mitigation device. These thresholds represent effects observed in 1% of exposed animals.

Impulse levels and thresholds are depth-dependent, so maximum exceedance distances vary between sites with different depths. The results for the four sites evaluated are presented in Table 35 through Table 38.

Table 35. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S1 (12 m water depth) for five UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 1: 12 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	5	5	7	5	23	6	66	21	90	34
Pilot and Minke whales	5	5	11	5	37	11	93	36	120	56
Beaked whales	7	5	19	9	60	29	130	79	161	105
Dolphins, Kogia, Pinnipeds and Sea Turtles	14	6	39	18	101	56	190	124	228	154
Porpoises	17	7	46	21	112	64	209	136	248	167

Table 36. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S2 (20 m water depth) for five UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion-depth and based on the threshold formula in Table 6.

Marine mammal group	Site 2: 20 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	5	5	6	5	21	6	69	20	105	34
Pilot and Minke whales	5	5	10	5	35	10	103	35	150	58
Beaked whales	6	5	18	8	60	27	151	85	206	127
Dolphins, Kogia, Pinnipeds and Sea Turtles	13	6	37	17	105	56	220	144	285	198
Porpoises	15	7	45	19	119	65	239	158	307	215

Table 37. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S3 (30 m water depth) for five UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 3: 30 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	5	5	6	5	20	6	68	19	109	31
Pilot and Minke whales	5	5	10	5	32	10	106	32	157	57
Beaked whales	6	5	17	8	58	25	160	86	220	132
Dolphins, Kogia, Pinnipeds and Sea Turtles	12	5	31	16	108	54	233	152	308	211
Porpoises	14	6	40	18	122	63	258	168	330	231

Table 38. Impulse exceedance distances (meters) for marine mammals and sea turtles, for Onset of Mortality at Site S4 (45 m water depth) for five UXO charge sizes with 10 dB mitigation. The Impulse thresholds are dependent on animal mass and submersion depth and based on the threshold formula in Table 6.

Marine mammal group	Site 4: 45 m depth – Impulse threshold exceedance distances for onset mortality (m)									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult	Calf/Pup	Adult
Baleen whales and Sperm whale	5	5	6	5	18	5	63	18	108	29
Pilot and Minke whales	5	5	9	5	29	9	105	30	162	50
Beaked whales	6	5	15	7	50	23	164	83	234	135
Dolphins, Kogia, Pinnipeds and Sea Turtles	11	5	26	14	106	44	247	155	332	224
Porpoises	12	6	29	16	122	56	270	173	353	243

9.5. Fish Injury Distances for Peak Pressure with 10 dB mitigation

Table 39. Mitigated exceedance distances for Onset of Injury for fish without and with a swim bladder due to peak pressure exposures, for various UXO charge sizes with 10 dB mitigation. Water depth 50 m. The threshold of 229 dB re 1 µPa is from Popper et al. (2014).

Species	Onset injury L_{pk} (dB re 1 µPa)	All sites: Maximum distance to L_{pk} threshold exceedance (m)				
		E4 (2.3 kg)	E6 (9.1 kg)	E8 (45.5 kg)	E10 (227 kg)	E12 (454 kg)
All fish hearing groups	229	49	80	135	230	290

9.6. Marine Mammals and Sea Turtles: PTS distances by SEL with 10 dB mitigation

The SEL effects thresholds are not dependent on animal depth, but the exposure levels are. The PTS threshold exceedance distances provided in Tables 40 to 43 are maxima over depth.

Table 40. Mitigated SEL-based criteria ranges to PTS-onset at Site S1 for various UXO charge sizes with 10 dB mitigation: Maximum ($R_{\max}$, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 µPa^{2}s)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		$R_{\max}$	$R_{95\%}$	$R_{\max}$	$R_{95\%}$	$R_{\max}$	$R_{95\%}$	$R_{\max}$	$R_{95\%}$	$R_{\max}$	$R_{95\%}$
Low-frequency cetaceans	183	632	552	1230	982	2010	1720	3080	2660	3640	3220
Mid-frequency cetaceans	185	<50	<50	79	75	175	156	419	337	535	461
High-frequency cetaceans	155	2100	1820	2940	2590	4220	3710	6090	5340	6960	6200
Phocid pinnipeds	185	192	182	413	357	822	690	1410	1220	1830	1600
Otariid pinnipeds	203	<50	<50	<50	<50	<50	<50	100	98	147	136
Sea turtles	204	<50	<50	<50	<50	166	159	366	348	518	472

Table 41. Mitigated SEL-based criteria ranges to PTS-onset at Site S2 for various UXO charge sizes with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	**Threshold (dB re 1 µPa^{2}s)**	**E4 (2.3 kg)**		**E6 (9.1 kg)**		**E8 (45.5 kg)**		**E10 (227 kg)**		**E12 (454 kg)**	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	183	450	421	954	850	1990	1730	3370	2970	4270	3780
Mid-frequency cetaceans	185	<50	<50	52	51	120	113	332	280	444	386
High-frequency cetaceans	155	1960	1680	3020	2550	4400	3860	5880	5390	6750	6190
Phocid pinnipeds	185	124	113	294	248	656	590	1340	1140	1630	1430
Otariid pinnipeds	203	<50	<50	<50	<50	<50	<50	62	61	93	89
Sea turtles	204	<50	<50	<50	<50	140	137	309	293	451	422

Table 42. Mitigated SEL-based criteria ranges to PTS-onset at Site S3 for various UXO charge sizes with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	**Threshold (dB re 1 µPa^{2}s)**	**E4 (2.3 kg)**		**E6 (9.1 kg)**		**E8 (45.5 kg)**		**E10 (227 kg)**		**E12 (454 kg)**	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	183	405	385	789	753	1660	1580	3040	2870	3900	3610
Mid-frequency cetaceans	185	<50	<50	<50	<50	100	85	349	323	484	412
High-frequency cetaceans	155	1960	1750	2940	2590	4330	3900	6000	5400	6840	6190
Phocid pinnipeds	185	89	89	221	204	566	538	1140	1020	1600	1480
Otariid pinnipeds	203	<50	<50	<50	<50	<50	<50	57	57	72	72
Sea turtles	204	<50	<50	<50	<50	89	89	242	228	385	369

Table 43. Mitigated SEL-based criteria ranges to PTS-onset at Site S4 for various UXO charge sizes with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	**Threshold (dB re 1 µPa^{2}s)**	**E4 (2.3 kg)**		**E6 (9.1 kg)**		**E8 (45.5 kg)**		**E10 (227 kg)**		**E12 (454 kg)**	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	183	288	269	800	757	1770	1580	3190	2930	3940	3610
Mid-frequency cetaceans	185	<50	<50	<50	<50	85	80	279	261	449	412
High-frequency cetaceans	155	1890	1700	2800	2550	4200	3790	6130	5400	6860	6160
Phocid pinnipeds	185	72	72	152	144	577	468	1100	988	1520	1350
Otariid pinnipeds	203	<50	<50	<50	<50	<50	<50	<50	<50	63	63
Sea turtles	204	<50	<50	<50	<50	63	63	190	189	297	288

9.7. Marine Mammals and Sea Turtles: TTS distances by SEL with 10 dB mitigation

The SEL effects thresholds are not dependent on animal depth, but the exposure levels are. The TTS threshold exceedance distances provided in Tables 44 to 47 are maxima over depth.

Table 44. Mitigated SEL-based criteria ranges to TTS-onset at Site S1 for various UXO charge sizes with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 $\mu\text{Pa}^2\text{s}$)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	3140	2710	4820	4160	7320	6500	10500	9610	12000	11000
Mid-frequency cetaceans	170	535	453	910	773	1520	1240	2400	2120	2820	2550
High-frequency cetaceans	140	6920	6160	8970	8000	11100	10200	14000	12900	15400	14100
Phocid pinnipeds	170	1730	1470	2710	2350	4080	3620	6460	5700	7480	6750
Otariid pinnipeds	188	131	125	254	238	539	472	1070	898	1310	1130
Sea turtles	189	214	203	498	448	1040	865	1720	1440	2020	1710

Table 45. Mitigated SEL-based criteria ranges to TTS-onset at Site S2 for various UXO charge sizes with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 $\mu\text{Pa}^2\text{s}$)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	3110	2820	5230	4680	8160	7490	11500	10500	13200	11900
Mid-frequency cetaceans	170	444	379	781	658	1450	1200	2310	1980	2930	2430
High-frequency cetaceans	140	6700	6140	8630	7960	11200	10300	13700	12600	15000	13800
Phocid pinnipeds	170	1450	1300	2510	2200	4340	3820	6490	5980	7610	6990
Otariid pinnipeds	188	70	68	165	155	392	364	803	721	1110	974
Sea turtles	189	169	165	441	383	985	870	2020	1780	2510	2250

Table 46. Mitigated SEL-based criteria ranges to TTS-onset at Site S3 for various UXO charge sizes with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	Threshold (dB re 1 $\mu\text{Pa}^2\text{s}$)	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	2910	2740	4860	4450	7760	7210	10900	10100	12500	11500
Mid-frequency cetaceans	170	484	410	777	653	1430	1230	2350	2030	2820	2480
High-frequency cetaceans	140	6770	6140	8620	7840	11200	10000	13700	12200	15000	13300
Phocid pinnipeds	170	1300	1210	2430	2180	4150	3810	6410	5840	7580	6900
Otariid pinnipeds	188	63	63	134	128	374	341	777	728	1010	922
Sea turtles	189	171	134	372	358	810	773	1780	1610	2270	2130

Table 47. Mitigated SEL-based criteria ranges to TTS-onset at Site S4 for various UXO charge sizes with 10 dB mitigation: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to specific thresholds.

Marine mammal group	**Threshold (dB re 1 µPa²s)**	**E4 (2.3 kg)**		**E6 (9.1 kg)**		**E8 (45.5 kg)**		**E10 (227 kg)**		**E12 (454 kg)**	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans	168	2890	2630	4860	4400	7820	7130	11700	10300	13500	11800
Mid-frequency cetaceans	170	437	400	800	707	1330	1180	2270	2000	2730	2480
High-frequency cetaceans	140	6720	6030	8650	7790	11300	10100	14600	12600	15600	13700
Phocid pinnipeds	170	1290	1130	2340	2130	4150	3800	6640	5970	7820	7020
Otariid pinnipeds	188	<50	<50	89	89	247	234	768	716	982	888
Sea turtles	189	120	108	286	283	833	796	1680	1590	2130	2000

10. Summary and Guide for Use of Results

This study has produced a large number of result tables containing effects threshold exceedance distances for multiple species or species groups, five charge sizes, and four locations. While the specific sites were chosen inside Orsted's Revolution Wind project area, the model results are expected to be valid for sites inside the Sunrise Wind and Ocean Wind 1 project areas and other sites having the same water depths and seabed properties. The results presented here also assume the full explosive weight of the combined UXO and donor charge are detonated, with a total equivalent-TNT weight matching the values in Table 1. A recent review of UXO detonations in the North Sea has found UXO detonations of charges that have remained underwater for more than 75 years yielded very little explosive energy. More research is needed to determine if older underwater UXO degrade over time to become partly benign, in which case methods such as deflagration may be preferred over explosive removal. Until that question is answered, for conservancy and for personnel safety reasons we recommend assuming their full explosive weights will detonate.

All threshold distances presented here are relevant to address NMFS's assessment requirements for species-dependent effects criteria for assessing injurious or lethal (Level-A) and disturbance or behavioural (Level-B) takes of marine mammals and sea turtles, and for assessing injurious effects on fish. The take criteria are based on three specific acoustic metrics: L_{pk}, J_p, and $L_{E,w}$. The frequency weighted SEL levels, $L_{E,w}$, are dependent on species group while the impulse levels are dependent on animal mass and submersion depth. All three metrics also have species or animal size dependent thresholds. The SEL and impulse levels vary with water depth or location. Five charge sizes are considered at four separate modeling sites with different depths. The consideration of these many results for estimating marine mammal and sea turtle takes, and fish effects zones is clearly not straightforward. To assist in that assessment, a summary of the Level-A and Level-B take context for each assessment metric is provided here, together with cross-references to the tables that contain the relevant exceedance distance information for each type of take. Examples of the maximum exceedance distance, resulting from the largest UXO charge weight, on the most-sensitive species group are provided here but the user will need to review the referenced exceedance distance tables to look up the relevant distances for other species groups and charge sizes. We expect the peak pressure based gastrointestinal tract injury distances and impulse based onset of lung injury and onset of mortality distances will be used primarily for setting mitigation zone requirements, but these distances could be used for Level A take estimates if animals could not be excluded from the respective zones.

10.1. Unmitigated Take Distances

10.1.1. Unmitigated Level-A Takes

The tables of threshold exceedance distances from UXO detonations relevant for Level-A (injurious) effects to marine mammals and sea turtles are:

- L_{pk}: Table 10 contains PTS (auditory injury) exceedance distances valid for all sites. The greatest PTS distance is 16,098 m from the 454 kg charge, for high-frequency cetaceans.
- J_p: Tables 12 to 15 contain onset of lung injury (1% of animals) distances for Sites S1 to S4, respectively. Note for each species group there are separate distances for small (calves/pups) and adult animals representative of the group. Smaller animals in each group have lower thresholds, leading to larger exceedance distances. The deeper sites often, but not always, have larger exceedance distances than shallower sites. The greatest distance for onset of lung injury is 1518 m from the unmitigated 454 kg charge at site S4 for porpoise calves.
- SEL (species-group frequency weighted): Tables 21 to 24 contain PTS threshold exceedance distances at Sites S1 to S4, respectively. These tables contain R_{max} and $R_{95\%}$ distances, and we recommend using the $R_{95\%}$ distances because R_{max} is often influenced by an artefact of the type

of models used, as discussed in Section 8.6. The greatest distance is 11,300 m for high-frequency cetaceans at Site S1.

- SEL and peak pressure auditory injury distances are always larger than the impulse non-auditory injury exceedance distances, so the impulse threshold exceedance distances will not dictate Level-A takes. Nevertheless, they are important and relevant for assessments of non-auditory injuries.

10.1.2. Unmitigated Level-B Takes

The tables relevant for Level-B (disturbance or behavioral effects) takes are:

- L_{pk}: Table 10 contains TTS (temporary effect not considered injurious) exceedance distances valid for all sites. The greatest TTS distance is 31,202 m from the 454 kg charge, for high-frequency cetaceans.
- SEL (species-group weighted): Tables 25 to 28 contain TTS threshold exceedance distances at Sites S1 to S4, respectively. We recommend using the $R_{95\%}$ distances as discussed in this report. The greatest distance is 20,200 m for high-frequency cetaceans at Sites S1, S2 and S3.
- Note: NMFS uses TTS onset as the threshold for Level-B takes by SEL for single detonations in a 24-hour period. NMFS applies a different threshold (TTS minus 5 dB) for multiple detonations in day, but its application is more difficult because it requires considering if animals receive SEL doses from more than one of the detonations. TTS zones for multiple blasts in a single day were not assessed.

10.1.3. Unmitigated Effects on Fish

- L_{pk}: Table 20 provides onset of injury distances relevant for all fish groups. The unmitigated distances for mortality or injury likely to lead to mortality range from 145 m from the 2.3 kg charge to 847 m from the 454 kg charge. These distances are relevant for all sites.
- A quantitative assessment of non-mortal effects to fish has not been included, but the guidelines of Popper et al. (2014) provide qualitative assessment information. This is discussed in Sections 6.4 and 6.5.

10.2. Mitigated Take Distances (10 dB Reduction)

Reduced effects threshold distances were calculated with a flat 10 dB reduction of pressure to all metrics, as an approximation of noise abatement that could be achieved, for example, using a bubble curtain. The mitigated results tables are provided in Section 9 and discussed here.

10.2.1. Mitigated Level-A Takes

The tables of threshold exceedance distances relevant for Level A (injurious) effects to marine mammals and sea turtles are:

- L_{pk}: Table 29 contains mitigated PTS (auditory injury) exceedance distances valid for all sites. The greatest PTS distance is 5,369 m from the 454 kg charge, for high-frequency cetaceans. The mitigated PTS distances from peak pressure for all other species groups are less than 1,000 m.
- L_{pk}: Table 30 contains mitigated onset of gastrointestinal injury (1% of exposed animals) exceedance distances valid for all sites and species. The greatest onset of effects distance is 125 m from the 454 kg charge.

- J_p: Tables 31 to 34 contain onset of lung injury (1% of animals) exceedance distances for Sites S1 to S4, respectively. The greatest distance for onset of lung injury is 648 m from the 454 kg charge at Site S4, for porpoise calves.
- SEL (species-group weighted): Tables 40 to 43 contain PTS threshold exceedance distances at Sites S1 to S4, respectively. The greatest $R_{95\%}$ distance is 6,200 m for high-frequency cetaceans at Site 1.

10.2.2. Mitigated Level-B Takes

The tables relevant for mitigated Level-B (disturbance or behavioral effects) takes of marine mammals and sea turtles are:

- Peak pressure: Table 29 contains TTS (temporary effect not considered injurious) exceedance distances valid for all sites. The greatest TTS distance is 10,367 m from the 454 kg charge, for high-frequency cetaceans.
- SEL (species-group weighted): Tables 44 to 47 contain TTS threshold exceedance distances at Sites S1 to S4, respectively. The greatest $R_{95\%}$ distance is 14,100 m for high-frequency cetaceans at Site S1.

10.2.3. Mitigated Effects on Fish

- Peak pressure: provides mitigated onset of injury for all fish groups. The unmitigated distances range from 49 m from the 2.3 kg charge to 290 m from the 454 kg charge. These values are relevant for all sites.
- A quantitative assessment of non-mortal effects to fish has not been included, as discussed in Section 6.4 and 6.5. Those sections provide a qualitative assessment approach.

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Appendix A. PTS and TTS Exceedance Zone Maps (Unmitigated)

This appendix presents PTS and TTS exceedance zone maps for various marine mammal hearing groups and sea turtles for 2.3 and 454 kg charges (minimum and maximum charge weights modeled) at each of the four sites.

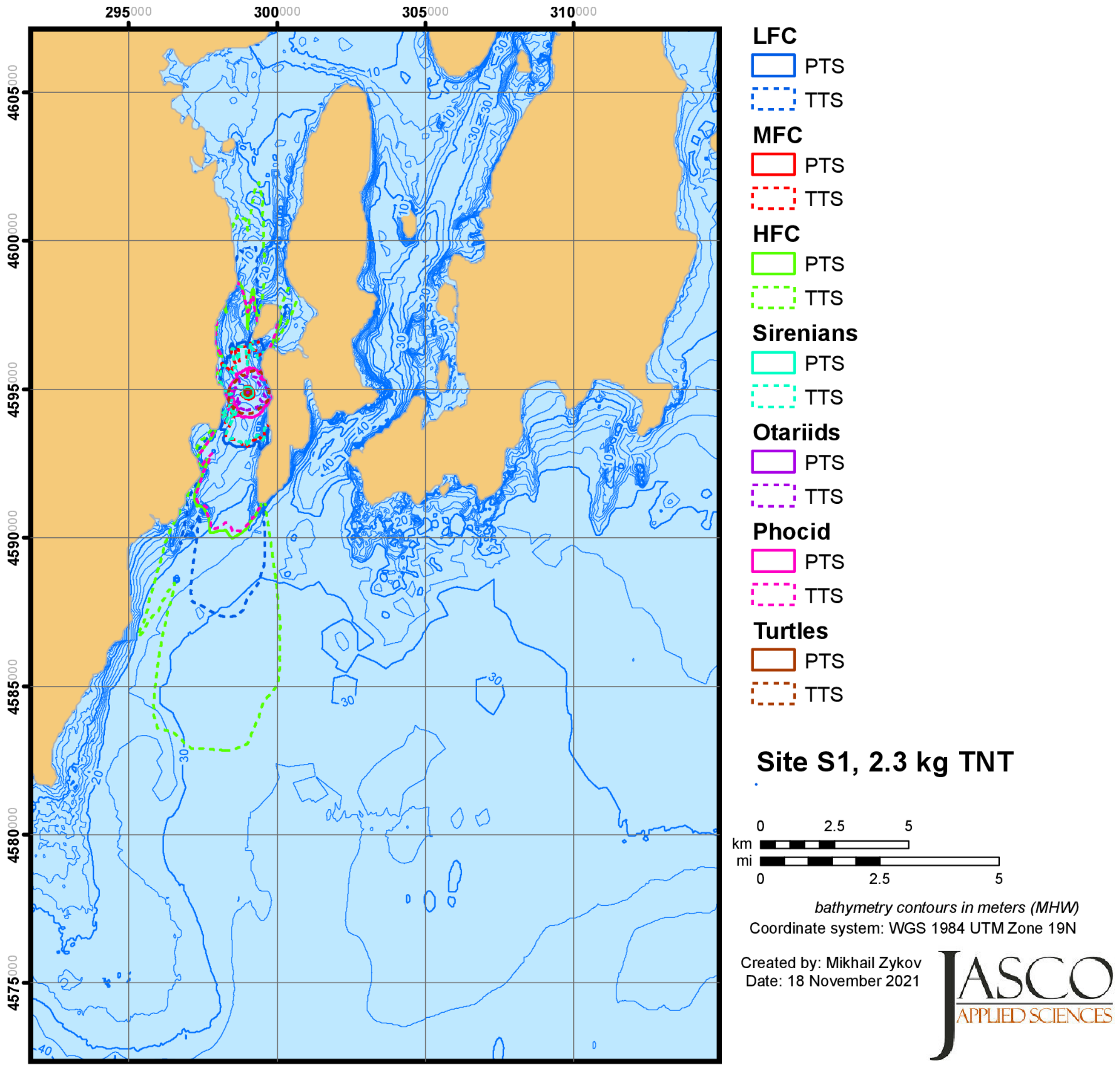

Figure A-1. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 2.3 kg charge size at Site S1.

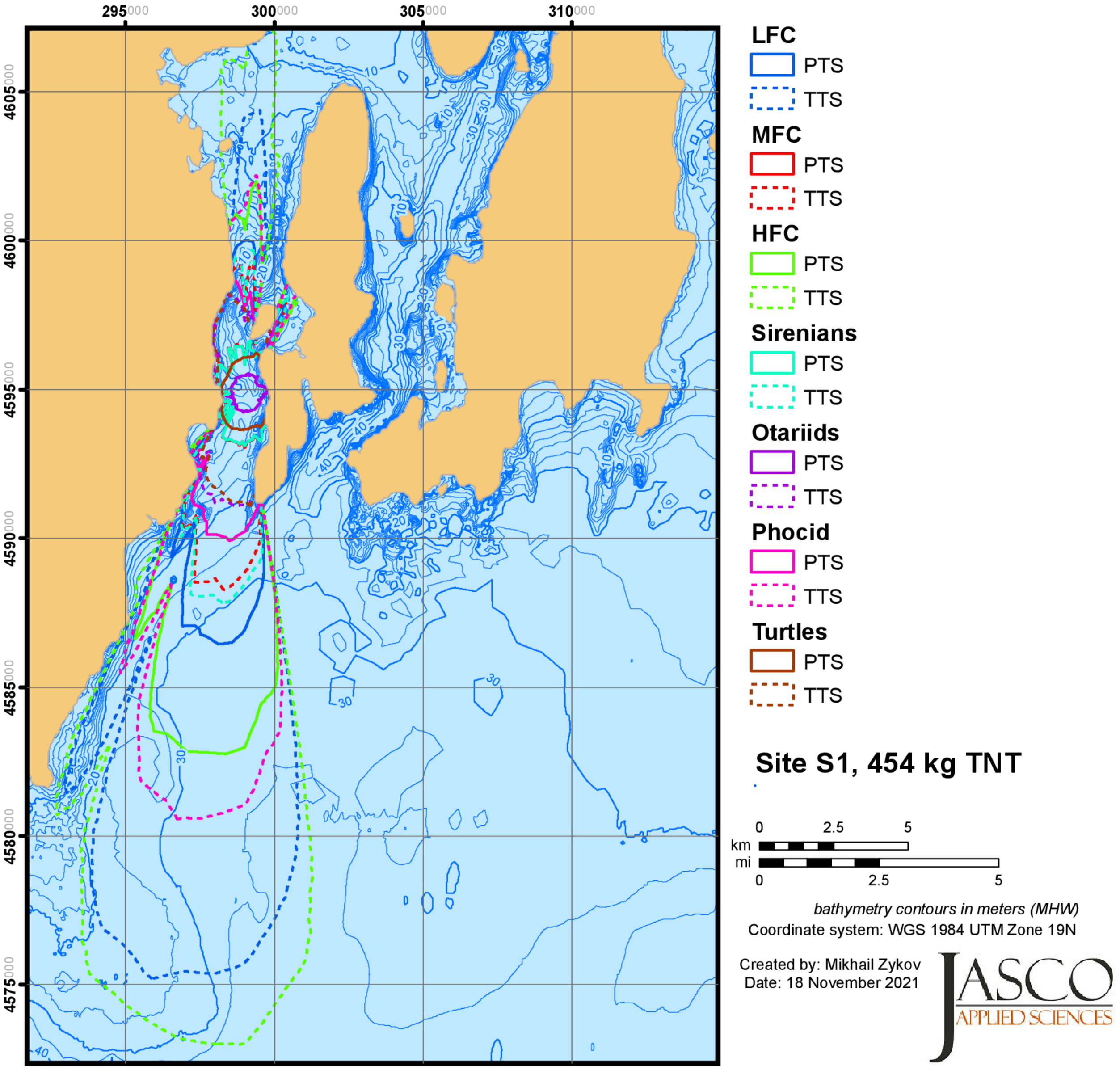

Figure A-2. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 454 kg charge size at Site S1.

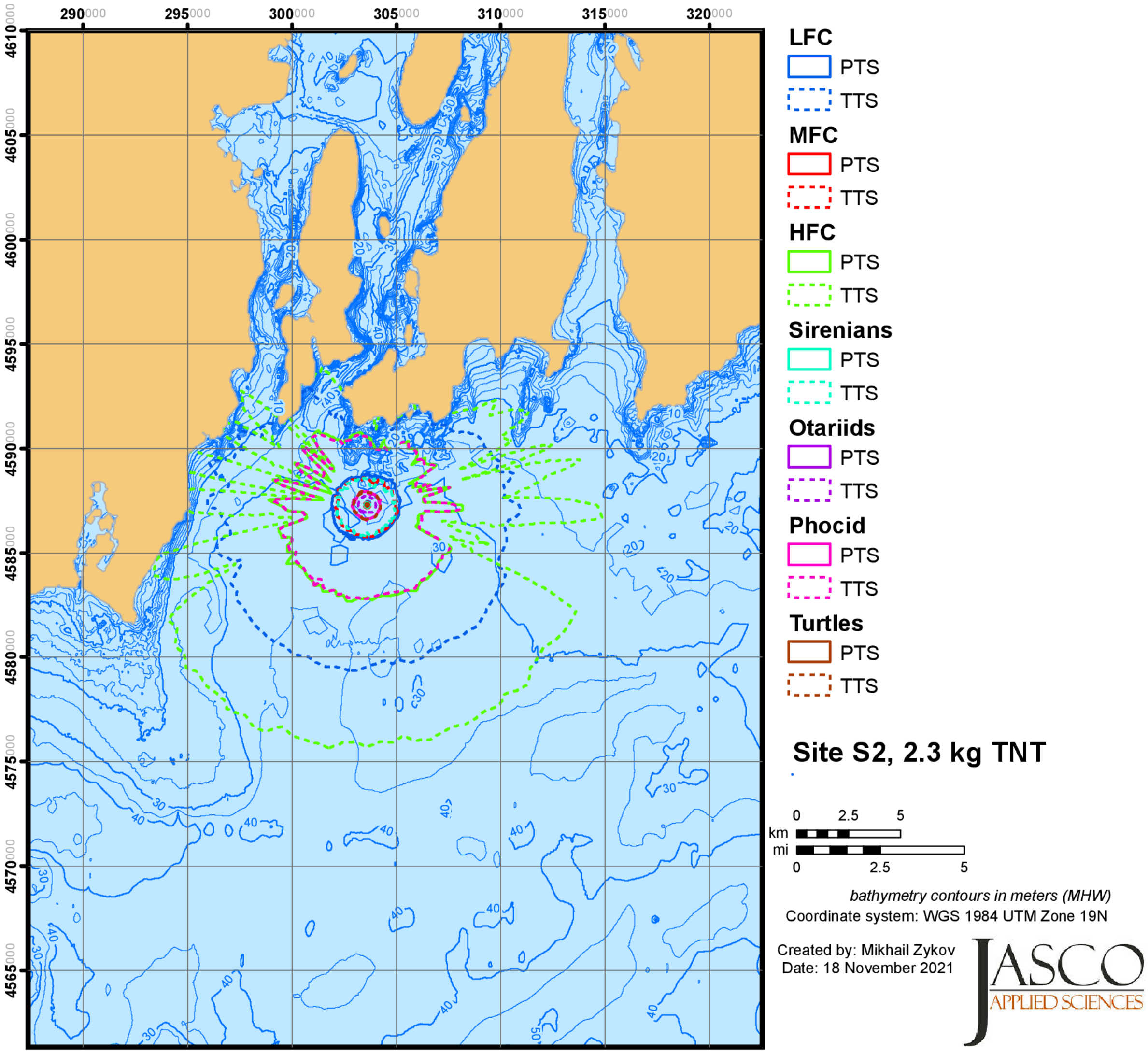

Figure A-3. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 2.3 kg charge size at Site S2.

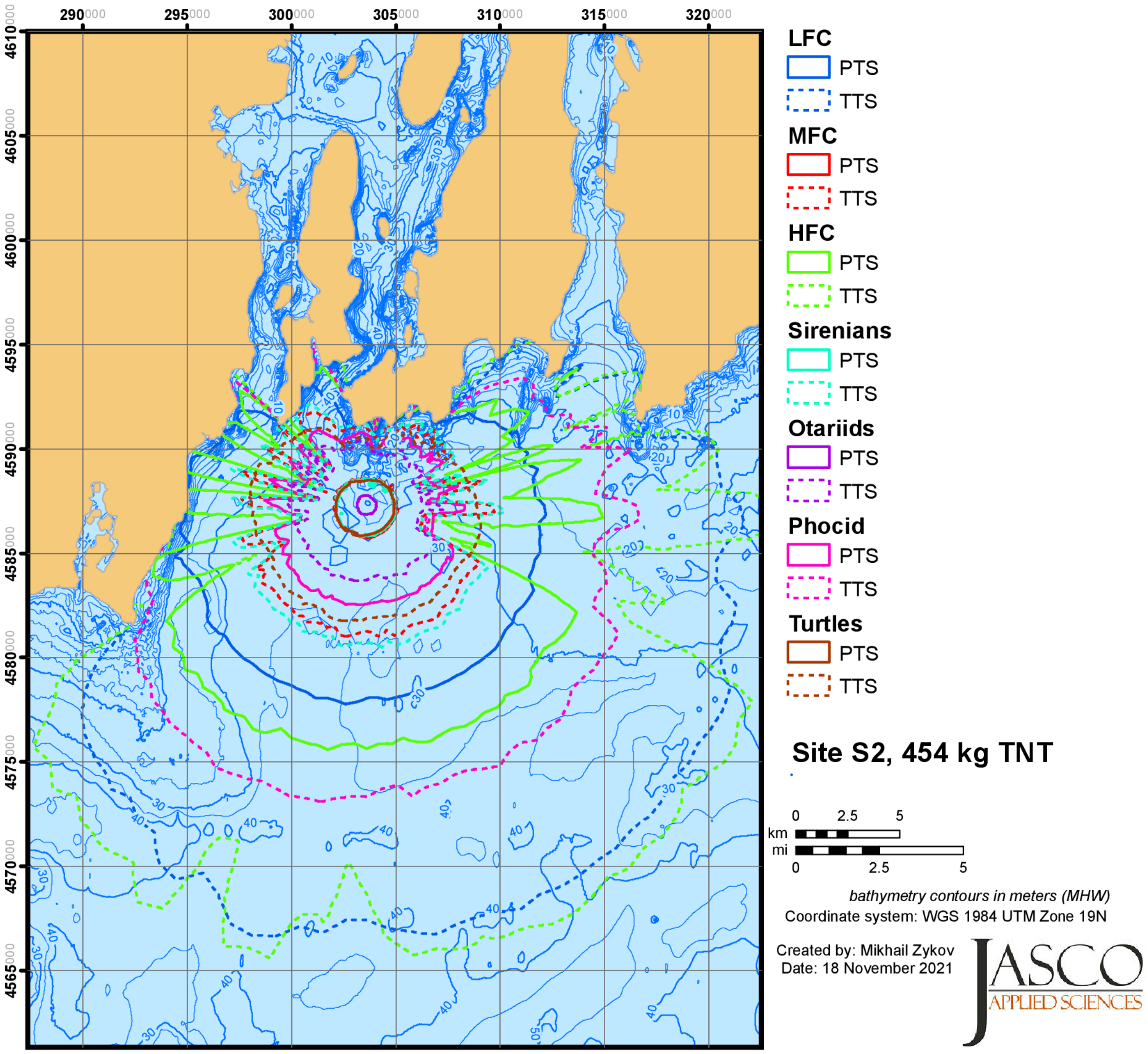

Figure A-4. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 454 kg charge size at Site S2.

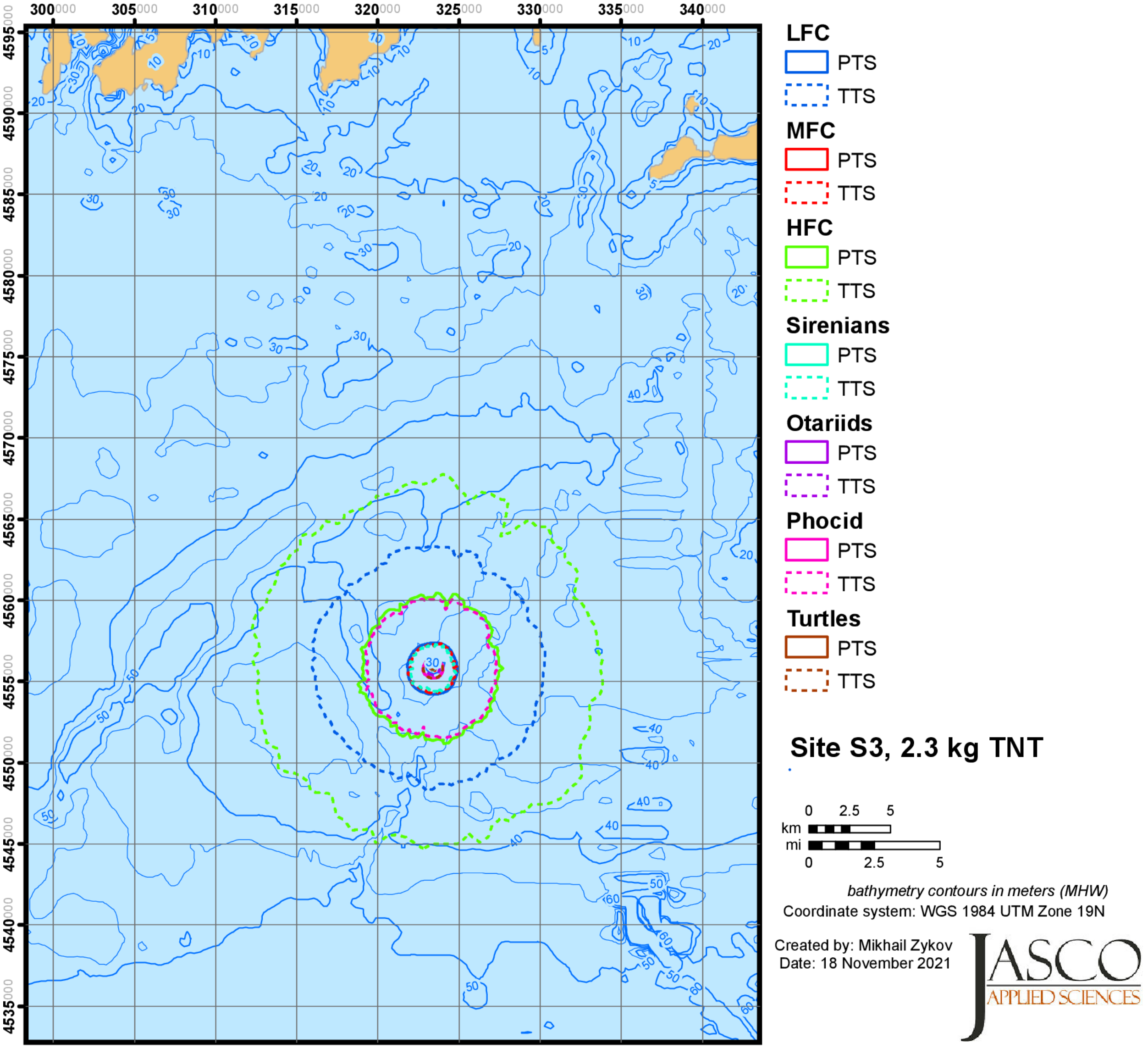

Figure A-5. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 2.3 kg charge size at Site S3.

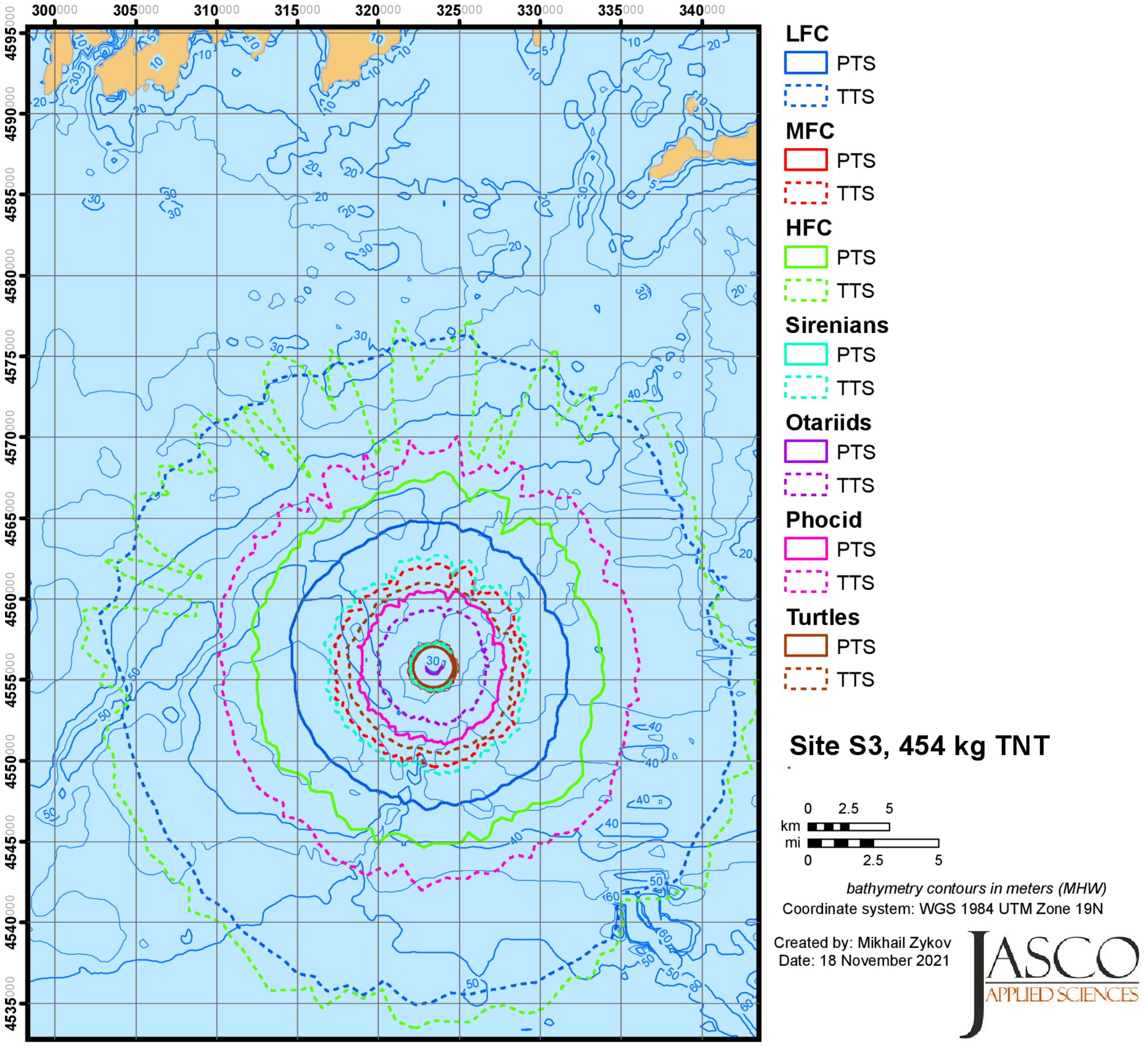

Figure A-6. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 454 kg charge size at Site S3.

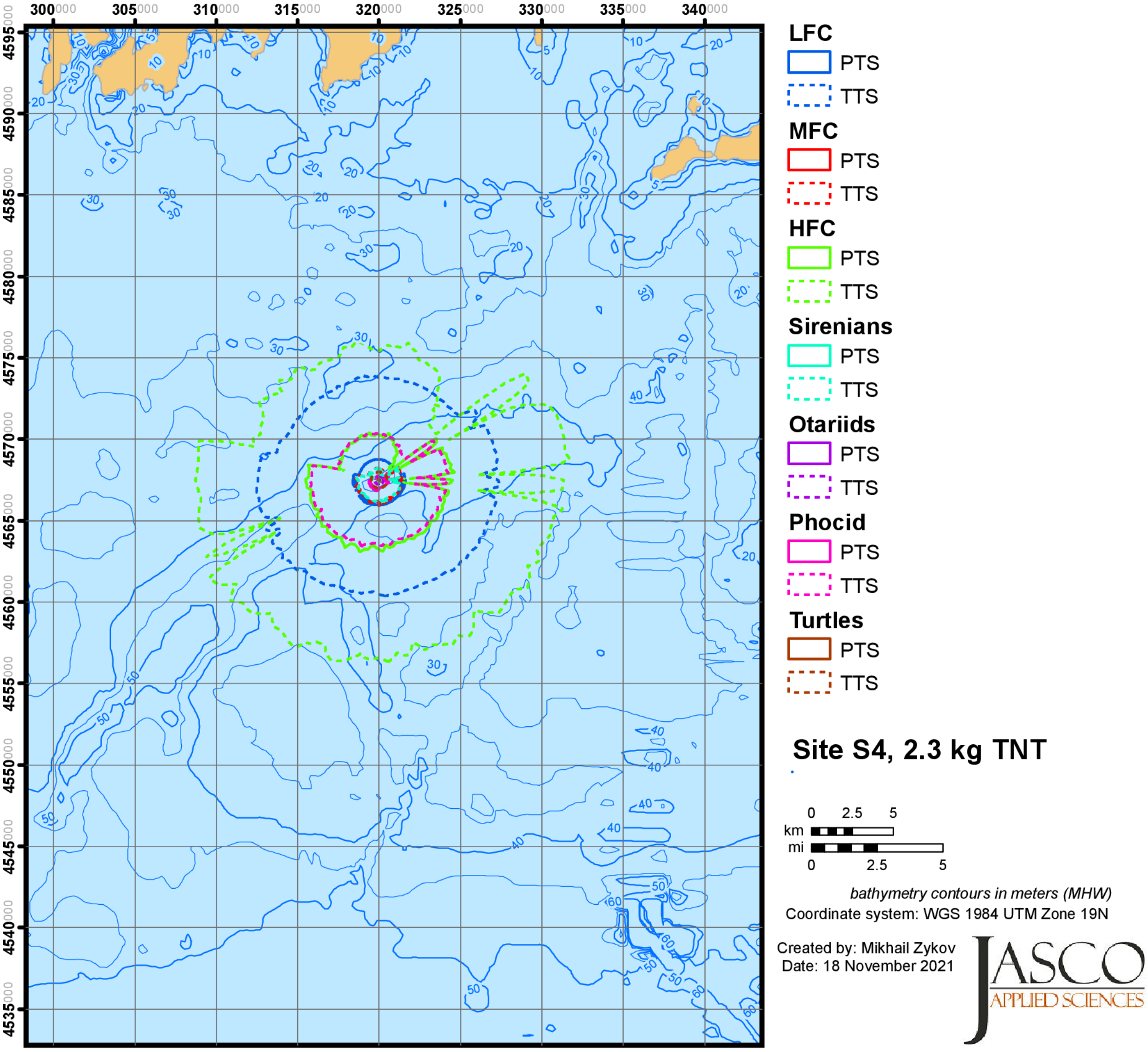

Figure A-7. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 2.3 kg charge size at Site S4.

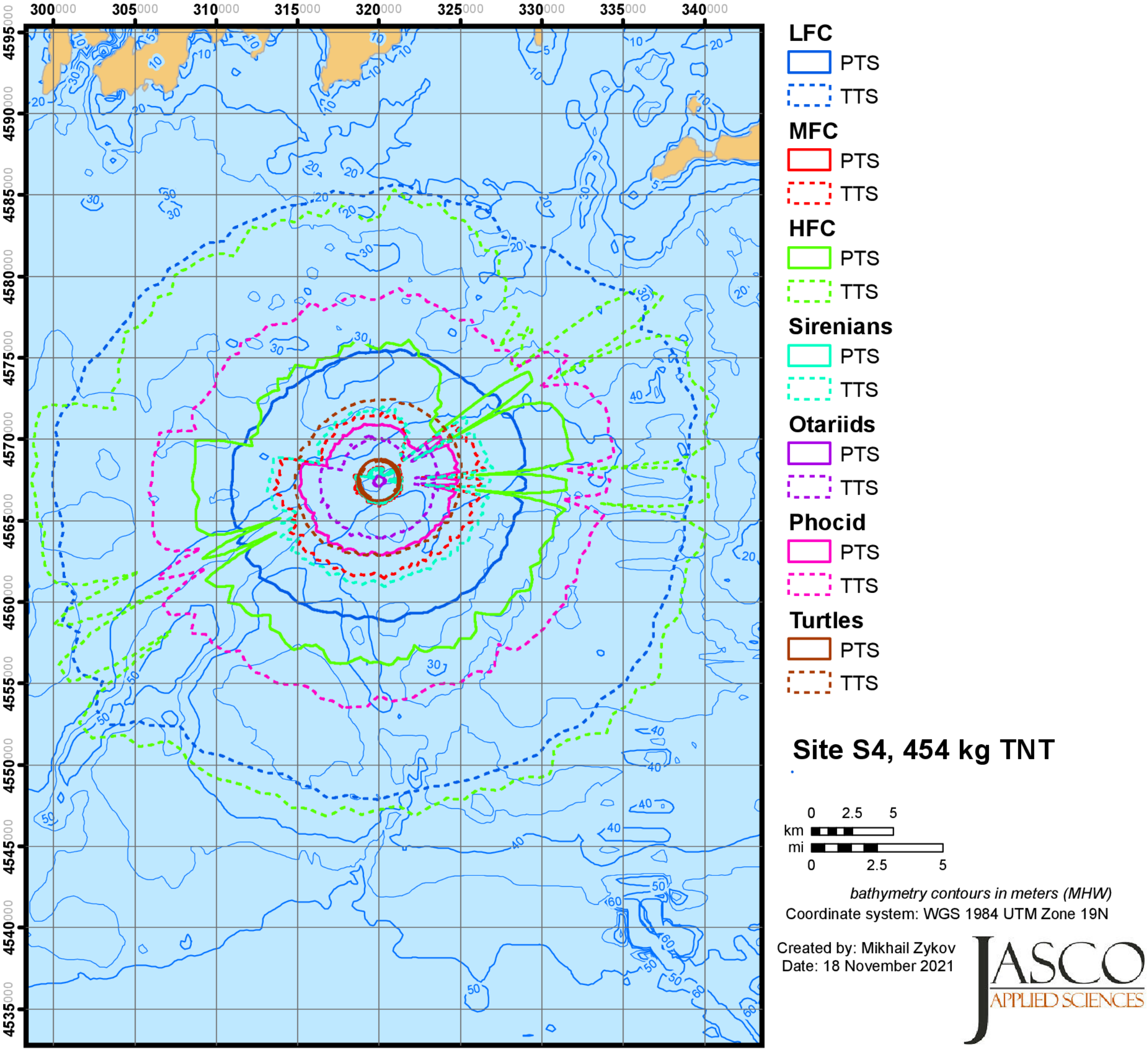

Figure A-8. Map of frequency-weighted SEL PTS and TTS exceedance zone for each species group for the 454 kg charge size at Site S4.

Protected Species Mitigation and Monitoring Plan

Revolution Wind, LLC

Revolution Wind | Powered by Ørsted & Eversource

February 2022

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List of Abbreviations and Acronyms

μPa	microPascal(s)
re 1 μPa	referenced to a pressure of 1 microPascal
AAR	autonomous acoustic recorder
ASV	autonomous surface vehicle
AUV	autonomous underwater vehicle
BBC	big bubble curtain
BO	Biological Opinion
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
cm	centimeter(s)
COP	Construction and Operations Plan
CPA	closest point of approach
CTV	crew transfer vessel
D	depleted
DASBRS	Drifting Autonomous Spar Buoy Recorders
dB	decibel(s)
DIFAR	Directional Frequency Analysis and Recording
DMA	Dynamic Management Area
E	Endangered
ECR	Export Cable Route
ESA	Endangered Species Act
FR	Federal Register
ft	foot/feet
GPS	global positioning system
HD	high definition
HF	high-frequency
HRG	high-resolution geophysical
HSD	Hydro-sound Damper
Hz	hertz
ITA	Incidental Take Authorization
IR	infrared
kg	kilogram(s)

kHz	kilohertz
kJ	kilojoule(s)
km	kilometer(s)
Lease Area	BOEM-designated Renewable Energy Lease Area OCS-A 0486
$L_{E,24h}$	sound exposure level, cumulative 24 hours
LF	low-frequency
$L_{p,0\text{-pk}}$	peak sound pressure level
m	meter(s)
MF	mid-frequency
min	minute(s)
mm	millimeter(s)
MMPA	Marine Mammal Protection Act
NARW	North Atlantic right whale
NL	not listed
nm	nautical mile(s)
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NMS	Noise Mitigation System
NVD	night-vision device
O&M	operations and maintenance
OCS	Outer Continental Shelf
Orsted	Orsted Wind Power North America LLC
OSS	offshore substation
PAM	passive acoustic monitoring
PECP	Permits and Environmental Compliance Plan
PK	peak sound pressure level
POC	point of contact
Project	Revolution Wind Offshore Wind Farm Project
PSMMP, or Plan	Protected Species Mitigation and Monitoring Plan
PSO	Protected Species Observer(s)
PTS	permanent threshold shift
QA	quality assurance
QC	quality control
rms	root mean square
ROD	Record of Decision

RWSAS	Right Whale Sighting Advisory System
S	strategic
SEL	sound exposure level
SFV	sound field verification
SMA	Seasonal Management Area
SNR	Signal to Noise Ratio
SOV	service operation vessel
SPL	sound pressure level
SPL_{rms}	root-mean-square sound pressure level
SZ	shutdown zone
TTS	temporary threshold shift
UHF	ultra-high frequency
USCG	United States Coast Guard
VHF	very high frequency
WDA	Wind Development Area
WEA	Wind Energy Area
WTG	wind turbine generator
ZOI	Zone of Influence

Glossary

Acoustic Monitoring Zone	The body of water around an activity that is acoustically monitored for the presence of marine mammals
Acoustic range	Range to acoustic thresholds calculated using acoustic modeling which assumes a stationary receiver and only considers sound propagation
Autonomous acoustic recorder (AAR)	Self-contained acoustic recording device designed for long-term deployment and data collection
Autonomous surface vehicle (ASV)	Unmanned surface vehicle or boat operated without a crew onboard
Clearance zone (CZ)	The area that must be visually and/or acoustically clear of protected species prior to starting an activity that produces sound at frequencies and amplitudes that could result in Level A or Level B exposures (e.g., HRG sources with operating frequencies <180 kHz; impact and vibratory pile driving)
Construction and Operations Plan (COP)	Plan submitted to BOEM by developers as required by 30 CFR part 585 to describe all planned facilities proposes for construction and use for the Project, along with all proposed activities including the proposed construction activities, commercial operations, and conceptual decommissioning plans for all planned facilities, including onshore and support facilities
Dynamic Management Area (DMA)	Areas established by NMFS to protect North Atlantic right whales (NARWs) from potential vessel strikes in which a voluntary speed restriction of 10 knots or less is encouraged while transiting through these areas
Ecological monitoring	Used to assess the effectiveness of mitigation measures within the context of long term or ecosystem-based assessments outside of any mitigation requirements
Shutdown Zone (SZ)	The area in which equipment shut down or other active mitigation measures must be applied once a source is active if a protected species is sighted inside the corresponding zone
Exposure range	Ranges to acoustic thresholds calculated using acoustic modeling which considers animal movement and behavior
Hydrophone	Microphone/audio recorder designed for use underwater
Incidental Take Authorization (ITA)	Authorization from NMFS per the MMPA for the “taking” of small numbers of marine mammals resulting from Project activities
Level A Zone	The area of water ensonified by a sound source to an acoustic isopleth defined as a threshold at which onset of a permanent threshold shift (PTS) in hearing can occur
Level B Zone	The area of water ensonified by a sound source to an acoustic isopleth defined as a threshold at which onset of a behavioral disturbance can occur
Mitigation	The set of personnel, equipment and protocols that are in place to minimize the risk of potential impacts to marine mammals from project activities
Mitigation monitoring	Typically comprised of PSOs who visually and acoustically monitor specified zones, during Project activities

Monitoring zone	The body of water around an activity that is visually monitored for the presence of marine protected species
Noise Mitigation System	Any device or suite of devices that reduces pile driving sound levels that are transmitted through the water. Primary systems reduce the source levels produced by the pile and secondary systems reduce the propagated sound levels of the piling.
Offshore substation (OSS)	Stations that collect and export the power generated by the WTGs, to be installed on monopile foundations within the RW Lease Area
Passive acoustic monitoring (PAM)	Real-time monitoring using an underwater recorder during Project activities for the presence of marine mammal vocalizations
Project Area	RW Lease Area (OCS-A 0486) and associated export cable routes
Protected species observer (PSO)	NMFS-approved visual observers trained to monitor the area around a vessel or platform during Project activities for the presence of protected species and implement appropriate mitigation as necessary
Record of decision (ROD)	Decision issued by BOEM following review of the COP which described their decision, any alternatives considered, and plans for mitigation and monitoring, as necessary
Seasonal Management Area (SMA)	Areas established by NMFS along the U.S. east coast at certain times throughout the year in which all vessels greater than 65 ft are required to travel at 10 knots or less while transiting these areas to reduce the threat of vessel strikes on NARWs
Sound field verification (SFV)	Acoustic measurements taken in the field of specific Project activities used to verify modeling results and confirm the monitoring and mitigation methods implemented for the Project are appropriate
Unexploded Ordinance (UXO)	Any sort of military ammunition or explosive ordnance which has failed to function as intended and may still pose a risk of detonation
Wind Farm Area	Maximum work area surrounding the Revolution Wind Lease Area (BOEM Lease OCS-A 0486)
Wind turbine generator (WTG)	A device that converts wind energy into electricity, to be installed on monopile foundations within the RWF Lease Area
Zone of influence (ZOI)	The area within which potential impacts to species are assessed and estimated

1 Introduction

This protected species mitigation and monitoring plan (PSMMP) is in place for high-resolution geophysical (HRG) survey, construction, and operations and maintenance (O&M) activities planned for Revolution Wind LLC's Revolution Wind Farm (RWF) located in the Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A-0486 and the associated Revolution Wind Export Cable (RWEC) herein referred to in this PSMMP as the Project Area. Revolution Wind, LLC (Revolution Wind) (formerly DWW Rev I, LLC) is a joint venture between Ørsted North America Inc. and Eversource Investment, LLC.

The purpose of this PSMMP is to provide protocols and guidelines for mitigation and monitoring activities to minimize potential impacts on marine mammals through both visual and passive acoustic means during Project-related activities. The PSMMP also serves as Section 11 (Mitigation Measures to Protect Marine Mammals and their Habitat) of the Application for Rulemaking and letter of Authorization for the Revolution Wind Project. The PSMMP provides consistency in the monitoring and mitigation methods employed across all Ørsted and Ørsted partnership wind projects in the Atlantic Outer Continental Shelf (OCS) and all development and operational phases. A PSMMP will be developed for each project.

1.1 PSMMP Format

Marine mammals[1] likely to occur in the Project area are presented in **Section 0** of this Plan. Standard conditions applicable to all Projects are presented in **Sections 3** of this Plan; while Project-specific activities will be reflected in **Section 4** and beyond as applicable. The Project-specific sections consider the range of activities and potential impacts; the biological and ecological information about species likely to occur within the Revolution Wind Project area; and permit conditions under which the work is being performed.

The protocols described in the Plan are designed to minimize impacts on marine mammals resulting from Project activities and document the occurrence of marine mammals in proximity to the Project area. Guidance for this plan comes from various resources of agreed-upon mitigation measures and monitoring protocols (Baker et al. 2013) as well as previous survey plans, ongoing agency reviews and coordination, and regulatory standard requirements where applicable.

The described monitoring and mitigation methods in each section of the Plan focus on marine mammals potentially exposed to underwater sound levels that would constitute "take" under the Marine Mammal Protection Act (MMPA). Subsequent sections of the Plan provide Project-specific details regarding the protocols that will be implemented during:

- High resolution geophysical (HRG) surveys
- UXO removal
- Construction, and
- Operations and Maintenance

Each activity section is designed to be used as a reference to the required measures that will be implemented during the corresponding activity including:

- designating mitigation and monitoring zones,
- defining measures related to potential impacts from underwater sounds, and

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[1] A separate version of this PSMMP outlines proposed mitigation and monitoring measures for other marine protected species (e.g., fish and sea turtles) in addition to marine mammals. This document is in development and will be provided to BOEM as an addendum to the Construction and Operations Plan for Revolution Wind.

- vessel strike avoidance measures as applicable for each activity.

Users should reference this Plan to confirm that all agreed and regulatory measures are being implemented using the accepted methods and practices. Additionally, sections are included that address longer term and marine mammal monitoring initiatives that are associated with specific projects or are in development through broader Ørsted and Ørsted partnership activities.

In this Plan, the units of Measure reported for construction activities are U.S. customary units, which are typically used in construction. Units of measure for scientific information, including acoustics, are metric. When appropriate, units are reported as both US customary and metric.

2 Marine Mammals Likely to Occur in the Project Area

Sixteen marine mammal species and/or stocks (Table 1) can be expected to reside, traverse, or routinely visit the Project Area. Five marine mammal species occurring in or near the Project area are listed as endangered under the ESA of 1973 (35 *Federal Register* (FR) 12222; 73 FR 12024) (Table 1). All marine mammals are protected under the MMPA.

Table 1: Marine Mammal Species in the Project Area for Which Level A and/or Level B Take is Requested.

Common name; species name; and stock	MMPA and ESA Status[a]	Relative Occurrence in the RWF[b]	Relative Occurrence in the RWEC[b]	Seasonality in Offshore Project Area[b]	Abundance[d] (NOAA Fisheries best available)
Mysticetes (baleen whales)					
Blue Whale *Balaenoptera musculus musculus* Western North Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Uncommon	Uncommon	Spring and summer	402
Fin Whale *Balaenoptera physalus physalus* Western North Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Common	Common	Year-round, but mainly spring and summer	6,802
Humpback Whale *Megaptera novaeangliae* Gulf of Maine Stock	MMPA Non-strategic	Common	Common	Year-round, but mainly spring and early summer (March to July)	1,396
Minke Whale *Balaenoptera acutorostrata acutorostrata* Canadian East Coast Stock	MMPA Non-strategic	Common	Common	Mainly spring and summer	21,968
North Atlantic Right Whale *Eubalaena glacialis* Western Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Common	Common	Year-round, but mainly winter and spring (December-April)	368

Common name; species name; and stock	MMPA and ESA Status[a]	Relative Occurrence in the RWF[b]	Relative Occurrence in the RWEC[b]	Seasonality in Offshore Project Area[b]	Abundance[d] (NOAA Fisheries best available)
Sei Whale *Balaenoptera borealis borealis* Nova Scotia Stock	ESA Endangered MMPA Depleted and Strategic	Regular	Uncommon	Spring and summer (March to July)	6,292
Odontocetes					
Atlantic Spotted Dolphin *Stenella frontalis* Western North Atlantic Stock	MMPA Non-strategic	Uncommon	Uncommon	Summer and fall	39,921
Atlantic White-Sided Dolphin *Lagenorhynchus acutus* Western North Atlantic Stock	MMPA Non-strategic	Common	Common	Year-round, but more abundant in the spring and summer	93,233
Common Bottlenose Dolphin *Tursiops truncatus truncatus* Western North Atlantic Offshore Stock	MMPA Non-strategic	Common	Common	Year-round	62,851
Common Dolphin *Delphinus delphis* Western North Atlantic Stock	MMPA Non-strategic	Common	Common	Year-round, but more abundant in summer	172,974
Harbor Porpoise *Phocoena phocoena* Gulf of Maine/Bay of Fundy Stock	MMPA Non-strategic	Common	Common	Year-round, but less abundant in summer	95,543
Pilot Whale, Long-Finned *Globicephalus melas* Western North Atlantic Stock	MMPA Depleted and Strategic	Common	Uncommon	Year-round, with peak occurrence in the spring	39,215
Risso's Dolphin *Grampus griseus* Western North Atlantic Stock	MMPA Non-strategic	Common	Uncommon	Year-round, but more abundant in summer	35,215
Sperm Whale *Physeter macrocephalus* North Atlantic Stock	ESA Endangered MMPA Depleted and Strategic	Common	Common	Year-round, but mainly summer and fall	4,349
Pinnipeds					
Gray Seal *Halichoerus grypus atlantica* Western North Atlantic Stock	MMPA Non-strategic	Regular	Regular	Year-round	27,300

Common name; species name; and stock	MMPA and ESA Status[a]	Relative Occurrence in the RWF[b]	Relative Occurrence in the RWEC[b]	Seasonality in Offshore Project Area[b]	Abundance[d] (NOAA Fisheries best available)
Harbor Seal *Phoca vitulina vitulina* Western North Atlantic Stock	MMPA Non-strategic	Regular	Regular	Year-round, with peak abundance (April to May)	61,336

ESA = Endangered Species Act; MMPA = Marine Mammal Protection Act; Project Area = includes the Revolution Wind Farm (RWF), Revolution Wind Export Cable (RWEC) – Outer Continental Shelf (OCS) and RWEC – Rhode Island (RI) state waters, and Onshore Facilities; SGCN = Species of Greatest Conservation Need.

NA = Not Applicable and/or insufficient data available to determine seasonal occurrence in the offshore project area.

[a] Special status accorded by the US Endangered Species Act (ESA), NMFS (Hayes et al. 2019, 2020), and Rhode Island Endangered Species Act (RI.gov 2021).

[b] Occurrence and seasonality were mainly derived from(Kenney and Vigness-Raposa 2010; Kraus et al. 2016) .

[c] Habitat descriptions from the 2019 Marine Mammal Stock Assessment Report (Hayes et al. 2019).

[d] "Best Available" abundance estimate is from the 2019 Marine Mammal Stock Assessment Report, published by NMFS on the Federal Register on 27 November 2019 (84 FR 65353); the 2020 Marine Mammal Stock Assessment Report (Hayes et al. 2020); and the draft 2021 Marine Mammal Stock Assessment Report (Hayes et al. 2021).

[e] Abundance estimates are from habitat-based density modeling of the entire Atlantic EEZ from (Roberts et al. 2016; Roberts et al. 2017; Roberts et al. 2018; Roberts et al. 2020, 2021)

[f] Under management jurisdiction of United States Fish and Wildlife Service rather than National Marine Fisheries Service and therefore not included in 2019 or the 2020 Stock Assessment Report; currently no reliable abundance estimate is available for this population

[g] Mesoplodont beaked whale abundance estimate accounts for all undifferentiated beaked whale species within the Western Atlantic (Hayes et al. 2019)

3 Standard Conditions for Mitigation and Monitoring

3.1 Defining Mitigation and Monitoring

For purposes of the Plan, mitigation and monitoring are defined as follows:

- **Mitigation** – defined as the set of personnel, equipment, and protocols that are in place to minimize the risk of any potential impacts to marine mammals that could result from Project activities.
- **Monitoring** – defined in two ways:
  1) Mitigation monitoring associated with ***mitigation activities***. Mitigation monitoring is typically comprised of protected species observers (PSOs) who visually and acoustically monitor specified zones (**Section 5.1, 6.1, 7.1)**, during Project activities for the purposes of implementing mitigation measures; and
  2) Ecological Monitoring to ***assess the effectiveness of mitigation measures***. Ecological monitoring is used within the context of long-term or ecosystem-based assessments outside of any mitigation requirements. While the same or similar methods and equipment as mitigation monitoring may be used, ecological monitoring typically addresses different questions or actions than mitigation monitoring. In this context, we use the term ecological monitoring in the Plan to differentiate the two monitoring regimes.

3.1.1 Zone Definitions

Throughout this Plan, zones are described that identify either an impact range, or areas within which mitigation and/or monitoring occurs. The size of the zones and the mitigation measures (if necessary) taken within each zone will be Project-, species-, and activity-specific and are identified in **Sections 5, 6, 7,** and **8** for marine mammals. Not all zones may be incorporated for all projects or activities. If additional zones are necessary for a project outside of the standard conditions, they will be defined in **Sections 5, 6, 7**, and **8** for Revolution Wind's PSMMP and in applicable Appendices for other species. The zones applicable to this Project are defined below.

- **Level A Zone** – the area encompassing the waters from a sound source to an isopleth defined by a threshold at which the **onset of a permanent threshold shift (PTS)** can occur. Level A zones may result from an instantaneous exposure, exposure over a 24-hour period, exposure to a single-strike or pulse, or other defined metric. Level A zones may be calculated or modeled, and their extent can be defined by acoustic ranges or by exposure ranges[2]. Entry by an animal into the Level A zone may or may not require mitigation measures be taken. Marine mammals detected between the sound source and the outer range limit of the Level A zone under the specified exposure conditions may constitute Level A exposure. Unless otherwise stated, the Level A zones for marine mammals use the following metrics:
    - Frequency-weighted cumulative sound exposure level (SEL_{cum}) and unweighted peak sound pressure level (SPL_{pk}). PTS thresholds as defined by the National Marine Fisheries Service (NMFS) (NMFS 2018).
- **Level B Zone** – the area encompassing the waters from a sound source to an isopleth defined by a threshold at which **onset of a behavioral disturbance can occur**. Level B zones may result from an instantaneous exposure, exposure to a single-strike or pulse, or other defined metric. Level B zones may be calculated or modeled, and their extent can be defined by acoustic ranges or by exposure ranges. Entry by an animal into the Level B zone may or may not require mitigation measures be taken. Marine mammals detected within this zone under the specified exposure conditions may constitute Level B exposure. Unless otherwise stated, the Level B zones for marine mammals use the following metrics:
    - Level B zone encompasses the distance from the sound source to an unweighted root-mean-square sound pressure level (SPL_{rms}) of 160 decibels (dB) referenced to (re) 1 micropascal (µPa) from impulsive or sweep sources are considered; and an unweighted SPL_{rms} of 120 dB re 1 µPa when non-impulsive sources are considered (NMFS 2019).
- **Pre-start Clearance Zone** – the area that must be visually and/or acoustically clear of protected species of marine mammal **prior to starting an activity**. Clearance zones may also be implemented after a shutdown in sound-producing activities prior to restarting the source. The size of the clearance zone is dependent on the activity and permit conditions. The clearance zone will be specific to species and/or faunal groups and may be larger than the species/faunal group-specific shutdown zone (SZ) (described below).
- **Shutdown Zone (SZ)** – the area in which a noise source must be shut down, or other active mitigation measures must be implemented **once a source is active**. The size of the SZ is dependent on the activity and permit conditions. The SZ may or may not encompass other zones. SZs will be specific to species and/or faunal groups.

- **Monitoring Zone** – encompasses the **waters around an activity to be visually and/or acoustically monitored** for the presence of protected species of marine mammals. The monitoring zone represents the farthest extent practicable that can be monitored for marine mammals. There are no mitigation or visibility requirements associated with the monitoring zone; however, all species detected within the monitoring will be recorded. The minimum size of the monitoring zone will help inform the appropriate monitoring methods that will be employed during activities. Monitoring zones can be considered an area of situational awareness for the project that carry no specific regulatory requirements.
- **Zone of Influence (ZOI)** – this is not a defined area for mitigation or monitoring purposes; rather, it is the area within which potential impacts to species are assessed and estimated. The ZOI would not be greater than the maximum Level B zone. While the ZOI provides the needed information to establish the other zones, it does not play an additional role in mitigation and monitoring during Project activities.

3.2 Permits and Agreements

Permits and agreements pertaining to the Project will define and modify the mitigation and monitoring requirements through the various stages of the permitting process. The permits and agreements in place for the Project are detailed in the individual Project activity sections (See **Sections, 5, 6, 7**, and **8**).

3.3 Personnel

Dedicated personnel may be required for carrying out mitigation and monitoring efforts onboard Project vessels. These roles are generally required to be filled by NMFS -approved and BOEM-accepted PSOs and passive acoustic monitoring (PAM) operators.

Personnel in the field have a responsibility to support these activities and will receive Project -specific training. A Permits and Environmental Compliance Plan (PECP) manual which will include the PSMMP will be prepared to describe species expected to occur in the Project Area, monitoring and mitigation measures, data collection and reporting measures, equipment specifications, etc.

The Project will conduct standardized pre-activity environmental awareness training for all crew members (e.g., PECP training). The training will summarize the PECP and other relevant topics including:

- The responsibilities of each party;
- Definition of the chains of command;
- Communication procedures;
- An overview of monitoring purposes;
- Review of operational procedures;
- Personnel training on mitigation requirements upon detection of a marine mammal(s);
- Procedures for sighting, reporting, and protection of marine mammals and other protected species;
- General review of protected species anticipated in the region; and
- Review of additional environmental requirements and awareness elements relevant to the Project.

3.3.1 Protected Species Observers

Protected species observers (PSOs) will, at a minimum, meet the observer standards outlined in Baker et al. (2013) and will have the appropriate approvals from NMFS for conducting PSO duties during wind farm activities including:

- At least one PSO must have prior experience performing the duties of a PSO during construction activity pursuant to a NMFS-issued incidental take authorization; and
- Other PSOs may substitute other relevant experience, education (degree in biological science or related field), or training for prior experience performing duties of a PSO during construction activity pursuant to a NMFS-issued take authorization.

The Project will deploy a PSO team consisting of PSOs with appropriate skills and in sufficient numbers to meet all mitigation and monitoring requirements.

The PSO field team will have a lead monitor (Lead PSO), designated and identified by the applicant to be approved by NMFS. The Lead PSO will have experience in the northwestern Atlantic Ocean on similar projects. The PSO team may also have one PSO supervisor who may work in the field or shore side for the duration of the mitigation activities to provide additional support to the Lead PSO and PSO team. The PSO supervisor would also facilitate the communication between PSOs and other shore side project parties. The remaining PSOs will have previous PSO experience on similar projects and the ability to work with the relevant software and equipment.

In addition to the PECP training indicated above, PSOs will also complete a two-day training and refresher session with the PSO provider and Project compliance representatives. The two-day training will review in detail the protected species expected in the Project Area and associated regulatory requirements and it will be conducted shortly before the anticipated start of Project activities. The refresher session will be tailored to the needs of the particular PSO teams and will consider what field projects the PSOs have recently been on.

3.3.2 Passive Acoustic Monitoring Operators

If real-time PAM is employed as a mitigation monitoring protocol, a PAM operator or PAM team will be deployed. PAM operators will have the qualifications and relevant experience to meet the needs of the PAM program including safe deployment and retrieval of equipment as necessary, set-up and monitoring of acoustic processing software, and knowledge in detecting and localizing marine mammal vocalizations. Like the PSO team, the PAM team will have a lead monitor (PAM Lead) who will have experience in the Northwestern Atlantic Ocean on similar projects. The remaining PAM operators will have previous PAM experience on similar projects and the ability to work with the relevant software and equipment. Resumes for all PAM team members will be submitted to NMFS for review and approve prior to the start of mitigation monitoring activities.

In addition to the PECP training indicated above, PAM operators will also complete a two-day training and refresher session with the PSO provider and Project compliance representatives. The two-day training will review in detail the protected species expected in the Project Area and associated regulatory requirements and it will be conducted shortly before the anticipated start of Project activities. The refresher session will be tailored to the needs of the particular PAM teams and will consider what field projects the PAM operators have recently been on.

3.3.3 Environmental Compliance Monitor

PSOs will be employed by a third-party provider. However, non-third-party observers who act as environmental compliance monitors in support of a Lead PSO will be approved by NMFS on a case-by-case basis for limited, specific duties in support of approved, independent PSOs. Environmental compliance monitors would support Lead PSOs during shallow water HRG activities.

3.3.4 PSO & PAM Operator Responsibilities

Prior to Project commencement, senior-level Lead PSOs will be designated for each team of PSOs on each asset (i.e., Project vessel or platform). These individuals shall have the experience and skill set to manage the team of PSOs on that asset and to make decisions related to mitigation and monitoring, including potential exposure assessments for each sighting as needed. The Lead PSO will be the single point-of-contact (POC) for PSO activities on that specific asset. The Lead PSO for each asset will report to the PSO Project Manager or Vessel Project Manager. The Lead PSOs shall provide daily sightings and mitigation summary reports to the designated Orsted Compliance Manager which is reported through to Project representatives for the previous day's operations. Changes to data logs may occur if errors are discovered during QA/QC steps. Revolution Wind will utilize Mysticetus software for its data error checks to reduce the possibility for such changes to occur. Any subsequent changes made to any reports submitted by the Lead PSO shall be documented in a change log and the review and acceptance by the Lead PSO noted. The Lead PSO is also responsible for quality assurance (QA)/quality control (QC) and management of data collection utilizing electronic data collection software and embedded QA/QC processes therein. They are the primary representative of observations, reports, and mitigation actions taken by the PSO team. Any PSO or PAM operator on duty will have authority to delay the start of operations or to call for a shutdown based on their observations or acoustic detections.

The PSO supervisor will oversee data collection at the highest level of all the PSO and PAM teams. The Lead PSOs and PAM Leads will be responsible for communicating to the vessel and client POCs (Revolution Wind/Orsted) directly or through agreed upon Project Management intermediaries and will ensure that the communication protocols established for the Project are maintained at all times and that all personnel are trained on the communication protocols (**Attachment 1**). These communication duties shall include the final responsibility for calling for a mitigation action.

Prior to the start of Project activities, the Lead PSO will work with the vessel captain and crew (i.e., operations team) on the asset to achieve compliance with all applicable regulatory documents and provide training when necessary to the vessel captain and crew.

Following established BOEM and NMFS standards, the PSO/PAM team(s) will work in designated shifts during monitoring. For PSOs, shifts will be set up such that no individual will work more than 4 consecutive hours without a 2-hour break, or longer than 12 hours during any 24-hour period. The Project will provide each PSO with one 8-hour break per 24-hour period to sleep. An example rotation is provided in **Attachment 2**. Actual rotations will be Project-, activity-, and vessel-specific, and implemented rotations will be documented with the Project's final PSO report. New or inexperienced PSOs will be paired with an experienced PSO qualified to mentor new PSOs so that the quality of marine mammal observations and data recording is kept consistent.

For PAM operators, minimum standard shifts are typically restricted to no more than 3 hours, but can be reduced if NMFS or BOEM directs a shorter shift. Typically, there is a "floater" PAM operator on the vessel who can rotate in to allow the PAM operator on shift to rest or eat. In some cases where vessels work under 24-hour operations, 4-hour PAM operator rotations may be scheduled. In the cases where PAM systems are monitored remotely (i.e., shore side) alternative rotations to the above may be requested on a case-by-case basis.

The combined PSO and PAM team will conduct monitoring efforts onboard Project vessels and, in some cases, shore side for remote and autonomously monitored systems. At all times during monitoring efforts, at least one dedicated vessel will be used to monitor for marine mammals relative to the activity being conducted. Autonomous, remotely operated systems may also be deployed to support the monitoring program. It is expected that during most activities, monitoring will take place from more than one platform.

The PSOs will watch for marine mammals from the best available vantage point on the vessels. Ideally this vantage point is a stable, elevated platform from which the PSOs have an unobstructed 360° view of the water. The PSOs will systematically scan with the naked eye and 7x50 reticle binoculars, supplemented with night-vision equipment when needed (see below). During activities with large monitoring zones, 25X 150 millimeter (mm) "big eye" binoculars may be used. All vessel personnel are provided the guidance "*If you see something, say something*" and are responsible for reporting to the PSO team any opportunistic sightings made as soon as they are able and it is safe to do so.

3.4 Equipment

The PSOs will be equipped with reticle binoculars and will have the ability to estimate distances to marine mammals located in proximity to their respective zones using range finders. Digital single-lens reflex camera equipment will be used to record sightings and verify species identification. During night operations, night-vision equipment (night-vision goggles with thermal clip-ons) and infrared (IR) technology will be used (**Attachment 3**). Position data will be recorded using hand-held or vessel global positioning system (GPS) units for each sighting. Recent studies have also concluded that the use of IR thermal imaging technology may allow for the detection of marine mammals at night as well as improve the detection during all periods with automated detection algorithms (Weissenberger et al. 2011; Smith et al. 2020; Zitterbart et al. 2020).

The exact equipment complement used by the PSO/PAM team will vary by the activity, mitigation and monitoring requirements, and observation platform constraints. Additional equipment may be added as necessary. The PSO/PAM team will typically use some combination of the following equipment for observation efforts:

- 7x50 reticle binoculars;
- 25x150 "big eye" binoculars;
- Personal computers/laptops/tablets (minimum of two on the primary vessel)
- Handheld GPS units (minimum of two on the primary vessel);
- High-definition digital single-lens reflex cameras with a minimum 300-mm zoom lens to record sightings and verify species identification, as possible (one per vessel);
- Hard drives to back up data (data will also be backed up daily to secure internet cloud location at least once per day or as often as internet access is available) (minimum of two per vessel);
- Laser rangefinder (one per vessel);
- Rangefinder stick (one per vessel);
- Night vision devices (NVDs);
- Mounted IR thermal imaging cameras;
- PAM hydrophone arrays and/or corresponding monitoring stations
- Computer-based PSO data recording system.

Specific equipment requirements for individual Project activities are provided after **Section 5 through Section 8**. Descriptions of the primary hardware used during mitigation and monitoring activities for all phases of wind farm development are provided in the following subsections.

3.4.1 IR Thermal Camera Systems

Studies have indicated that IR thermal camera performance is independent of daylight and has demonstrated effectiveness ranges exceeding 3 km. Results of studies demonstrate that IR thermal imaging can be used for reliable and continuous marine mammal monitoring (Zitterbart et al. 2013; Smith et al. 2020; Zitterbart et al. 2020). For this reason, the Project finds that use of IR thermal camera systems for mitigation and monitoring purposes warrants additional application in the field as both a stand-alone tool and in conjunction with other alternative monitoring methods (e.g., night vision binoculars, PAM, visual monitoring). See **Table 3** in **Attachment 3** for a summary of available systems.

3.4.2 Night Vision Devices

Night Vision Devices (NVDs) work on a different principle than IR thermal cameras. NVDs enhance available light to provide an image of what is being viewed through the device in such a way that it resembles viewing during higher light conditions (Smultea et al. 2021). In this way, NVDs are less dependent on temperature differentials necessary for the IR thermal camera systems. However, NVDs have a narrow field of view and a relatively short effective range (Smultea et al. 2021).

Equipment used by PSOs will be tailored to the size of the zones being monitored on each part of the Project. Specifications for representative NVD and IR thermal camera will be provided for individual projects as needed. Specific NVD and IR thermal camera equipment models will be subject to availability. See **Table 4** in **Attachment 3** for a summary of available systems.

3.4.3 PAM Systems

A PAM system is defined as any system or device that uses hydrophones, arrays of hydrophones, or other sensors (e.g., vector sensors such as Directional Frequency Analysis and Recording devices [DIFAR] capable sonobuoys) to detect sounds produced by marine mammals. A review of PAM systems that are under consideration is provided in **Attachment 4** which gives a general overview of the different types of applicable PAM systems including some of their advantages and disadvantages.

Within environmental impact statements and mitigation guidelines, there is often a general presumption that animal vocalizations will be consistently detected regardless of operator experience or background noise conditions encountered (Ludwig et al. 2016; Verfuss et al. 2018; Barkaszi and Kelly 2019). Impact estimates and risk assessments also rely on the assumption that animals within an SZ will be detected and localized immediately, so that sound exposures over certain criteria thresholds can either be avoided or enumerated (Verfuss et al. 2018; Barkaszi and Kelly 2019). In reality, detection performance at a given distance can be highly variable due to variability in the frequency, amplitude, directionality, and repetition rate of marine mammal vocalizations; as well as the continually changing background noise levels that effectively reduce the ability to detect signals generated within a monitoring zone (Parks et al. 2009; Van Parijs et al. 2009; Andriolo et al. 2018; Clausen et al. 2019; Thode and Guan 2019). Furthermore, localization, when required, often relies on the detection of multiple high quality signals. When the detection performance of signals is diminished, the actual time required to localize an animal or group of animals might be prolonged or impossible (Barkley et al. 2016; Abadi et al. 2017; Thode and Guan 2019). The types and configurations of PAM systems considered for all monitoring on Ørsted and Ørsted Partnership projects are discussed in **Sections 3.4.3** and Section **3.4.3.3** and in **Attachment 4**.

3.4.3.1 PAM Systems for Real-Time Mitigation Monitoring

PAM is widely used to monitor mitigation zones around vessels and other platforms during survey and installation activities that could negatively impact marine mammals. The primary goal of mitigation monitoring with PAM is to allow compliance personnel to detect and spatially localize marine mammals such that a mitigation decision can be made in a short period of time (seconds to minutes). However, the complexity of acoustic detection and localization is hindered by practical operational conditions that are commonly encountered during mitigation monitoring, described further below.

The requirement for real-time detection and localization limits the types of PAM technologies that can be used to those systems that are either cabled, satellite, or radio-linked. The system chosen will dictate the design and protocols of the PAM operations. Seafloor cabled PAM systems are not considered here, due to high installation and maintenance costs, environmental issues related to cable laying, permitting, and other reasons.

Towed PAM systems are cabled hydrophone arrays that are deployed from a vessel and typically monitored by personnel on that vessel. By and large, towed PAM systems are the mainstay of mitigation PAM applications due to the relatively low cost, high mobility, and ease and reliability of operation. However, the main challenge of a towed PAM system is the fact that it is usually towed from a vessel that may not be fit-for-purpose and that may also be towing other equipment, operating sound sources, and is working in patterns that are permit and Project-driven rather than driven by acoustic monitoring needs. All of these challenges can result in less-than-optimal conditions in which to employ PAM systems. In particular, detection and localization of low-frequency signals (e.g., baleen whale calls) can be challenging in many commercial deployment configurations because of masking caused by vessel sounds. One significant value of towed PAM systems, however, is their ability to work in unison with visual monitoring efforts. The ability to coordinate call types and call rates with visually detected species and group sizes provides important information for analyzing data from non-towed systems used for other types of monitoring. While towed PAM systems have a place in mitigation monitoring (e.g., in support of visual observation), alternative PAM systems are more appropriate for long-range and low frequency signal monitoring.

Mobile and hybrid PAM systems utilizing autonomous surface vehicles (ASVs) and radio-linked autonomous acoustic recorders (AARs) shall be considered when they can meet monitoring and mitigation requirements in a cost-effective manner. Mobile systems are defined here as systems that are not fixed (e.g., moored or bottom-mounted) at one location. Examples of mobile systems include autonomous underwater vehicles (AUVs), ASVs, and drifting PAM buoys. A review for ASVs and AUVs was recently conducted by Verfuss et al. (2019). Examples of drifting PAM buoys include sonobuoys, the Que-phone, Drifting Autonomous Spar Buoy Recorders (DASBRS), and SonarPoint (in the drifter configuration). Due to their drifting nature, these systems are typically deployed in pelagic environments, or for very short periods (e.g., sonobuoys). Real-time (e.g., radio-linked) PAM buoys can be used for regional monitoring of large areas and have an advantage over AARs in that they can telemeter data to shore or a monitoring station nearby in real, or near real-time. Examples of real-time PAM buoys are also provided in **Attachment 4**.

3.4.3.2 Placement of Mitigation PAM Systems

Ideally, deployment of a mitigation PAM array will be outside the perimeter of the SZ to optimize the PAM system's capability to monitor for the presence of animals potentially entering these zones. The total number of PAM stations and array configuration will depend on the size of the zone to be monitored, the amount of noise expected in the area, and the characteristics of the signals being monitored. There is no single optimal array configuration for all animal call types or noise conditions.

In general, large cetaceans such as baleen whales that produce relatively loud, low-frequency vocalizations can be monitored with a few hydrophones that can be separated by several hundreds of meters or more, whereas smaller cetaceans such as toothed whales and dolphins produce shorter, lower level signals (e.g., whistles, echolocation clicks) that require hydrophones to be spaced more closely, tens of meters to less than a meter apart, and thus may require more hydrophones in an array.

Using closely-spaced clusters of hydrophones (i.e., an array) or vector sensors will allow the direction and, in some cases, the range to vocalizing animals to be estimated. However, this approach adds greater complexity and costs to both the hardware and software, can reduce reliability of the system, and can make real-time monitoring and mitigation difficult for PAM operators. Of course, detection and localization of animals is only possible if they are vocally active.

3.4.3.3 PAM Systems for Ecological Monitoring

The type of system chosen for any ecological monitoring programs will depend on the monitoring priorities (i.e., species and areas to be monitored), the environment (e.g., water depths), bottom fishing (e.g., trawling) in the area to be monitored, and other factors which contribute to detection probabilities.

AARs are a good option for long-term ecological monitoring. AARs are available in a variety of configurations and specifications (**Attachment 4**) (Sousa-Lima et al. 2013). Typically, AARs are deployed on the seafloor for some period of time from several days, weeks, months, up to one year. They are later retrieved from the seafloor, and the data are downloaded. An acoustic release device is typically used to release the recorder from the seafloor, however, grappling methods can also be used in some shallow water environments (usually 50 meters [m] or less). Some shallow water systems can also be retrieved with divers, but this approach is becoming less common due to safety issues and availability of more reliable and low-cost release devices. Once retrieved, the recording devices can be serviced, the data downloaded, and then re-deployed for additional missions. One major disadvantage of AARs over other PAM systems is that the recorders must be periodically retrieved in order to access the data because they record and store data internally and therefore are not capable of real-time monitoring. However, due to their autonomous nature, an advantage of these systems is that an infinite variety of deployment configurations are possible.

Most AARs consist of a single omni-directional hydrophone, and therefore it is not possible to obtain bearings or localizations to sound sources from this type of single device. However, other advanced systems utilize a directional hydrophone/sensor (e.g., DIFAR), or multiple hydrophones connected to a single multi-channel recorder (e.g., a hydrophone array) and thus can localize. In some systems, multiple AAR units can be precisely time-synchronized (e.g., using an acoustic pinger or electronic cable), so that bearings can be obtained and in some deployment configurations localizations of sound sources is thus possible. If an animal or tightly clustered group of animals (e.g., a small pod of dolphins) vocalize consistently through time, it may also be possible to track their movements. In general, the more hydrophones that receive the calls, the higher certainty there will be in the animal locations and tracks, until the increased complexity of processing multiple channels of data in real time becomes an issue.

One downside of AARs is that if a failure occurs (e.g., electronic malfunction, flooding, or a failure to retrieve them) significant volumes of data can be lost. This issue is of particular concern for long-term deployments. Also, the data storage and batteries required for extended deployment periods increase the size and costs of these systems.

There is also a cost associated with deployment and retrieval which typically requires a vessel with a hoist, A-frame, or other heavy machinery. The size of the vessel required depends on size and ease of deployment of the AAR system. Some smaller systems can be deployed from a small boat or rigid-hulled inflatable boat, while others might require a large and costly research or other type of vessel with an A-frame. Finally, the fact that data must be post-processed results in additional analysis expense. However, depending on the level of and type of processing, this approach is usually cheaper (per unit of data collected) than real-time monitoring, which typically requires experienced and relatively costly personnel working on vessels or platforms at sea.

There are also hybrid systems that have some components of both real-time and autonomous systems. For example, many types of real-time systems also record data internally, so they can function both as a real-time system, and as autonomous recorders in case the radio or satellite link is not reliable. Some hybrid systems only send status reports or whale-call detection summaries to shore or a vessel nearby via the radio or satellite-link.

The optimal system will depend on cost considerations, the target species, the length of deployment desired, and a variety of other factors. It is important to realize that there is no single system that is capable of mitigation and monitoring of all species of marine mammals for all areas and noise conditions, so it is possible that several systems, or combinations of systems will be needed.

3.5 Software and Informational Tools

When a marine mammal is detected (either visually or acoustically), data will be collected using software designed for such collection. Software systems exist or are being developed that allow for real-time or near real-time uploads into internet-based cloud storage systems, enabling that information to be downloaded by other vessels or PSOs/PAM operators in the area. This regular and ongoing sharing of sighting data and acoustic detections across platforms will integrate into a Project-wide *Situational Awareness System* that will also include, as feasible, Ørsted's Marine Operation Centers vessel monitoring system, external sources of information such as WhaleAlert (http://www.whalealert.org/) and the interactive map of North Atlantic Right Whale (NARW) sightings (NOAA Right Whale Sighting Advisory System (RWSAS)) (https://apps-nefsc.fisheries.noaa.gov/psb/surveys/MapperiframeWithText.html), detections from external sources of sighting information such as any existing North Atlantic right whale (NARW) Listening Network detections, 3rd party sightings, and any designated and overlapping designated seasonal and dynamic management areas (SMA and DMA).

The overall goal will be to create a Common Operating Picture (i.e., the ability to describe current conditions or species presence in real time or near real time) viewable by Project personnel across multiple project assets and provide a mechanism to manage multiple assets or activities throughout the Project Area in a systematic way. The system as named supports increased situational awareness of marine mammals and facilitates active whale avoidance (Gende et al. 2019) which is an *active and adaptive* mitigation approach for marine mammal monitoring and supports quick decision making for vessel operators, Project crew, or PSO/PAM operators during Project activities.

As a secondary measure, at least once per 4 hours (or as otherwise requested by the Project), PSOs will check additional available information sources including Whale Alert.

3.5.1 Mysticetus Software

Mysticetus^{tm} (https://www.mysticetus.com) is field-tested technology specifically designed to facilitate PSO operations and enhance protective measures for marine mammals. Mysticetus provides a standardized data collection system customized for data collection protocols specified by the Project across all vessel operators and PSO providers. The standardized data collection includes monitoring effort, Project updates, and animal detection data forms and can be updated as needed. Some of the Mysticetus capabilities that enhance Project situational awareness include:

- Real-time graphical display of all relevant information from all boats in the network and 3rd party data feeds defined by the Project.
- Graphically displayed content includes current SZs and CZs around work boats, work zones, and survey areas.
- Display that enables instantaneous mitigation decision support features including display of sighting distances and prediction paths of both animals and vessels, enabling informed PSO decisions for survey path adjustment, operational shutdowns, clearance delays, etc.
- Instantaneous sharing of sightings and alerting between all Mysticetus stations in the network (i.e., any animal sighted by any observer shows up on the maps of all nearby Project vessels) creates a multiplying effect of "eyes on water," and can be used by vessel crews to actively avoid animals.
- Automatic display of NMFS NARW DMAs on display map.
- Standardized QA and reporting processes and tools for all PSOs, regardless of which PSO provider or vessel sub-contractor they work for.
- Email and text message instant alerts in the case of sightings of dead, injured, or entangled animals, as well as all NARW sightings.
- Automatic, accurate localization of sighted animals based on reticle binoculars or clinometer readouts, including deck and PSO eye height, taking into account curvature of the earth.
- IR thermal camera integration of video recording, animal localization support, effort, etc.
- PAM integration and the recording of PAM effort and acoustic detections to Project-specified data collection standards.

3.6 Recording

As part of all monitoring programs, PSOs, PAM operators, and crew members (as applicable) will record all sightings of marine mammals observed anywhere within the monitoring zone. For mitigation monitoring, data on all PSO observations will be recorded based on standard PSO data collection requirements and specific permit conditions. A data collection software system (e.g., Mysticetus ^{TM} or similar software) will be used to record and collate data obtained from visual and acoustic observations during mitigation monitoring. The PSOs and PAM operators will enter the data into the selected data entry program (e.g. Mysticetus or a similar software) installed on field laptops/tablets. PSO data records will include:

- The presence and location (if determinable) of any marine mammal detected by PSOs, PAM operators, or crew members.

- Identification of marine mammal species, numbers of individuals, and behaviors as able. PAM detections are rarely suitable for enumeration or behavior of animals unless verified by visual detections.
- Detections will be annotated with information regarding vessel activity, environmental conditions, and by other operational parameters (e.g., number of vessels in areas, equipment start and stop times, operational duration, etc.).
- Size of all regulatory and monitoring zones.
- Implementation of vessel strike avoidance measures.
- Implementation of clearance, ramp-up and soft start, and shutdown measures as applicable for shutdown and monitoring zones.
- Implementation of specific NARW mitigation measures.
- Observations of any potential injured or dead protected species (e.g., stranding events).

The following information about each marine mammal detection will be carefully and accurately recorded:

- Species, group size, age/size/sex categories (if determinable), and physical description of features that were observed or determined not to be present in the case of unknown or unidentified animals;
- Behavior when first sighted and during any subsequent sightings;
- Heading (if consistent), bearing, and distance from observer;
- Location of confirmed acoustic detections within Project Area (if PAM operator is able to localize the animal);
- Tracks of marine mammals derived from PAM systems if accurate localization is attainable;
- Entry of animal into any regulatory or monitoring zones and duration in those zones;
- Closest point of approach to the applicable activities and/or vessels and assets;
- Apparent reaction to activities (e.g., none, avoidance, approach, paralleling, etc.) with annotations regarding animal headings, pace, or other information that could help assess changes in behavior;
- Time, location, speed, and Project activity/active sound sources in operation;
- How the animal was detected (i.e., with what monitoring method) and if the animal was detected by any other monitoring method; and
- Mitigation measures requested and implemented (if any).

At regular intervals and at each detection the following information will be recorded by PSOs and PAM operators when the information is determinable:

- Sea state, visibility, and sun glare;
- Noise performance of PAM systems and effective detection ranges for species;
- Vessel or Project activities and location (if mobile);
- PSO shift changes;
- Monitoring equipment being used; and
- Any NARW SMA or DMAs placed during that particular watch.

3.7 Reporting

The following situations would require immediate reporting to appropriate POCs:

- If a stranded, entangled, injured, or dead protected species is observed, the sighting shall be reported within 24 hours to the NMFS RWSAS hotline (see **Attachment 5**).
- In the event a protected species is injured or killed as a result of Project activities, the vessel captain or PSO on board shall call for an immediate cessation of all activities until NMFS Office of Protected Resources (OPR) is able to review the circumstances of the incident and determine what, if any, additional measures are appropriate to ensure compliance. Additionally the vessel captain or PSO on board shall report immediately to (see **Attachment 5**):
    - NMFS OPR (301-427-8401) and Greater Atlantic Regional Fisheries Office no later than within 24 hours;
    - NOAA Fisheries Marine Mammal and Sea Turtle Stranding and Entanglement Hotline (866-755-6622) or alternative electronic reporting systems as approved by the NOAA stranding program, as well as the U.S. Coast Guard.
- Any NARW sightings should be reported as soon as feasible and no later than within 24 hours to the NMFS RWSAS hotline or via the Whale Alert Application.

Data and Final Reports will be prepared using the following protocols (see **Attachment 8**):

- All vessels will utilize a standardized data entry format.
- A QA/QC'd database of all sightings and associated details (e.g., distance from vessel, behavior, species, group size/composition) within and outside of the designated SZs, monitoring effort, environmental conditions, and Project-related activity will be provided after field operations and reporting are complete. This database will undergo thorough quality checks and included all variables required by the NMFS-issued Incidental Take Authorization (ITA) and BOEM Lease OCS-A 0486 and will be required for the Final Technical Report due to BOEM and NMFS.
- During construction, weekly reports briefly summarizing sightings, detections, and activities will be provided to NMFS and BOEM on the Wednesday following a Sunday-Saturday period.
- Final reports will follow a standardized format for PSO reporting from activities requiring marine mammal mitigation and monitoring.
- An annual report will be provided to NMFS and to BOEM on April 1 every calendar year summarizing the prior year's activities.

3.7.1 Post-Construction HRG Survey Reports

Post construction, Revolution Wind will provide to BOEM and NMFS a final report annually for HRG survey activities. The final report must address any comments on the draft report provided to Revolution Wind by BOEM and NMFS. The report must include a summary of survey activities, all PSO and incident reports, and an estimate of the number of listed marine mammals observed and/or taken during these survey activities.

3.8 Noise Attenuation Systems

Noise attenuation systems (NAS) are employed during pile driving activities to reduce the sound pressure levels that are transmitted through the water in an effort to reduce ranges to acoustic thresholds and minimize acoustic impacts resulting from pile driving activities.

There are two categories of NAS, primary and secondary. A primary NAS is used to reduce the level of noise produced by the pile driving activities at the source, typically by adjusting parameters related to the pile driving methods or the impulse produced by a hammer strike. However, primary NAS are not fully effective at eliminating all harmful noise levels that can propagate from construction activities, so a secondary NAS is typically employed to further mitigate pile driving noise.

A secondary NAS is a device or devices employed to reduce the noise as it is transmitted through the water (and through the seabed) from the pile. The noise is typically reduced by some sort of physical barrier that either reflects or absorbs sound waves and therefore decreases the distance over which higher energy sound is propagated through the water column.

Primary NAS are still evolving and will be considered for mitigation when matured with demonstrated efficacy in commercial projects (e.g., blue piling). There are generally three types of secondary NAS considered for impact pile driving within the PSMMP. The final selection of the single or suite of technologies that comprise the NAS will be dependent upon the pile and environmental characteristics of the piling location. The demonstrated effectiveness of these systems is described in Bellmann et al. (2020). The three NAS technologies considered for the Project include:

- Big bubble curtain (BBC):
    - A BBC consists of a flexible tube fitted with special nozzle openings and installed on the seabed around the pile. Compressed air is forced through the nozzles producing a curtain of rising, expanding bubbles. These bubbles effectively attenuate noise by scattering sound on the air bubbles, absorbing sound, or reflecting sound off the air bubbles.
- Hydro-Sound Damper (HSD):
    - An HSD system consists of a fish net holding different sized elements arranged at various distances from each other that encapsulates the pile. HSD elements can be foam plastic or gas-filled balloons. Noise is reduced as it crosses the HSD due to reflection and absorption by air spaces contained in the elements.
- AdBm, Helmholz resonator:
    - The AdBm system consists of large arrays of Helmholtz resonators, or air fill containers with an opening on one side that can be set to vibrate at specific frequencies to absorb noise, deployed as a “fence” around pile driving activities.

There are other available systems, however, these may not be technically feasible for the Project (e.g., noise mitigation screen), are either in early stages of development, or have yet to demonstrate their expected performance during field tests and are therefore not being currently considered for use during construction of the Revolution Wind Project. Although Orsted believes 10 dB can be achieved with a single BBC, Revolution Wind is committed to achieving the modeled ranges with 10 dB of noise attenuation using a single BBC paired with an additional noise attenuation device or dBBC.

The configuration of any secondary NAS will optimize its efficacy based on the location, operations, and environmental and oceanographic parameters of the project. For the context of this PSMMP, the

standard BBC (as compared to prior wind farm deployments) configuration is defined as a BBC that has been professionally deployed and further optimized after initial deployment based on local conditions and *in-situ* measurement results.

3.9 Vessel Strike Avoidance Policy

The Project will implement a vessel strike avoidance policy for all vessels under contract to Ørsted to reduce the risk of vessel strikes and the potential of death and/or serious injury to marine mammals. In addition to vessels transiting and working (e.g., HRG surveys, construction, O&M) within the Project Area, there will be vessels transiting to and from the Project Area transporting materials, equipment, and personnel. A Project-specific vessel strike avoidance plan is provided in **Attachment 6**.

Marine mammals may not be able to avoid vessels, especially fast-moving ones, and may even have difficulty identifying the location and direction of travel of the vessel due to sound propagation characteristics in the marine environment. All vessels will comply with the vessel strike avoidance measures as specified below, except under extraordinary circumstances when complying with these requirements would put the safety of the vessel or crew at risk.

1. Vessel operators and crews shall receive protected species identification training. This training will cover sightings of marine mammals and other protected species known to occur or which have the potential to occur in the Project Area. It will include training on making observations in both good weather conditions (i.e., clear visibility, low wind, low sea state) and bad weather conditions (i.e., fog, high winds, high sea states, glare). Training will include not only identification skills but information and resources available regarding applicable federal laws and regulations for protected species. It will also cover any Critical Habitat requirements, migratory routes, seasonal variations, behavior identification, etc.
2. Vessel operators and crews will maintain a vigilant watch for marine mammals and other protected species and change course or respond with the appropriate action (e.g., slow down) to avoid striking marine mammals.
3. Vessel operators will monitor the Project's *Situational Awareness System* and the Coast Guard VHF Channel 16 as well as the Whale Alert and the NMFS RWSAS for the presence of NARWs once every PSO shift during Project-related activities.
4. All vessels will comply with NMFS regulations and speed restrictions and state regulations as applicable for NARW.
5. All vessels 65 ft (20 m) or longer subject to the jurisdiction of the U.S. will comply with the 10-knot speed restriction when entering or departing a port or place subject to U.S. jurisdiction. This includes any vessel 65 ft or longer travelling in any SMA[3] during NARW migratory and calving periods from November 1 to April 30. The Mid-Atlantic SMAs specific to the Project area include ports of New York/New Jersey and the entrance to the Delaware Bay in the vicinity of the Project area. The same speed restriction will apply to vessels travelling within important feeding areas including Cape Cod Bay from January 1 – May 15, off of Race Point from March 1 – April 30, and in the Great South Channel from April 1 – July 31.

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[3] Compliance Guide for Right Whale Ship Strike Reduction Rule (50 CFR 224.105), available at: https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales#seasonal-management-areas---mid-atlantic

6. All vessels will comply with the approved adaptive speed plan which will include additional measures when vessels are travelling through established NARW Slow zones (See **Attachment 6**).
7. When whales are sighted, the vessel shall maintain a distance of 91 m (100 yards) or greater between the whale(s) and the vessel; for smaller cetaceans or sea turtles, a distance of 45 m (50 yards) or greater is best; for right whales this distance is 457 m (500 yards).
8. All attempts shall be made to remain parallel to the animal's course when a travelling marine mammal is sighted in proximity to the vessel in transit. All attempts shall be made to reduce any abrupt changes in vessel direction until the marine mammal has moved beyond its associated separation distance (as described above).
9. If an animal or group of animals is sighted in the vessel's path or in close proximity to it, or if the animals are behaving in an unpredictable manner, all attempts shall be made to divert away from the animals or, if unable due to restricted movements, reduce speed and shift gears into neutral until the animal(s) have moved beyond the associated separation distance (with the exception of voluntary bow riding dolphin species).

Additionally, all vessel operators will be briefed to ensure they are familiar with the measures listed above and discussed throughout this Plan. The Project will continue to support external initiatives to further mitigate marine traffic impacts and currently is a supporter of the Whale Alert system and is investing in development and advancement of the whale listening network.

4 Revolution Wind Farm Project Area

4.1 Applicable Project Area

The area covered by the PSMMP includes Lease Area OCS-A 0486, the Wind Farm Area, the RWEC, transit corridors, and cable landfall locations.

For the purpose of this Plan, the Project area is defined as state and federal waters of the Revolution Wind BOEM Lease Area OCS-A 0486, which is a portion of the Rhode Island/Massachusetts Wind Energy Area (RI-MA WEA) and Massachusetts Wind Energy Area (MA WEA) (Figure 1). Project activities include construction, HRG surveys, UXO detonations, and O&M.

The boundaries of the Project area depicted in (Figure 1) consist of the following:

- Revolution Wind Farm (RWF): area where the turbines (WTGs), array cables, offshore substation(s) (OSS), and OSS interconnector cables
- Revolution Wind Export Cable (RWEC): area in which the offshore export cable systems will be installed and the cable landfall installation

The key components of the Project for offshore infrastructure are as follows:

- Up to 100 WTGs connected by a network of inter-array cables
- Up to two OSSs connected by OSS-link cable
- Up to two export cables

The RWF is located within federal waters, in both the RI-MA WEA and the MA-WEA. The RWEC will traverse both federal and state territorial waters of Rhode Island, extending up to approximately 50 mi

(80 km) from the RWF to the Landfall Work Area at Quonset Point in North Kingstown, Rhode Island (Figure 1).

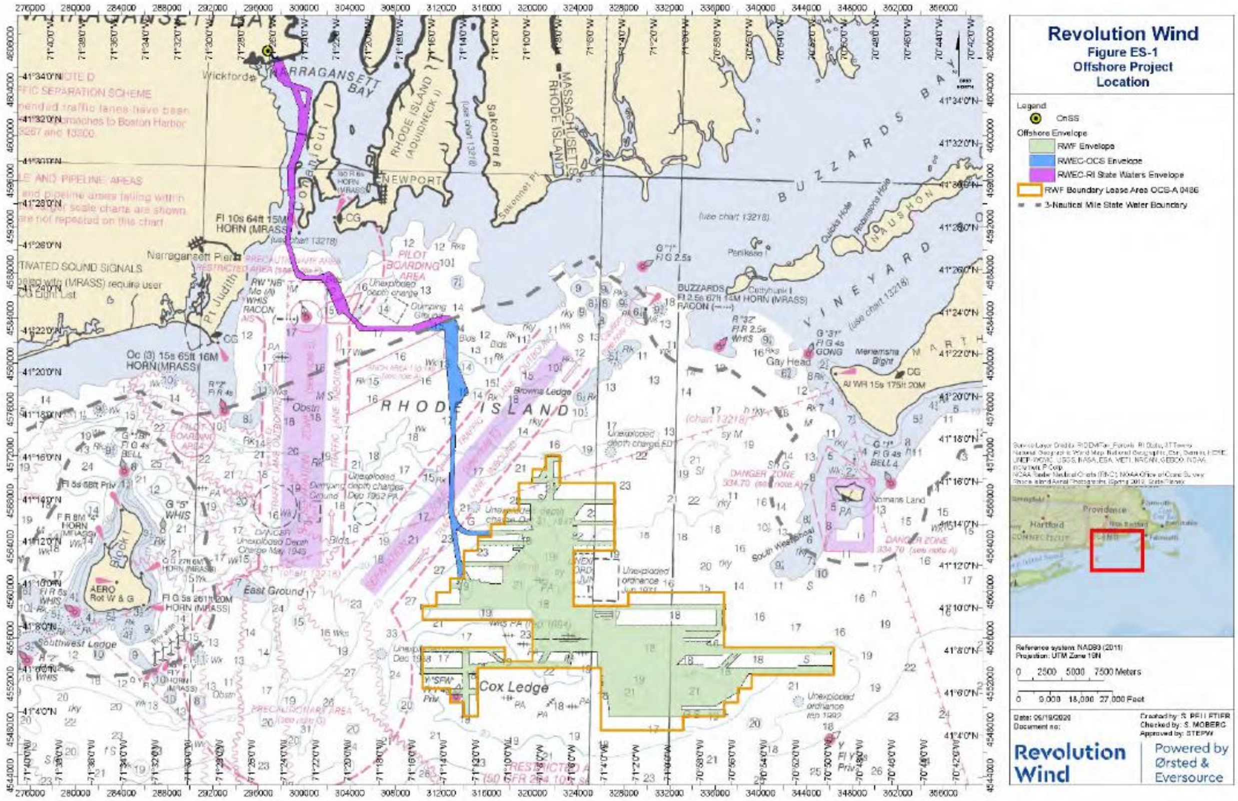


Figure 1. Location of the RWF within Lease Area OCS-A 0486 and the RWEC.

5 HRG Survey Monitoring and Mitigation

HRG survey activities may be required during construction and O&M phases of the Project. During such surveys, activities would include, but are not limited to:

- Depth sounding (multibeam depth sounders) to determine site bathymetry and elevations/seafloor morphology;
- Seafloor imaging (side-scan sonar surveys) for seabed sediment classification purposes to identify natural and man-made acoustic targets resting on the bottom as well as any anomalous features;
- Shallow-penetration Sub-bottom profiling surveys to map the near surface stratigraphy (0 m to 10 m below seabed); and
- Medium penetration sub-bottom profiling (0 m to 70 m below seabed)

When underway, HRG survey operations will be conducted 24-hours per day, although some vessels may only operate during daylight hours (12-hour survey days). To provide survey flexibility, specific locations and vessel numbers to be utilized for such surveys will be determined at the time of contractor selection.

The mitigation procedures outlined in this section have evolved from protocols and procedures that have been previously implemented for similar offshore wind projects HRG surveys within the Lease Area and approved by NMFS. Unless otherwise specified, the following mitigation measures apply to HRG survey activities for this Project. The mitigation and monitoring for HRG surveys apply only to sound sources with operating frequencies below 180 kHz. There are no mitigation or monitoring protocols required for sources operating >180 kHz.

5.1 HRG Survey Monitoring and Mitigation Zones

The monitoring and mitigation zones established in ITAs, lease conditions, and best practices are provided in **Table 2** and displayed in **Figure 2**.

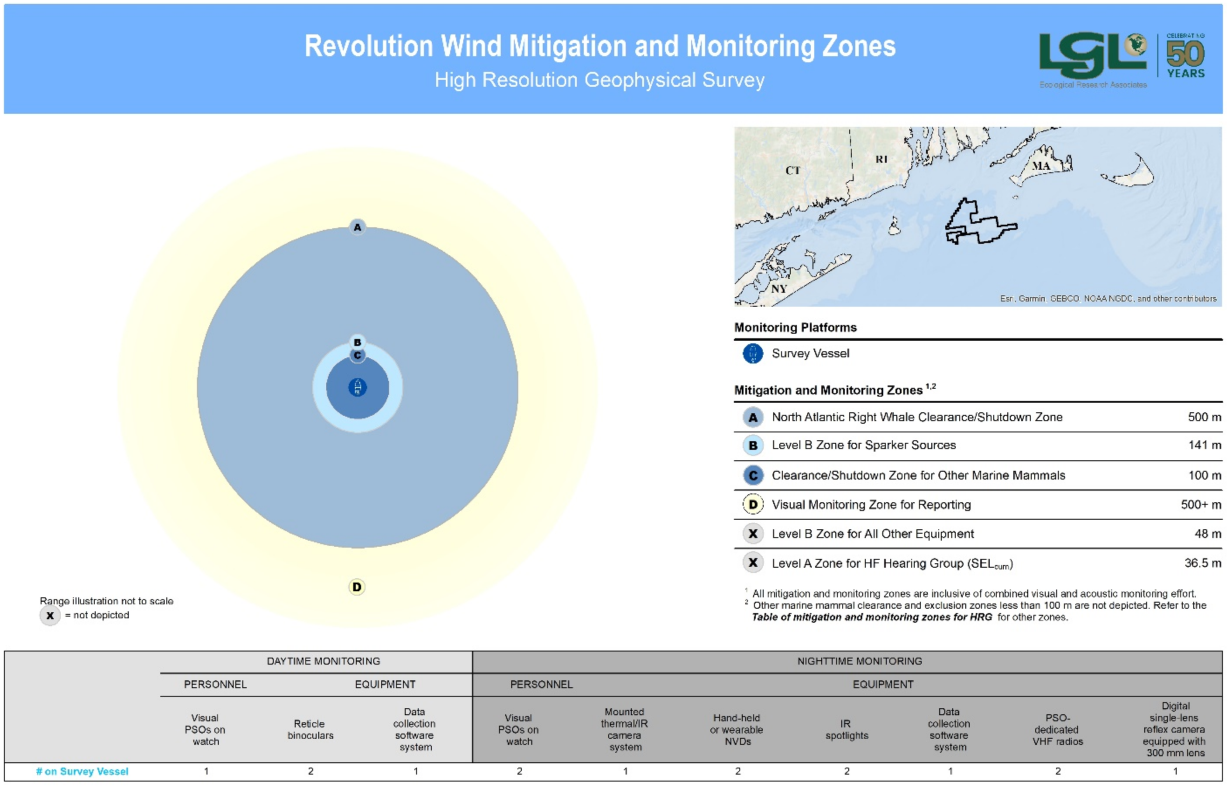
Table 2: Standard monitoring and mitigation zones established for HRG survey activities.

Species	Level A Zone (SEL) (m)	Level A Zone (PK) (m)	Level B Monitoring Zone, Boomers/Sparkers (m)	Level B Monitoring Zone, all other equipment (m)	Pre-start Clearance Zone[1] (m)	Shutdown Zone (m)	Vessel Separation Distance (m)
Low-Frequency Cetaceans							
Fin whale*	1.5	<1	141	48	100	100	100
Minke whale	1.5	<1			100	100	100
Sei whale*	1.5	<1			100	100	100
Humpback whale	1.5	<1			100	100	100
North Atlantic right whale*	1.5	<1			500	500	500
Blue whale*	1.5	<1			100	100	100
Medium-Frequency Cetaceans							
Sperm whale*	<1	<1	141	48	100	100	100
Atlantic white sided dolphin	<1	<1			100	--	50
Atlantic spotted dolphin	<1	<1			100	--	50
Short-beaked common dolphin	<1	<1			100	--	50
Risso's dolphin	<1	<1			100	100	50
Bottlenose dolphin, offshore	<1	<1			100	--	50
Long-finned pilot whale	<1	<1			100	100	50
Short-finned pilot whale	<1	<1			100	100	50
High-Frequency Cetaceans							
Harbor porpoise	36.5	4.7	141	48	100	100	50
Pinnipeds in Water							
Gray seal	<1	<1	141	48	100	100	50
Harbor seal	<1	<1			100	100	50

* = denotes species listed under the Endangered Species Act; SEL = sound exposure level in units of decibels referenced to 1 micropascal squared second PK = peak sound pressure level in units of decibels referenced to 1 micropascal.

[1] Pre-start clearance zones for ESA-listed species may change based on the final Biological Opinion.

A dash “-“ means no shutdown zone mitigation measures will be applied.



Monitoring Platforms

Survey Vessel

Mitigation and Monitoring Zones [1,2]

A	North Atlantic Right Whale Clearance/Shutdown Zone	500 m
B	Level B Zone for Sparker Sources	141 m
C	Clearance/Shutdown Zone for Other Marine Mammals	100 m
D	Visual Monitoring Zone for Reporting	500+ m
X	Level B Zone for All Other Equipment	48 m
X	Level A Zone for HF Hearing Group (SEL_{cum})	36.5 m

[1] All mitigation and monitoring zones are inclusive of combined visual and acoustic monitoring effort.
[2] Other marine mammal clearance and exclusion zones less than 100 m are not depicted. Refer to the ***Table of mitigation and monitoring zones for HRG*** for other zones.

	DAYTIME MONITORING			NIGHTTIME MONITORING						
	PERSONNEL	EQUIPMENT		PERSONNEL	EQUIPMENT					
	Visual PSOs on watch	Reticle binoculars	Data collection software system	Visual PSOs on watch	Mounted thermal/IR camera system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Survey Vessel	1	2	1	2	1	2	2	1	2	1

Figure 2: Marine Mammal Mitigation and Monitoring Zones for HRG Surveys.

Note to Figure: All large whales have a shutdown zone of 100 m except the NARW, which has a 500-m shutdown zone. Sperm whales, Risso's dolphins, and pilot whales have a 100-m shutdown zone, but there is no shutdown zone for other delphinids.

5.2 HRG Survey Monitoring and Mitigation Protocols

HRG surveys using sound sources that require mitigation per the BOEM Lease (below 180 kHz) are subject to the mitigation and monitoring protocols described in the following subsections.

There will be four to six visual PSOs on all 24-hr survey vessels, and two to three visual PSOs on all 12-hour survey vessels[4]. **Table 3** provides the list of the personnel on watch and monitoring equipment available onboard each HRG survey vessel.

Table 3: Personnel and equipment compliment for monitoring vessels during HRG surveys.

Item	# on Survey Vessel
PSOs on watch (Daytime)	1
PSOs on watch (Nighttime)	2
Reticle binoculars	2
Mounted thermal/IR camera system	1
Hand-held or wearable NVD	2

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[4] A 24-hour vessel is considered any vessel expected to conduct operations after daylight hours; a 12-hour vessel is considered a vessel that conducts operations during daylight hours only.

IR spotlights	2
Data collection software system	1
PSO-dedicated VHF radios	2
Digital single-lens reflex camera equipped with 300-mm lens	1

IR = infrared; NVD = night vision devices; PSO = protected species observer; VHF = very high frequency.

5.2.1 Visual Observation Protocols and Methods

The following visual observation protocols will be implemented by all PSOs employed on Project vessels:

- Visual monitoring of the established CZs and SZs and monitoring zone will be performed by PSO teams on each survey vessel.
- Observations will take place from the highest available vantage point on all the survey vessels. General 360° scanning will occur during the monitoring periods, and target scanning by the PSO will occur if cued to a marine mammal. PSOs will adjust their positions appropriately to ensure adequate coverage of the entire shutdown and monitoring zones around the respective sound sources.
- PSOs will work in shifts such that no one PSO will work more than 4 consecutive hours without a 2-hour break or longer than 12 hours during any 24-hour period.
- The PSOs will begin observation of the CZs prior to initiation of HRG survey operations and will continue observation of the SZs throughout the survey activity and for 30 minutes following cessation of the survey activity using equipment operating below 180 kHz.
- The PSOs will be responsible for visually monitoring and identifying marine mammals approaching or entering the established zones during survey activities.
- It will be the responsibility of the PSO(s) on duty to communicate the presence of marine mammals as well as to communicate the recommended mitigation action(s) that are necessary to ensure mitigation and monitoring requirements are implemented as appropriate.

5.2.1.1 Daytime Visual

The following protocols will be applied to visual monitoring during daytime surveys:

- One PSO on watch during pre-clearance periods and all source operations.
- PSOs will use reticle binoculars and naked eye to scan the monitoring zone for marine mammals.

5.2.1.2 Nighttime and Low Visibility Visual Observations

Visual monitoring during nighttime surveys or periods of low visibility will utilize the following protocols:

- The lead PSO will determine if conditions warrant implementing reduced visibility protocols.
- Two PSOs on watch during pre-clearance periods, all operations, and for 30 minutes following use of HRG sources operating below 180 kHz.

- Each PSO should use the most appropriate available technology (e.g., IR camera and NVD) and viewing locations to monitor the CZs and SZs and maintain vessel separation distances.

5.2.1.3 ASV Operations

Should an ASV be utilized during surveys, the following procedures will be implemented:

- PSOs will be stationed aboard the mother vessel to monitor the ASV in a location which will offer a clear, unobstructed view of the ASV’s shutdown and monitoring zones.
- When in use, the ASV will be within 800 m (2,625 ft) of the primary vessel while conducting survey operations.
- For monitoring around an ASV, if utilized, a dual thermal/high definition (HD) camera will be installed on the mother vessel facing forward and angled in a direction so as to provide a field of view ahead of the vessel and around the ASV.
- PSOs will be able to monitor the real-time output of the camera on hand-held iPads or tables. Images from the cameras can be captured for review and to assist it verifying species identification.
- A monitor will also be installed on the bridge displaying the real-time picture from the thermal/HD camera installed on the front of the ASV itself, providing an additional forward field of view of the craft.
- Night-vision goggles with thermal clip-ons, as mentioned above, and a hand-held spotlight will be provided such that PSOs can focus observations in any direction around the mother vessel and/or the ASV.

5.2.2 Pre-Start Clearance

- PSOs will implement a 30-minute clearance period of the CZs immediately prior to the initiation of equipment ramp-up.
- The CZs must be visible using the naked eye or appropriate visual technology during the entire clearance period for operations to start. If the CZs are not visible, source operations <180 kHz may not commence.
- Ramp-up may not be initiated if any marine mammal(s) is detected within its respective CZ.
- If a marine mammal is observed within its respective CZ during the pre-start clearance period, ramp-up may not begin until the animal(s) has been observed exiting its respective CZ or until an additional time period has elapsed with no further sighting (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

5.2.3 Ramp-up

- Where technically feasible, a ramp-up procedure will be used for HRG survey equipment capable of adjusting energy levels at the start or re-start of HRG survey activities. Ramp-up procedures provide additional protection to marine mammals near the Project Area by allowing them to vacate the area prior to the commencement of survey equipment use at full power.
- The ramp-up procedure will not be initiated during periods of inclement conditions or if the CZs cannot be adequately monitored by the PSOs, using the appropriate visual technology for a 30-minute period immediately prior to ramp up.

- Ramp-up will begin with the power of the smallest acoustic equipment at its lowest practical power output. When technically feasible the power will then be gradually turned up and other acoustic sources added in a way such that the source level would increase gradually.
- Ramp-up activities will be delayed if a marine mammal(s) enters its respective CZ. Ramp-up will continue if the animal has been observed exiting its respective CZ or until an additional time period has elapsed with no further sighting (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

5.2.4 Operations Monitoring

- PSOs will monitor Mysticetus (or similar data system) and/or appropriate data systems for DMAs established within their survey area.
- PSOs will also monitor the NMFS NARW reporting systems including Whale Alert and RWSAS once every PSO shift during Project-related activities within, or adjacent to, SMAs and/or DMAs.

5.2.5 Shutdown Protocols

- An immediate shutdown of the applicable HRG survey equipment (i.e., select sources operating at frequencies <180 kHz) will be required if a marine mammal is sighted at the perimeter of or within its respective SZ.
- The vessel operator must comply immediately with any call for shutdown by the Lead PSO. Any disagreement between the Lead PSO and vessel operator should be discussed only after shutdown has occurred.
- Subsequent restart of the survey equipment will not be initiated until either the marine mammal(s) that triggered the shutdown has voluntarily left and been visually confirmed beyond the relevant clearance zone, or when 30 minutes have elapsed without re-detection (for mysticetes, sperm whales, Risso's dolphins and pilot, whales) or 15 minutes have elapsed without re-detection (for all other marine mammals).

5.2.6 Pauses And Silent Periods

- If the acoustic source is shut down for reasons other than mitigation (e.g., mechanical difficulty) for less than 30 minutes, it may be activated again without ramp-up if PSOs have maintained constant observation and no detections of any marine mammal have occurred within the respective SZs.
- If the acoustic source is shut down for a period longer than 30 minutes or PSOs were unable to maintain constant observation, then pre-start clearance and ramp-up procedures will be initiated as described in **Section 5.2.2 and 5.2.3**.

5.2.7 Vessel Strike Avoidance

- The Project will follow vessel strike avoidance measures outlined previously in the *Vessel Strike Avoidance Policy* section (**Section 3.9**).

5.2.7.1 Vessel Speed Restrictions

- The Project will follow vessel strike avoidance measures outlined previously in the *Vessel Strike Avoidance Policy* section (**Section 3.9**).

5.2.8 Data Recording

- All data recording will be conducted using Mysticetus or similar software.
- Operations, monitoring conditions, observation effort, all marine mammal detections, and any mitigation actions.
- Members of the monitoring team must consult NMFS' NARW reporting systems for the presence of NARWs in the Project Area as previously described.

5.3 HRG Survey Reporting

- The Project will follow reporting measures as described in **Section 3.7 and Attachment 8**.

5.3.1 DMAs

- DMAs will be reported across all vessels.

5.3.2 Injured and Dead Protected Species

- The Project will follow reporting measures as described in **Section 3.7 and Attachment 8.**

6 Mitigation and Monitoring Plan for UXO detonation

6.1 Mitigation and Monitoring Zones

Mitigation zones for UXO detonation presented here are based on the results of underwater sound propagation modeling specialized for this noise source (Hannay and Zykov 2021). Modeling was undertaken to estimate the threshold distances for onset of TTS and PTS for all functional hearing groups of marine mammals using the frequency-weighted SEL metric, for a selection of charge weights spanning all potential UXO types that may be encountered. Non-auditory injury (mortality and slight lung injury) threshold distances were modeled using the peak pressure (PK) metric, for five species groups based on body mass. The modeling for this assessment used criteria for charge weights based on definitions created by the U.S. Navy (DoN (U.S. Department of the Navy) 2017), which classified weapons and munitions into five bins based on similar characteristics and charge weight equivalent to trinitrotoluene, more commonly known as TNT. The charge weight bins were categorized and labeled as follows (2.3 kg [E4]; 9.1 kg [E6]; 45.5 kg [E8]; 227 kg [E10]; 454 kg [E12]). In this location, sound speed profiles change little with depth, so these environments do not have strong seasonal dependence. The propagation modeling was performed using a sound speed profile representative of September, which is slightly downward refracting and therefore conservative, and also represents the most likely time of year for UXO removal activities (Hannay and Zykov 2021). No UXO detonations are planned from December through April.

All mitigation and monitoring zones assume the use of an NAS resulting in a 10 dB reduction of noise levels. Mitigation and monitoring zones specific to marine mammal hearing groups for the five different charge weight bins are presented in Table 4**.** The full suite of threshold distances for non-auditory injury (impulse metric), as well as PTS and TTS (PK and SEL metrics) are presented in Hannay and Zykov (2021). Non-auditory injury and PTS are considered Level A harassment, and TTS is considered Level B harassment. Because Revolution Wind has committed to no more than a single detonation event in any given 24-hour period, no behavioral harassment is anticipated (Hannay and Zykov 2021). Four different sites (S1–S4; two within shallow depths along the export cable route and two from inside the lease area) ranging from 12-45 m water depth were chosen to model the threshold distances for each of the five bins. PTS and TTS distances were calculated for each charge weight bin (E4–E12) and mitigation and monitoring zones were determined by selecting the largest distance to the respective thresholds from across each of the four sites.

Table 4: Mitigation and Monitoring Zones Associated with UXO Detonation of Binned Charge Weights, with a 10 dB Noise Mitigation System.

Species	UXO Charge Weight[1]									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Pre-Start Clearance Zone[2] (m)	Level B Monitoring Zone[3] (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)
Low-Frequency Cetaceans										
Fin whale*	560	280	1,000	440	1,750	750	3,000	1,300	8,800	3,800
Minke whale										
Sei whale*										
Humpback whale										
NARW*										
Blue whale*										
Mid-Frequency Cetaceans										
Sperm whale*	50	90	80	140	760	230	350	390	470	500
Atlantic white-sided dolphin										
Atlantic spotted dolphin										
Short-beaked common dolphin										
Risso's dolphin										
Bottlenose dolphin, offshore										
Long-finned pilot whale										
Short-finned pilot whale										
High-Frequency Cetaceans										
Harbor porpoise	1,850	950	2,600	1,500	3,900	4,850	5,400	8,250	6,200	10,400
Phocid Pinnipeds										
Gray seal	190	160	460	260	700	450	1,220	750	1,600	950
Harbor seal										

* = denotes species listed under the Endangered Species Act; m = meters;

[1] UXO charge weights are groups of similar munitions defined by the U.S. Navy and binned into five categories (E4-E12) by weight (equivalent weight in TNT). For this assessment, four project sites (S1-S4) were chosen and modeled (see (Hannay and Zykov 2021), **Appendix B**) for the detonation of each charge weight bin.

[2] Pre-start clearance zones were determined by selecting the largest distance to a Level A threshold (the larger of either the PK or SEL noise metric). The chosen values were the most conservative per charge weight bin across each of the four modeled sites.

[3] Level B monitoring zones were determined by selecting the largest distance to the TTS threshold (the larger of either the PK or SEL noise metric). The chosen values were the most conservative per charge weight bin across each of the four modeled sites.

Table 5: Mitigation and Monitoring Zones Associated with Unmitigated UXO Detonation of Binned Charge Weights.

Species	UXO Charge Weight[1]									
	E4 (2.3 kg)		E6 (9.1 kg)		E8 (45.5 kg)		E10 (227 kg)		E12 (454 kg)	
	Pre-Start Clearance Zone[2] (m)	Level B Monitoring Zone[3] (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)	Pre-Start Clearance Zone (m)	Level B Monitoring Zone (m)
Low-Frequency Cetaceans										
Fin whale*	1,710	7,340	2,810	10,300	4,880	13,900	7,520	17,500	8,800	19,300
Minke whale										
Sei whale*										
Humpback whale										
NARW*										
Blue whale*										
Mid-Frequency Cetaceans										
Sperm whale*	214	1,520	385	2,290	714	3,490	1,220	5,040	1,540	5,860
Atlantic white-sided dolphin										
Atlantic spotted dolphin										
Short-beaked common dolphin										
Risso's dolphin										
Bottlenose dolphin, offshore										
Long-finned pilot whale										
Short-finned pilot whale										
High-Frequency Cetaceans										
Harbor porpoise	4,300	11,200	5,750	13,400	7,810	16,000	12,775	19,100	16,098	20,200
Phocid Pinnipeds										
Gray seal	804	4,200	1,310	6,200	2,190	9,060	3,740	12,000	4,520	13,300
Harbor seal										

* = denotes species listed under the Endangered Species Act; m = meters;

[1] UXO charge weights are groups of similar munitions defined by the U.S. Navy and binned into five categories (E4-E12) by weight (equivalent weight in TNT). For this assessment, four project sites (S1-S4) were chosen and modeled (see (Hannay and Zykov 2021), **Appendix B**) for the detonation of each charge weight bin.

[2] Pre-start clearance zones were determined by selecting the largest distance to a Level A threshold (the larger of either the PK or SEL noise metric). The chosen values were the most conservative per charge weight bin across each of the four modeled sites.

[3] Level B monitoring zones were determined by selecting the largest distance to the TTS threshold (the larger of either the PK or SEL noise metric). The chosen values were the most conservative per charge weight bin across each of the four modeled sites.

6.2 UXO Monitoring and Mitigation Protocols

There are six primary mitigation and monitoring efforts associated with UXO detonation:

1. Pre-start clearance;
    a) Vessel-based visual PSOs and associated visual monitoring tools stationed on the primary monitoring vessel and on any additional marine mammal monitoring vessels (when monitoring zones with radii greater than 2,000 m may require an additional monitoring vessel);
    b) Alternate Plan for clearance zones >5 km associated with unmitigated detonation: Aerial-based visual observers conducting pre-start surveys of the clearance zone.
2. PAM operators and an associated mitigation PAM array in support of the visual PSOs;
3. NMSs as feasible;
4. Post-detonation monitoring;
5. Acoustic measurement data collection to verify distances to regulatory or mitigation zones; and
6. Monitoring and mitigation protocols applicable to UXO detonation are described further in the following subsections.

There will be a team of 6 - 8 visual and acoustic PSOs on monitoring vessels**.** The number of vessels will depend on the size of the zones to be monitored. A single vessel is anticipated to adequately cover a radius of 2,000 m. There will be a team of four to eight visual and acoustic PSOs on each monitoring vessel. The number of vessels will be sufficient to observe the maximum clearance zones 100% of the time and be determined by:

- the detonation category and associated clearance zone size,
- use of NMS (as feasible), and
- minimum distance allowed to the detonation location.

PAM operators may be located remotely/onshore**.** Error! Reference source not found. provides the list of the personnel on watch and the PSO and PAM monitoring equipment available onboard the primary vessel and the additional vessel.

Table 6: Personnel and Equipment Use for all Marine Mammal Monitoring Vessels during Pre-start Clearance and Post-detonation Monitoring.

Item	**Standard Daytime**	**Monitoring for Nighttime and Low Visibility**
	Number on each PSO Vessel	N/A
Visual PSOs on watch	2	
PAM operators on duty[1]	1	
Reticle binoculars	2	
Mounted “big-eye” binocular	1	
Monitoring station for real time PAM system[2]	1	
Data collection software system	1	
PSO-dedicated VHF radios	2	
Digital single-lens reflex camera equipped with 300-mm lens	1	

PSO = protected species observer; VHF=very high frequency.

[1] The selected PAM system will transmit real time data to PAM monitoring stations on the vessels and/or a shore side monitoring station.

6.2.1 Visual Monitoring: Vessel

Visual monitoring will be conducted from the primary monitoring vessel, and additional vessels in cases where the mitigation zone cannot be covered by a single vessel. Daytime visual monitoring is defined by the period between civil nautical twilight rise and set for the region. The intent of the visual monitoring program is to provide complete visual coverage of the UXO clearance zones using the following protocols:

- During the pre-start clearance period and 60-minutes after the detonation event, two PSOs will maintain watch at all times on the primary vessel; likewise, two PSOs will also maintain watch during the same time periods from the additional vessel. During the pre-start clearance period and 60-minutes after the detonation event, two PSOs will maintain watch at all times on the primary vessel; likewise, two PSOs will also maintain watch during the same time periods from the additional vessel.
- The total number of observers will be dictated by the personnel necessary to adhere to standard shift schedule and rest requirements while still meeting mitigation monitoring requirements for the Project. A sample crew rotation is provided in Attachment 2.
- During daytime observations, two PSOs on each vessel will monitor the clearance zones with the naked eye and reticle binoculars. One PSO will periodically scan outside the clearance zones using the mounted big eye binoculars.
- PSOs will visually monitor the maximum Low Frequency (Large Whale) Level A zone which constitutes the pre-start clearance zone. This zone encompasses the maximum Level A exposure ranges for all marine mammal species except harbor porpoise, where Level A take has been requested due to the large zone sizes associated with High Frequency cetaceans.
- The number of vessels deployed will depend on monitoring zone size and safety set back distance from detonation. A sufficient number of vessels will be deployed to provide 100% temporal and spatial coverage of the clearance zones.
- There will be a PAM operator on duty (see Section 6.2.3) conducting acoustic monitoring in coordination with the visual PSOs during all pre-start clearance periods and post-detonation monitoring periods.
- Acoustic monitoring, as described in Section 6.2.3, will include, and extend beyond, the Large Whale pre-start clearance zone.

6.2.2 Visual Monitoring: Aerial Alternative

Aerial surveys are typically limited by low cloud ceilings, aircraft availability, survey duration, and HSE considerations and therefore are not considered feasible or practical for all detonation monitoring. However, some scenarios may necessitate the use of an aerial platform. For unmitigated detonations with clearance zones greater than 5 km, deployment of sufficient vessels may not be feasible or practical. For these events, visual monitoring will be conducted from an aerial platform. The intent of the aerial visual monitoring is to provide complete visual coverage of the UXO clearance zones using the following protocols:

- During the pre-start clearance period and 60-minutes after the detonation event as flight time allows, two PSOs will be deployed on an aerial platform.

- Surveys will be conducted in a grid with 1 km line spacing, encompassing the clearance zone.
- PSOs will monitor the clearance zones with the naked eye and reticle binoculars.
- Aerial PSOs may exceed 4-hour watch duration but will be limited by total flight duration not likely to exceed 6 hours.
- PSOs will visually monitor the maximum Low-Frequency (Large Whale) Level A zone which constitutes the pre-start clearance zone. This zone encompasses the maximum Level A exposure ranges for all marine mammal species except harbor porpoise, where Level A take has been requested due to the large zone sizes associated with High-Frequency cetaceans.
- There will be a PAM operator on duty (see Section **Error! Reference source not found.**) conducting acoustic monitoring in coordination with the visual PSOs during all pre-start clearance periods and post-detonation monitoring periods.
- Acoustic monitoring, as described in Section 6.1.3, will include, and extend beyond, the Large Whale Pre-Start Clearance Zone.

6.2.3 Passive Acoustic Monitoring

Acoustic monitoring will be conducted prior to any UXO detonation event in addition to visual monitoring in order to ensure that no marine mammals are present in the designated pre-clearance zones. PAM operators will acoustically monitor a zone that encompasses a minimum of 10 km radius around the source. PAM will be conducted in the daylight only as no UXO will be detonated during nighttime hours.

PAM devices proposed for monitoring during UXO detonation activities are not likely to be towed from the vessel, but rather will be independent (e.g., autonomous or moored remote) stations located around the area to be monitored. The specific placement of PAM devices or systems will be determined based on the final mitigation zones determined in the regulatory review process. As detailed in Attachment 4**,** there are multiple available PAM systems with demonstrated capability for monitoring and localizing marine mammal calls, including large whales, within the proposed monitoring and mitigation zones (e.g., sonobuoy arrays or similar retrievable buoy systems).

The following PAM protocols will be followed for UXO detonation events:

- It is expected there will be a PAM operator stationed on at least one of the dedicated monitoring vessels in addition to the PSOs; or located remotely/onshore.
- PAM operators will complete specialized training for operating PAM systems prior to the start of monitoring activities.
- All on-duty PSOs will be in contact with the PAM operator on-duty, who will monitor the PAM systems for acoustic detections of marine mammals that are vocalizing in the area.
- For real-time PAM systems, at least one PAM operator will be designated to monitor each system by viewing data or data products that are streamed in real-time or near real-time to a computer workstation and monitor located on a Project vessel or onshore. No archival recording systems will be used.
- The PAM operator will inform the Lead PSO on duty of animal detections approaching or within applicable ranges of interest to the detonation activity via the data collection software system (i.e., Mysticetus or similar system). The Lead PSO will be responsible for requesting the designated crewmember to implement a delay in UXO detonation.

6.2.4 Pre-Start Clearance

A 60-min pre-start clearance period will be implemented prior to any UXO detonation. Visual PSOs will begin surveying the monitoring zone at least 60 min prior to the detonation event. PAM will also begin 60 min prior to the detonation event.

- The Large Whale clearance zone (See distances to low-frequency cetacean thresholds in **Table 4 and Table 5)** must be fully visible for at least 60 min immediately prior to commencing detonation.
- All marine mammals must be confirmed to be out of the clearance zone prior to initiating detonation.
- If a marine mammal is observed entering or within the relevant clearance zones prior to the initiation of detonation activity, the detonation must be delayed.
- The detonation may commence when either the marine mammal(s) has voluntarily left the respective clearance zone and been visually confirmed beyond that clearance zone, or, when 60 min have elapsed without redetection for whales, including the NARW, or 15 min have elapsed without redetection of dolphins, porpoises, and seals.

6.2.5 Data Recording

- All data recording will be conducted using Mysticetus or similar software.
- Operations, monitoring conditions, observation effort, all marine mammal detections, any mitigation actions, as well as any other reporting requirements prescribed by NMFS will be recorded.
- Members of the monitoring team must consult NMFS' NARW reporting systems for presence of NARWs in the Project area.

6.3 UXO Detonation Reporting

- Revolution Wind will follow reporting measures as stipulated in **Section 3.7 and Attachment 8**

6.3.1 Injured and Dead protected species

- Revolution Wind will follow reporting measures as stipulated in **Section 3.7 and Attachment 8**

6.4 Noise Attenuation for UXO Detonation

- As feasible, Revolution Wind will use a NAS for all detonation events and is committed to achieving the modeled ranges associated with 10 dB of noise attenuation (see ITA application **Section 6.3.2**). If a NAS system is not feasible, Revolution Wind will implement mitigation measures for the larger unmitigated zone sizes, with deployment of vessels or use of an aerial platform adequate to cover the entire clearance zones.

6.5 Sound Measurements during UXO Detonations

Received sound measurements will be collected during UXO detonations. The measurement plan will be similar to that described for impact pile driving provided in **Attachment 7**, which is designed to collect data on approximate source levels, the directionality of the sounds produced, and transmission loss in at least one direction. The distances at which acoustic recorders are placed from the UXO detonation will be determined based on the modeled distances to Level A and Level B thresholds for the applicable UXO size being detonated.

- The goals of the field verification measurements include: verification of modeled ranges to the Level A harassment and Level B harassment isopleths and providing sound measurements of UXO detonations using International Organization for Standardization (ISO)-standard methodology (ISO 2017) for comparison among projects and informing future operations.

7 Construction Monitoring and Mitigation Plan for Impact Pile Driving

Up to 100 wind turbine generators (WTG) and up to two (2) offshore substations (OSS) will be installed on monopile foundations using impact pile driving. Each WTG foundation will have a maximum diameter of 12 m, while OSS foundations will include a maximum diameter of 15 m. Impact pile driving for both the WTG foundations and the OSS foundations will take approximately 1-4 hours (6 to 12 hours maximum) to install a single monopile foundation. After completion of the pile-driving activities for each foundation, the installation vessel will move to the next position and a secondary vessel will complete installation (i.e., attachment of external and internal platforms, commissioning, etc.).

Monitoring and mitigation zones are based on the results of underwater sound propagation modeling, which took seasonal sound speed profiles into account and defined summer as May through November, and winter as December through April (See Appendix A). No impact pile driving is planned for the months of January through April.

7.1 Impact Pile Driving Monitoring and Mitigation Zones

Mitigation and monitoring zones for Level A harassment are based on modeled, species-specific exposure ranges. The maximum exposure range was chosen for any piling scenario in a given season (summer and winter). The Level B acoustic ranges, which will be applied to all marine mammal species, are based on the R95% acoustic range for any piling scenario in the given season (unweighted R95% 160 dB threshold). The Level A exposure and acoustic ranges and Level B acoustic ranges along with the summer mitigation zones for both WTG and OSS foundations are provided in **Table 7** and **Table 9** and displayed in **Figure 3** and **Figure 5**. The corresponding zones for winter are provided in **Table 8** and **Table 10** and displayed in **Figure 4** and **Figure 6**. These zones and ranges are based on the modeled monopile installation for both seasonal periods (Küsel et al. 2021) and assume 10 dB broadband noise attenuation. Mitigation zones established for all species, including NARW (See **Table 11**), will be applied accordingly depending on the month in which work is performed. Level A and Level B harassment zones implemented during the Project may be modified in consultation with and approval by NMFS, based on measurements of the received sound levels during piling operations. The sound field measurement plan is described in **Attachment 7**.

To calculate the Level B monitoring zones for WTG and OSS monopile foundations for all marine mammals in summer (May through November), the unweighted flat R95% 160 dB value each foundation type with a hammer energy of 4000 kJ (3.88 km and 4.1 km for WTG and OSS foundations respectively see Table H-1 and H-2 in Appendix A) was selected. The same method was used to calculate the Level B monitoring zone for winter (December only) (4.271 km and 4.698 for WTG and OSS foundations respectively see Tables H-3 and H-4 in Appendix A). Mitigation and monitoring zones for Level A harassment for WTG foundations assume three monopiles driven per day, and OSS foundations assume one monopile per day. The pre-start clearance zones for large whales, porpoise, and seals are based upon the maximum non-humpback whale Level A zone for each hearing group. The North Atlantic right whale (NARW) zone was set equal to the Level B zone to avoid any unnecessary take (Tables 7-11). The shutdown zones for large whales, NARW, porpoise, and seals are based upon the maximum non-humpback Level A zone for each hearing group.

Table 7: Threshold ranges and mitigation and monitoring zones[1] [2] during WTG impact pile driving in Summer (May through November).

Species	Level A Zone (m) (SEL_{cum})[3]	Level A Zone (m) (SPL_{pk})	Monitoring and mitigation zones in meters (m)[2]			Vessel Separation Distance (m)
			Level B Zone	Monitoring Zone	Pre-start Clearance and Shutdown Zone[4]	
Low-frequency Cetaceans						
Fin whale*	2,230	≤10	3,833	>3,900	2,300	100
Minke whale	1,510	≤10	3,833	>3,900	2,300	100
Sei whale*	1,810	≤10	3,833	>3,900	2,300	100
Humpback whale	2,660	≤10	3,833	>3,900	2,300	100
North Atlantic right whale*	1,930	≤10	3,833	See Table 11	See Table 11	500
Blue whale*[6]	2,230	≤10	3,833	>3,900	2,300	100
Mid-frequency Cetaceans						
Sperm whale*	-	≤10	3,833	>3,900	2,300	100
Atlantic spotted dolphin	-	≤10	3,833	>3,900	NAS[7]	50
Atlantic white-sided dolphin	-	≤10	3,833	>3,900	NAS	50
Common dolphin	-	≤10	3,833	>3,900	NAS	50
Risso's dolphin	10	≤10	3,833	>3,900	NAS	50
Bottlenose dolphin	-	≤10	3,833	>3,900	NAS	50
Long-finned pilot whale	-	≤10	3,833	>3,900	NAS	50
High-frequency Cetaceans						
Harbor porpoise	1,340	160	3,833	>3,900	1,400	50
Phocid Pinnipeds in Water						
Gray seal	440	≤10	3,833	>3,900	500	50
Harbor seal	240	≤10	3,833	>3,900	500	50

* = denotes species listed under the Endangered Species Act; dB = decibel; SEL_{cum} = cumulative sound exposure level SPL_{pk} = peak sound pressure level. NAS= Noise Attenuation System.

[1] Zones are based upon the following modeling assumptions:

8/12-m monopile installation with10 dB broadband noise attenuation from a noise mitigation system.

three monopiles driven per day

[2] Zone monitoring will be achieved through a combined effort of passive acoustic monitoring and visual observation.

[3] The Level A zone represents the exposure ranges of species derived from animal movement modeling.

[4] The pre-start clearance zone for large whales, porpoise, and seals is based upon the maximum non-humpback whale Level A zone rounded up for PSO clarity. The North Atlantic right whale zone was set equal to the Level B zone to avoid any unnecessary take;

[5] The shutdown zone for large whales (including North Atlantic right whale), porpoise, and seals is based upon the maximum Level A zone and rounded up for PSO clarity.

[6] No Level A exposures were calculated for blue whales resulting in no expected Level A exposure range; therefore, the exposure range for fin whales was used as a proxy due to similarities in species.

[7] Noise attenuation systems (NAS) are employed during pile driving activities to reduce the sound pressure levels that are transmitted through the water in an effort to reduce ranges to acoustic thresholds and minimize acoustic impacts resulting from pile driving activities.

Table 8: Threshold ranges and mitigation and monitoring zones[1] [2] during WTG impact pile driving in Winter (December only).

Species	Level A Zone (m) (SEL$_{\text{cum}}$)[3]	Level A Zone (m) (SPL$_{\text{pk}}$)	Monitoring and mitigation zones in meters (m)[2]			Vessel Separation Distance (m)
			Level B Zone	Monitoring Zone	Pre-start Clearance and Shutdown Zone[4]	
Low-frequency Cetaceans						
Fin whale*	4,380	≤10	4,271	>4,400	4,400	100
Minke whale	3,450	≤10	4,271	>4,400	4,400	100
Sei whale*	3,670	≤10	4,271	>4,400	4,400	100
Humpback whale	6,290	≤10	4,271	>4,400	4,400	100
North Atlantic right whale*	3,970	≤10	4,271	See Table 11	See Table 11	500
Blue whale*[6]	4,380	≤10	4,271	>4,400	4,400	100
Mid-frequency Cetaceans						
Sperm whale*	-	≤10	4,271	>4,400	4,400	100
Atlantic spotted dolphin	-	≤10	4,271	>4,400	NAS[7]	50
Atlantic white-sided dolphin	-	≤10	4,271	>4,400	NAS	50
Common dolphin	-	≤10	4,271	>4,400	NAS	50
Risso's dolphin	-	≤10	4,271	>4,400	NAS	50
Bottlenose dolphin	-	≤10	4,271	>4,400	NAS	50
Long-finned pilot whale	-	≤10	4,271	>4,400	NAS	50
High-frequency Cetaceans						
Harbor porpoise	2,330	160	4,271	>4,400	2,400	50
Phocid Pinnipeds in Water						
Gray seal	810	≤10	4,271	>4,400	900	50
Harbor seal	500	≤10	4,271	>4,400	900	50

* = denotes species listed under the Endangered Species Act; SELcum = cumulative sound exposure level; SPLpk = peak sound pressure level; NAS = noise attenuation system (i.e., the physical placement of the bubble curtain will preclude take in cases where the Level A zone is smaller than the distance of the NMS from the pile).

[1] Zones are based upon the following modeling assumptions (see Appendix A for details):

- 7/12-m (tapered) monopile with 10 dB broadband sound attenuation.

  Three monopiles driven per day

When modeled injury (Level A) threshold distances differed among these scenarios, the largest for each species group was chosen for conservatism. Likewise, the largest modeled behavioral threshold distance for any was used to calculate the monitored Level B zone for all marine mammal species.

[2] Zone monitoring will be achieved through a combined effort of passive acoustic monitoring and visual observation (but not to monitor vessel separation distance).

[3] The Level A zone represents the exposure ranges of species derived from animal movement modeling.

[4] The pre-start clearance zones for large whales, porpoise, and seals are based upon the maximum non-humpback whale Level A zone for each and rounded up for PSO clarity. The NARW pre-start clearance zone was set equal to the Level B zone to avoid any unnecessary take.

[5] The shutdown zones for large whales (including NARW), porpoise, and seals are based upon the maximum Level A zone for each and rounded up for PSO clarity.

[6] No Level A exposures were calculated for blue whales resulting in no expected Level A exposure range; therefore, the exposure range for fin whales was used as a proxy due to similarities in species.

[7] Noise attenuation systems (NAS) are employed during pile driving activities to reduce the sound pressure levels that are transmitted through the water in an effort to reduce ranges to acoustic thresholds and minimize acoustic impacts resulting from pile driving activities.

Table 9: Threshold ranges and mitigation and monitoring zones during OSS impact pile driving in Summer (May through November).

Species	Level A Zone (m) (SEL_{cum})[3]	Level A Zone (m) (SPL_{pk})	Monitoring and mitigation zones in meters (m)[2]			Vessel Separation Distance (m)
			Level B Zone	Monitoring Zone	Pre-start Clearance and Shutdown Zone[4]	
Low-frequency Cetaceans						
Fin whale*	1,570	≤10	4,100	>4,100	1,600	100
Minke whale	940	≤10	4,100	>4,100	1,600	100
Sei whale*	1,220	≤10	4,100	>4,100	1,600	100
Humpback whale	1,790	≤10	4,100	>4,100	1,600	100
North Atlantic right whale*	1,250	≤10	4,100	See Table 11	See Table 11	500
Blue whale*[6]	1,570	≤10	4,100	>4,100	1,600	100
Mid-frequency Cetaceans						
Sperm whale*	-	≤10	4,100	>4,100	1,600	100
Atlantic spotted dolphin	-	≤10	4,100	>4,100	NAS[7]	50
Atlantic white-sided dolphin	-	≤10	4,100	>4,100	NAS	50
Common dolphin	-	≤10	4,100	>4,100	NAS	50
Risso's dolphin	-	≤10	4,100	>4,100	NAS	50
Bottlenose dolphin	-	≤10	4,100	>4,100	NAS	50
Long-finned pilot whale	-	≤10	4,100	>4,100	NAS	50
High-frequency Cetaceans						
Harbor porpoise	830	110	4,100	>4,100	900	50
Phocid Pinnipeds in Water						
Gray seal	370	≤10	4,100	>4,100	400	50
Harbor seal	10	≤10	4,100	>4,100	400	50

* = denotes species listed under the Endangered Species Act; SELcum = cumulative sound exposure level; SPLpk = peak sound pressure level; NAS = noise attenuation system (i.e., the physical placement of the bubble curtain will preclude take in cases where the Level A zone is smaller than the distance of the NMS from the pile).

[1] Zones are based upon the following modeling assumptions (see Appendix A for details):

- 7/15-m (tapered) monopile with 10 dB broadband sound attenuation.

One monopile driven per day

When modeled injury (Level A) threshold distances differed among these scenarios, the largest for each species group was chosen for conservatism. Likewise, the largest modeled behavioral threshold distance for any was used to calculate the monitored Level B zone for all marine mammal species.

[2] Zone monitoring will be achieved through a combined effort of passive acoustic monitoring and visual observation (but not to monitor vessel separation distance).

[3] The Level A zone represents the exposure ranges of species derived from animal movement modeling.

[4] The pre-start clearance zones for large whales, porpoise, and seals are based upon the maximum non-humpback whale Level A zone for each and rounded up for PSO clarity. The NARW pre-start clearance zone was set equal to the Level B zone to avoid any unnecessary take.

[5] The shutdown zones for large whales (including NARW), porpoise, and seals are based upon the maximum Level A zone for each and rounded up for PSO clarity.

[6] No Level A exposures were calculated for blue whales resulting in no expected Level A exposure range; therefore, the exposure range for fin whales was used as a proxy due to similarities in species.

[7] Noise attenuation systems (NAS) are employed during pile driving activities to reduce the sound pressure levels that are transmitted through the water in an effort to reduce ranges to acoustic thresholds and minimize acoustic impacts resulting from pile driving activities.

Table 10: Threshold ranges and mitigation and monitoring zones during OSS impact pile driving in Winter (December only).

Species	Level A Zone (m) (SEL_{cum})[3]	Level A Zone (m) (SPL_{pk})	Monitoring and mitigation zones in meters (m)[2]			Vessel Separation Distance (m)
			Level B Zone	Monitoring Zone	Pre-start Clearance and Shutdown Zone[4]	
Low-frequency Cetaceans						
Fin whale*	2,680	≤10	4,698	>4,700	2,700	100
Minke whale	1,810	≤10	4,698	>4,700	2,700	100
Sei whale*	2,050	≤10	4,698	>4,700	2,700	100
Humpback whale	3,560	≤10	4,698	>4,700	2,700	100
North Atlantic right whale*	2,660	≤10	4,698	See Table 11	See Table 11	500
Blue whale*[6]	2,680	≤10	4,698	>4,700	2,700	100
Mid-frequency Cetaceans						
Sperm whale*	-	≤10	4,698	>4,700	2,700	100
Atlantic spotted dolphin	-	≤10	4,698	>4,700	NAS[7]	50
Atlantic white-sided dolphin	-	≤10	4,698	>4,700	NAS	50
Common dolphin	-	≤10	4,698	>4,700	NAS	50
Risso's dolphin	-	≤10	4,698	>4,700	NAS	50
Bottlenose dolphin	-	≤10	4,698	>4,700	NAS	50
Long-finned pilot whale	-	≤10	4,698	>4,700	NAS	50
High-frequency Cetaceans						
Harbor porpoise	1,250	80	4,698	>4,700	1,300	50
Phocid Pinnipeds in Water						
Gray seal	370	≤10	4,698	>4,700	400	50
Harbor seal	110	≤10	4,698	>4,700	400	50

* = denotes species listed under the Endangered Species Act; SELcum = cumulative sound exposure level; SPLpk = peak sound pressure level; NAS = noise attenuation system (i.e., the physical placement of the bubble curtain will preclude take in cases where the Level A zone is smaller than the distance of the NMS from the pile).

[1] Zones are based upon the following modeling assumptions (see Appendix A for details):

- 7/15-m (tapered) monopile with 10 dB broadband sound attenuation.

  One monopile driven per day

When modeled injury (Level A) threshold distances differed among these scenarios, the largest for each species group was chosen for conservatism. Likewise, the largest modeled behavioral threshold distance for any was used to calculate the monitored Level B zone for all marine mammal species.

[2] Zone monitoring will be achieved through a combined effort of passive acoustic monitoring and visual observation (but not to monitor vessel separation distance).

[3] The Level A zone represents the exposure ranges of species derived from animal movement modeling.

[4] The pre-start clearance zones for large whales, porpoise, and seals are based upon the maximum non-humpback whale Level A zone for each and rounded up for PSO clarity. The NARW pre-start clearance zone was set equal to the Level B zone to avoid any unnecessary take.

[5] The shutdown zones for large whales (including NARW), porpoise, and seals are based upon the maximum Level A zone for each and rounded up for PSO clarity.

[6] No Level A exposures were calculated for blue whales resulting in no expected Level A exposure range; therefore, the exposure range for fin whales was used as a proxy due to similarities in species.

[7] Noise attenuation systems (NAS) are employed during pile driving activities to reduce the sound pressure levels that are transmitted through the water in an effort to reduce ranges to acoustic thresholds and minimize acoustic impacts resulting from pile driving activities.

Table 11: NARW Clearance and Real-time PAM Monitoring Zones[1] during Impact Piling in Summer (May through November) and Winter (December only).

Season	Minimum Visibility Zone[2]	Visual Clearance Delay and shutdown (m)	PAM Monitoring Zone (km)	PAM Clearance Zone (m)[3]	PAM Shutdown Zone (m)
Summer WTG	2,300	Any Distance	10	3,900	2,300
Winter WTG	4,400	Any Distance	10	4,400[4]	4,400
Summer OSS	1,600	Any Distance	10	4,100	1,600
Winter OSS	2,700	Any Distance	10	4,700	2,700

[1] Revolution Wind may request modification to zones based on results of sound field verification.

[2] The minimum visibility zones for NARWs are based upon the maximum non-humpback whale Level A zones for the whale group rounded up for PSO clarity.

[3] The PAM pre-start clearance zone was set equal to the Level B zone to avoid any unnecessary take.

[4] The Level A zone for NARW was less than the Level B zone, so the Level B zone has been used for all distances.

Revolution Wind Mitigation and Monitoring Zones

Impact Pile Driving 7-12 m Monopile 10 dB Attenuation in Summer

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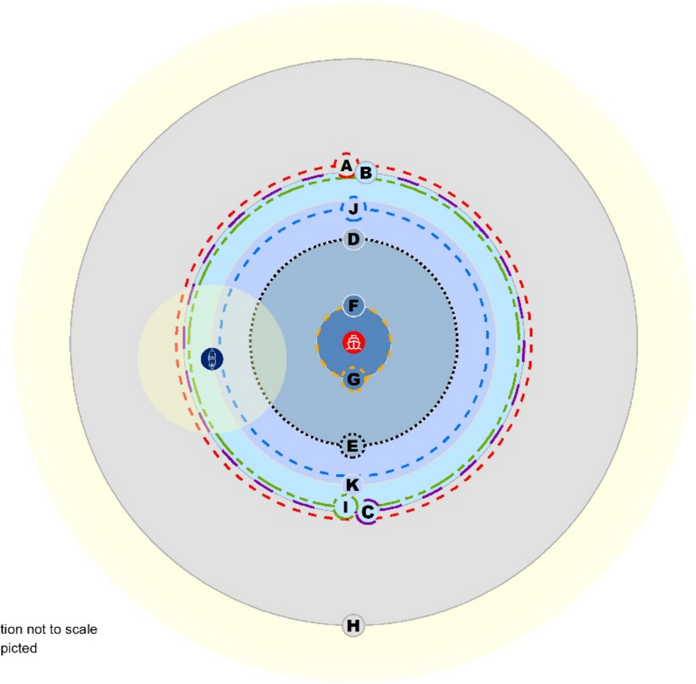
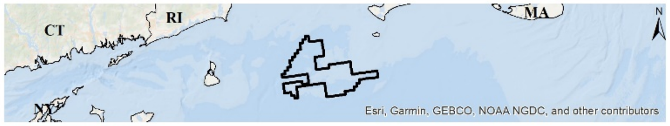


Range illustration not to scale

X = not depicted



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Monitoring Platforms

●	Pile/Construction Vessel
●	Secondary Vessel

Mitigation and Monitoring Zones [1,2]

A	North Atlantic Right Whale Minimum Visibility Zone	2,300 m
B	Large Whale Clearance Zone	2,300 m
C	Large Whale Shutdown Zone	2,300 m
D	Harbor Porpoise Clearance Zone	1,400 m
E	Harbor Porpoise Shutdown Zone	1,400 m
F	Seal Clearance Zone	500 m
G	Seal Shutdown Zone	500 m

Monitoring Zones and Reporting

H	Level B Monitoring Zone	3,833 m
I	Fin/Blue Whale Level A Exposure	2,230 m
J	Sei Whale Level A Exposure	1,810 m
K	North Atlantic Right Whale Level A Exposure	1,930 m
X	Level A Zone for HF Hearing Groups SPL_{PK}	160 m

[1] All mitigation and monitoring zones are inclusive of combined visual and acoustic monitoring effort.

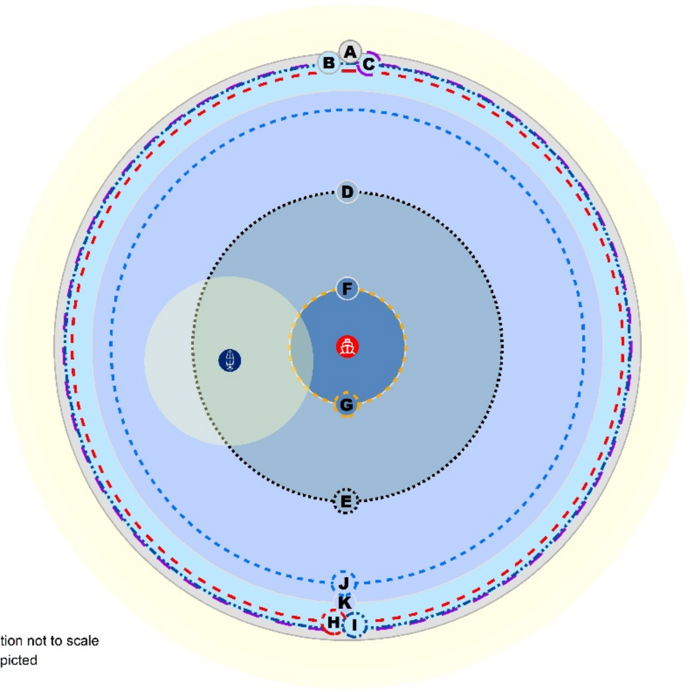
[2] Marine mammal clearance and exclusion zones less than 100 m are not depicted. Refer to the ***Table of mitigation and monitoring zones for WTG impact pile driving in summer (Table 6)*** for other zones.

	DAYTIME MONITORING											NIGHTTIME MONITORING										
	PERSONNEL		EQUIPMENT									PERSONNEL		EQUIPMENT								
	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Construction Vessel	2	1	2	1	1	1	0	0	1	2	1	2	1	0	1	0	1	2	2	1	2	0
# on Secondary Vessel	2	1	2	1	1	1	0	0	1	2	1	2	1	0	1	0	1	2	2	1	2	0

Figure 3: Marine Mammal Mitigation and Monitoring Zones during WTG Impact Pile Driving in Summer (May through November).

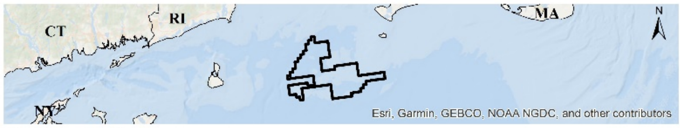
Revolution Wind Mitigation and Monitoring Zones

Impact Pile Driving 7-12 m Monopile 10 dB Attenuation in Winter



Range illustration not to scale

X = not depicted



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Monitoring Platforms

- 🔴 Pile/Construction Vessel
- 🔵 Secondary Vessel

Mitigation and Monitoring Zones [1,2]

A	North Atlantic Right Whale Minimum Visibility Zone	4,400 m
B	Large Whale Clearance Zone	4,400 m
C	Large Whale Shutdown Zone	4,400 m
D	Harbor Porpoise Clearance Zone	2,400 m
E	Harbor Porpoise Shutdown Zone	2,400 m
F	Seal Clearance Zone	900 m
G	Seal Shutdown Zone	900 m

Monitoring Zones and Reporting

H	Level B Monitoring Zone	4,271 m
I	Fin/Blue Whale Level A Exposure	4,380 m
J	Sei Whale Level A Exposure	3,670 m
K	North Atlantic Right Whale Level A Exposure	3,970 m
X	Level A Zone for HF Hearing Groups SPL_{PK}	160 m

[1] All mitigation and monitoring zones are inclusive of combined visual and acoustic monitoring effort.

[2] Marine mammal clearance and exclusion zones less than 100 m are not depicted. Refer to the ***Table of mitigation and monitoring zones for WTG impact pile driving in winter (Table 7)*** for other zones.

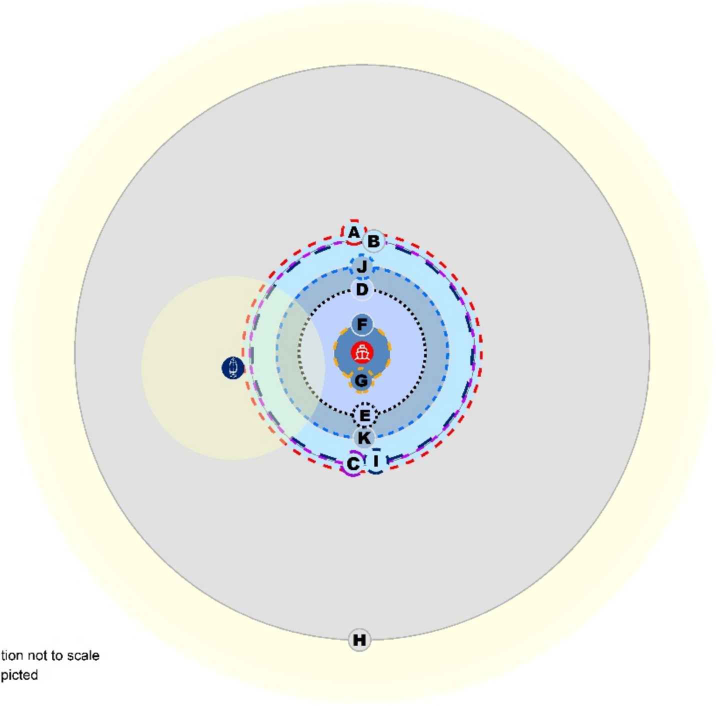
	DAYTIME MONITORING										
	PERSONNEL		EQUIPMENT								
	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Construction Vessel	2	1	2	1	1	1	0	0	1	2	1
# on Secondary Vessel	2	1	2	1	1	1	0	0	1	2	1

	NIGHTTIME MONITORING										
	PERSONNEL		EQUIPMENT								
	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Construction Vessel	2	1	0	1	0	1	2	2	1	2	0
# on Secondary Vessel	2	1	0	1	0	1	2	2	1	2	0

Figure 4: Marine Mammal Mitigation and Monitoring Zones during WTG Impact Pile Driving in Winter (December only).

Revolution Wind Mitigation and Monitoring Zones

OSS Impact Pile Driving 7-15 m Monopile 10 dB Attenuation in Summer



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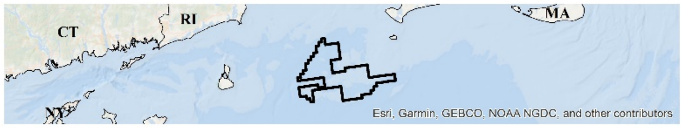
X = not depicted



Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Monitoring Platforms

🟥	Pile/Construction Vessel
🟦	Secondary Vessel

Mitigation and Monitoring Zones [1,2]

A	North Atlantic Right Whale Minimum Visibility Zone	1,600 m
B	Large Whale Clearance Zone	1,600 m
C	Large Whale Shutdown Zone	1,600 m
D	Harbor Porpoise Clearance Zone	900 m
E	Harbor Porpoise Shutdown Zone	900 m
F	Seal Clearance Zone	400 m
G	Seal Shutdown Zone	400 m

Monitoring Zones and Reporting

H	Level B Monitoring Zone	4,100 m
I	Fin/Blue Whale Level A Exposure	1,570 m
J	Sei Whale Level A Exposure	1,220 m
K	North Atlantic Right Whale Level A Exposure	1,250 m
X	Level A Zone for HF Hearing Groups SPL_{PK}	110 m

[1] All mitigation and monitoring zones are inclusive of combined visual and acoustic monitoring effort.

[2] Marine mammal clearance and exclusion zones less than 100 m are not depicted. Refer to the ***Table of mitigation and monitoring zones for OSS impact pile driving in summer (Table 8)*** for other zones.

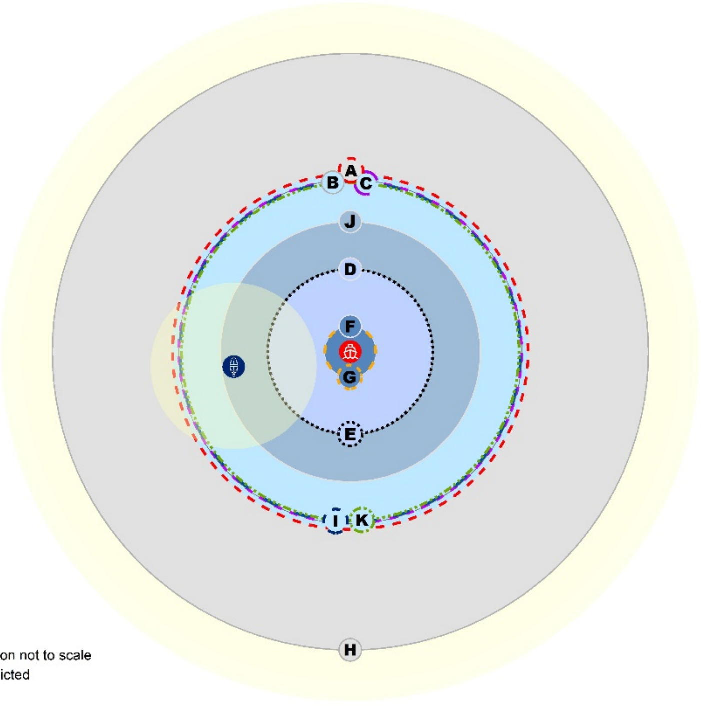
	DAYTIME MONITORING										
	PERSONNEL		EQUIPMENT								
	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Construction Vessel	2	1	2	1	1	1	0	0	1	2	1
# on Secondary Vessel	2	1	2	1	1	1	0	0	1	2	1

	NIGHTTIME MONITORING										
	PERSONNEL		EQUIPMENT								
	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Construction Vessel	2	1	0	1	0	1	2	2	1	2	0
# on Secondary Vessel	2	1	0	1	0	1	2	2	1	2	0

Figure 5: Marine Mammal Mitigation and Monitoring Zones during OSS Impact Pile Driving in Summer (May through November).

Revolution Wind Mitigation and Monitoring Zones

OSS Impact Pile Driving 7-15 m Monopile 10 dB Attenuation in Winter



Range illustration not to scale
X = not depicted

Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Monitoring Platforms

●	Pile/Construction Vessel
●	Secondary Vessel

Mitigation and Monitoring Zones [1,2]

A	North Atlantic Right Whale Minimum Visibility Zone	2,700 m
B	Large Whale Clearance Zone	2,700 m
C	Large Whale Shutdown Zone	2,700 m
D	Harbor Porpoise Clearance Zone	1,300 m
E	Harbor Porpoise Shutdown Zone	1,300 m
F	Seal Clearance Zone	400 m
G	Seal Shutdown Zone	400 m

Monitoring Zones and Reporting

H	Level B Monitoring Zone	4,698 m
I	Fin/Blue Whale Level A Exposure	2,680 m
J	Sei Whale Level A Exposure	2,050 m
K	North Atlantic Right Whale Level A Exposure	2,660 m
X	Level A Zone for HF Hearing Groups SPL_{PK}	80 m

[1] All mitigation and monitoring zones are inclusive of combined visual and acoustic monitoring effort.
[2] Marine mammal clearance and exclusion zones less than 100 m are not depicted. Refer to the ***Table of mitigation and monitoring zones for OSS impact pile driving in winter (Table 9)*** for other zones.

	DAYTIME MONITORING											NIGHTTIME MONITORING										
	PERSONNEL		EQUIPMENT									PERSONNEL		EQUIPMENT								
	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens	Visual PSOs on watch	PAM operators on duty	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Monitoring station for real time PAM system	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Construction Vessel	2	1	2	1	1	1	0	0	1	2	1	2	1	0	1	0	1	2	2	1	2	0
# on Secondary Vessel	2	1	2	1	1	1	0	0	1	2	1	2	1	0	1	0	1	2	2	1	2	0

Figure 6: Marine Mammal Mitigation and Monitoring Zones during OSS Impact Pile Driving in Winter (December only).

7.2 Impact Pile Driving Project Monitoring and Mitigation Protocols

There are four primary mitigation and monitoring efforts associated with impact pile driving:

1) Vessel-based visual PSOs and associated visual monitoring tools stationed on the construction and any secondary marine mammal monitoring vessels will monitor at night for marine mammals and other protected species using night-vision goggles with thermal clip-ons and a hand-held spotlight;
2) PAM operators and an associated mitigation PAM array in support of the visual PSOs;
3) Noise attenuation systems (NAS); and
4) Acoustic measurement data collection to verify distances to regulatory or mitigation zones.

Monitoring and mitigation protocols applicable to impact pile driving activities during RWF construction are described further in the following subsections. Impact pile driving may be initiated after dark or during reduced visibility periods following the protocols in **Sections 7.2.1** through **7.2.4** and include utilization of alternative monitoring methods. Pile driving during nighttime hours could potentially occur when a pile installation is started during daylight and, due to unforeseen circumstances, would need to be finished after dark.

There will be a team of six to eight visual and acoustic PSOs on the pile driving vessel, and a team of four to eight visual and acoustic PSOs on any secondary marine mammal monitoring vessel (secondary vessel). PAM operators may be located remotely/onshore. Table 12 provides the list of the personnel on watch and the PSO and PAM monitoring equipment available onboard the construction vessel and the secondary vessel.

Table 12: Personnel and equipment use for all marine mammal monitoring vessels during pre-start clearance, impact pile driving, and post piling monitoring.

Item	Standard Daytime		Monitoring for Nighttime and Low Visibility	
	# on Construction Vessel	# on Secondary Vessel	# on Construction Vessel	# on Secondary Vessel
Visual PSOs on watch	2	2	2	2
PAM operators on duty[1]	1	1	1	1
Reticle binoculars	2	2	0	0
Mounted thermal/IR camera system[2]	1	1	1	1
Mounted "big-eye" binocular	1	1	0	0
Monitoring station for real time PAM system[3]	1	1	1	1
Hand-held or wearable NVDs	0	0	2	2
IR spotlights	0	0	2	2
Data collection software system	1	1	1	1
PSO-dedicated VHF radios	2	2	2	2
Digital single-lens reflex camera equipped with 300-mm lens	1	1	0	0

IR = infrared; NVD = night vision device; PSO = Protected Species observer; VHF=very high frequency.

[1] PAM operator may be stationed on the vessel or at an alternative monitoring location.

[2] The camera systems will be automated with detection alerts that will be checked by a PSO on duty; however, cameras will not be manned by a dedicated observer.

[3] The selected PAM system will transmit real time data to PAM monitoring stations on the vessels and/or a shore side monitoring station.

7.2.1 Daytime Visual Monitoring

Visual monitoring will occur from the construction vessel and a secondary vessel. Daytime visual monitoring is defined by the period between nautical twilight rise and set for the region. The intent of the visual monitoring program is to provide complete visual coverage of the clearance zone during the clearance period prior to pile driving and the SZs during impact pile driving using the following protocols:

- During the pre-start clearance period, throughout pile driving, and 30-minutes after piling is completed, two PSOs will maintain watch at all times on the construction vessel; likewise, two PSOs will also maintain watch during the same time periods from the secondary vessel.
- The total number of observers will be dictated by the personnel necessary to adhere to standard shift schedule and rest requirements while still meeting mitigation monitoring requirements for the Project. A sample crew rotation is provided in **Attachment 2**.
- It is expected the full complement of PSOs will not always be required (i.e., full coverage will be in place during piling activities, however, in between piling events, the PSO team can consist of only one PSO on duty). Piling is anticipated to take approximately 1-4 hours (12 hours maximum) per piling event (i.e., 4 hours at a given foundation location) after which the construction vessel moves away to a new location for the next piling event.
- During daytime observations, two PSOs on each vessel will monitor the clearance zone and SZ with the naked eye and reticle binoculars. One PSO will periodically scan outside the SZ using the mounted big eye binoculars.
- PSOs will visually monitor, the maximum Level A zone which constitutes the pre-start clearance zone. This zone encompasses the maximum Level A exposure ranges for all marine mammal species.
- PSOs will visually monitor the harbor porpoise, pinniped, and dolphin SZs **Table 7, Table 8, Table 9**, and **Table 10** .
- The secondary vessel will be positioned and circling at the outer limit of the Large Whale SZ (**Figures 3-6).**
- PSOs stationed on the secondary vessel will ensure the outer portion of the SZs and pre-start clearance zone are visually monitored.
- There will be a PAM operator on duty (see **Section 6.2.3**) conducting acoustic monitoring in coordination with the visual PSOs during all pre-start clearance periods, piling, and post-piling monitoring periods.
- Acoustic monitoring, as described in **Section 6.2.3,** will extend beyond the Large Whale Pre-Start Clearance Zone.
- The NARW pre-start clearance zone will be monitored visually out to the extent of the Large Whale SZ and acoustically out to the extent of the Level B zone.

7.2.2 Daytime Periods of Reduced Visibility

- If the monitoring zone is obscured, the two PSOs on watch on each vessel will continue to monitor the SZ utilizing thermal camera systems and PAM.
- During nighttime or other low visibility conditions, two PSO on each vessel will monitor the SZ with the mounted IR camera and available handheld night vision as able.
- All on-duty PSOs will be in contact with the PAM operator on-duty who will monitor the PAM systems for acoustic detections of marine mammals that are vocalizing in the area.

7.2.3 Nighttime Visual: Construction and Secondary Vessel

- During nighttime operations, visual PSOs on-watch will rotate in pairs: one observing with an NVD and one monitoring the IR thermal imaging camera system. There will also be a PAM operator on duty (see next section) conducting acoustic monitoring in coordination with the visual PSOs.
- The mounted thermal cameras may have automated detection systems or require manual monitoring by a PSO.
- PSOs will focus their observation effort during nighttime watch periods within the SZs and waters immediately adjacent to the vessel.
- If possible, deck lights will be extinguished or dimmed during night observations when using the NVDs (strong lights compromise the NVD detection abilities); alternatively, if the deck lights must remain on for safety reasons, the PSO will attempt to use the NVDs in areas away from potential interference by these lights.

7.2.4 Passive Acoustic Monitoring

Since visual observations within the applicable SZs can become impaired at night or during daylight hours due to fog, rain, or high sea states, visual monitoring with thermal and NVDs will be supplemented by PAM during these periods. A PAM operator will be on watch during all pre-start clearance, piling operations and post monitoring periods. A combination of alternative monitoring measures, including PAM, has been demonstrated to have comparable detection rates (although limited to vocalizing individuals) to daytime visual detections for several species (Smith et al. 2020).

PAM devices proposed for monitoring during Project impact pile driving activities are not likely to be towed from the vessel, but rather will be independent (e.g., autonomous or moored remote) stations located around the area to be monitored. The specific placement of PAM devices or systems will be determined based on the final mitigation zones determined in the regulatory review process. As detailed in **Attachment 4** there are multiple available PAM systems with demonstrated capability for monitoring and localizing marine mammal calls, including large whales, within the proposed monitoring and mitigation zones (e.g. sonobuoy arrays or similar retrievable buoy systems).

PAM will be used to monitor the following zones during piling:

- PAM operators will acoustically monitor a zone that encompasses the Level B zone for all marine mammals, which also encompasses the NARW clearance zone and Level A zones for all marine mammal species.

In general, the following monitoring protocols related to PAM will be followed for this Project:

  - A PAM operator will be stationed on at least one of the dedicated monitoring vessels in addition to the PSOs; or the PAM operator may be located remotely/onshore if the PAM system allows for remote monitoring.
  - PAM operators will complete specialized training for operating PAM systems prior to the start of monitoring activities.
  - All on-duty PSOs will be in contact with the PAM operator on-duty, who will monitor the PAM systems for acoustic detections of marine mammals that are vocalizing in the area.
  - For real-time PAM systems, at least one PAM operator will be designated to monitor each system by viewing data or data products that are streamed in real-time or near real-time to a computer workstation and monitor located on a Project vessel or onshore.
  - The PAM operator will inform the PSOs on duty, who will be responsible for requesting that the Lead PSO implement the necessary mitigation protocols of, at least, probable or confirmed, detections of all of marine mammals, and possible detections of NARW via the data collection software system (i.e., Mystcetus or similar system).
  - Acoustic monitoring during nighttime and low visibility conditions during the day will complement visual monitoring (e.g., visual PSOs and thermal cameras) and will cover an area of at least the SZ around each foundation.

7.2.5 Mitigation Measures During Impact Pile Driving

Mitigation measures implemented during a piling event include:

- Pre-start clearance;
- Soft start of the pile strikes;
- Post-piling monitoring;
- Shutdowns, and
- Monitoring during unforeseen pauses in piling

The parameters of these mitigation measures are summarized in **Table 13, Table 14, Table 15,** and **Table 16** for summer (May through November) and winter (December only) mitigation measures respectively and detailed in **Section 7.2.5.1** through **7.2.5.5** below.

Table 13: Summary of mitigation measures during WTG impact pile driving with a noise attenuation system in Summer (May through November).

	Piling with an NAS, 10 dB broadband attenuation				
	NARW	Large Whale	Delphinids	Harbor Porpoise	Seals
Pre-Start Clearance and Shutdown Zone[1] [2]	At any distance[3]	2,300 m	N/A	1,400 m	500 m
Clearance Duration	60 min visual monitoring, 60 min PAM monitoring; zone must be clear for 30 min				
Soft Start	All Piles				
Post-piling monitoring	30 min				

m=meters; min=minutes; NARW=North Atlantic right whale; NAS=Noise Attenuation System

[1] Clearance and Shutdown zones will be monitored using a combination of visual and acoustic methods.

[2] Shutdowns may be initiated by either visual or acoustic detection. Only acoustic detections that meet criteria (e.g. localization) for determining that the call originated inside the given zone will be considered for mitigation.

[3]The NARW visual clearance delay and shutdown zone will occur at any distance.

Table 14: Summary of mitigation measures during WTG impact pile driving with a noise attenuation system in Winter (December only).

	Piling with an NAS, 10 dB broadband attenuation				
	NARW	Large Whale	Delphinids	Harbor Porpoise	Seals
Pre-Start Clearance and Shutdown Zone[1] [2]	At any distance[3]	4,400 m	N/A	2,400 m	900 m
Clearance Duration	60 min visual monitoring, 60 min PAM monitoring; zone must be clear for 30 min				
Soft Start	All Piles				
Post-piling monitoring	30 min				

m=meters; min=minutes; NARW=North Atlantic right whale; NAS=Noise Attenuation System

[1] Clearance and Shutdown zones will be monitored using a combination of visual and acoustic methods.

[2] Shutdowns may be initiated by either visual or acoustic detection. Only acoustic detections that meet criteria (e.g. localization) for determining that the call originated inside the given zone will be considered for mitigation.

[3]The NARW visual clearance delay and shutdown zone will occur at any distance.

Table 15: Summary of mitigation measures during OSS impact pile driving with a noise attenuation system in Summer (May through November).

	Piling with an NAS, 10 dB broadband attenuation				
	NARW	Large Whale	Delphinids	Harbor Porpoise	Seals
Pre-Start Clearance and Shutdown Zone[1] [2]	At any distance[3]	1,600 m	N/A	900 m	400 m
Clearance Duration	60 min visual monitoring, 60 min PAM monitoring; zone must be clear for 30 min				
Soft Start	All Piles				
Post-piling monitoring	30 min				

m=meters; min=minutes; NARW=North Atlantic right whale; NAS=Noise Attenuation System

[1] Clearance and Shutdown zones will be monitored using a combination of visual and acoustic methods.

[2] Shutdowns may be initiated by either visual or acoustic detection. Only acoustic detections that meet criteria (e.g. localization) for determining that the call originated inside the given zone will be considered for mitigation.

[3] The NARW visual clearance delay and shutdown zone will occur at any distance.

Table 16: Summary of mitigation measures during OSS impact pile driving with a noise attenuation system in Winter (December only).

	Piling with an NAS, 10 dB broadband attenuation				
	NARW	Large Whale	Delphinids	Harbor Porpoise	Seals
Pre-Start Clearance and Shutdown Zone[1] [2]	At any distance[3]	2,700 m	N/A	1,300 m	400 m
Clearance Duration	60 min visual monitoring, 60 min PAM monitoring; zone must be clear for 30 min				
Soft Start	All Piles				
Post-piling monitoring	30 min				

m=meters; min=minutes; NARW=North Atlantic right whale; NAS=Noise Attenuation System

[1] Clearance and Shutdown zones will be monitored using a combination of visual and acoustic methods.

[2] Shutdowns may be initiated by either visual or acoustic detection. Only acoustic detections that meet criteria (e.g. localization) for determining that the call originated inside the given zone will be considered for mitigation.

[3] The NARW visual clearance delay and shutdown zone will occur at any distance.

7.2.5.1 Pre-Start Clearance

A 60-minute pre-start clearance period that will be implemented for impact pile driving activities. Visual PSOs will begin surveying the monitoring zone at least 60 minutes prior to the start of pile driving. PAM monitoring will also begin at least 30-minutes prior to the start of piling.

- The large whale clearance zone (2,300 m or as modified) must be fully visible for at least 30 minutes prior to commencing ramp-up.
- All marine mammals must be confirmed to be out of the clearance zone prior to initiating soft start.
- If a marine mammal is observed entering or within the relevant clearance zones prior to the initiation of pile driving activity, pile driving activity will be delayed.

- An acoustic detection localized to a position within the CZ(s) will trigger a delay.
- A NARW sighted at any distance will trigger a delay.
- Impact pile driving may commence when either the marine mammal(s) has voluntarily left the respective clearance zone and been visually confirmed beyond that clearance zone, or, when 30 minutes have elapsed without re-detection for whales, including NARW; or 15 minutes have elapsed without re-detection of dolphins, porpoises, and seals.

7.2.5.2 Soft Start

Every monopile installation will begin with a soft start procedure of a minimum of 20-minute duration. The soft start procedure is detailed in Table 17.

- Soft start of pile driving will not begin until the CZ has been cleared by the visual PSO (and PAM operators when applicable).
- If any marine mammals are detected within the applicable CZ prior to or during the soft start, activities will be delayed until the animal has been observed exiting the CZ or until an additional time period has elapsed with no further sighting.

Table 17: Generic soft start procedure overview.

% of max hammer blow energy	Soft Start
	10–20%
Monopile blow energy	600–800 kJ
Strike Rate	4–6 strikes/min
Duration	Minimum of 20 minutes or greater until pile verticality/self-stability is secured.

kJ=kilojoule.

7.2.5.3 Post-Piling Monitoring

- PSOs will continue to survey the monitoring zone using visual and acoustic protocols throughout the pile installation and for a minimum of 30 minutes after piling has been completed.

7.2.5.4 Shutdown Protocols

For reference, a generic piling procedure has been broken down into three different steps where blows, strike ratio and duration envelopes are defined. The Piling Procedure follows these general criteria:

1. The piling schedule (and therefore resulting sound field) does not exceed the maximum scenario modelled for regulatory authorizations.
2. Refusal criteria is not exceeded
    (i) 125 blows/25 centimeters (cm) over an increment of 6 × 25 cm
    (ii) 200 blows/25 cm over an increment of 2 × 25 cm
    (iii) 325 blows/25 cm over an increment of 1 × 25 cm.
3. The hammer drives the pile to target penetration.

If a marine mammal is entering or within the respective SZs (or a NARW sighted at any distance) after pile driving has commenced, an immediate shutdown of pile driving will be implemented unless RW and/or its contractor determines shutdown is not feasible due to an imminent risk of injury or loss of life to an individual; or risk of damage to a vessel that creates risk of injury or loss of life for individuals.

There are two scenarios, approaching pile refusal and pile instability, where this imminent risk could be a factor (*See Deferred Shutdown Scenarios*).

If shutdown is called for but RW and/or its contractor determines shutdown is not feasible due to risk of injury or loss of life, reduced hammer energy must be implemented.

After a shutdown, pile driving must only be initiated once all SZs are confirmed by PSOs to be clear of marine mammals for the minimum species-specific time periods.

Deferred Shutdown Scenarios: Scenarios that would prevent shutdown of piling operations typically have a low likelihood of occurrence based on Ørsted's extensive pile driving experience and low occurrence of these situations.

Scenario 1: **Pile Refusal**: The pile driving sensors indicate the pile is approaching refusal, and a shutdown would lead to a stuck pile which then poses an imminent risk of injury or loss of life to an individual, or risk of damage to a vessel that creates risk for individuals.

Risk Likelihood/Mitigation: Each pile is specifically engineered to manage the sediment conditions at the location at which it is to be driven, and therefore designed to avoid and minimize the potential for piling refusal. Ørsted uses these pre-installation engineering assessments and design together with real-time hammer log information during installation to track progress and continuously judge whether a stoppage would cause a risk of injury or loss of life. Due to this advanced engineering and planning, circumstances under which piling could not stop if a shutdown is requested are very limited.

Scenario 2: Pile Instability: For a specified project and installation vessel, weather conditions criteria will be established that determine when a piling vessel would have to "let go" of a pile being installed for safety reasons. A pile may be deemed unstable and unable to stay standing if the piling vessel were to "let go". During these periods of instability, the lead engineer may determine a shutdown is not feasible because the shutdown combined with impending weather conditions may require the piling vessel to "let go" which then poses an imminent risk of injury or loss of life to an individual, or risk of damage to a vessel that creates risk for individuals.

Risk Likelihood/Mitigation: To reduce the risk that a requested shutdown would not be possible due to weather, Ørsted actively assesses weather, using two independent forecasting systems. Initiation of piling also requires a *Certificate of Approval* by the Marine Warranty Supervisor. In addition to ensuring that current weather conditions are suitable for piling, this *Certificate of Approval* process considers forecasted weather for 6 hours out and will evaluate if conditions would limit the ability to shut down and "let go" of the pile. If a shutdown is not feasible due to pile instability and weather, piling would continue only until a penetration depth sufficient to secure the pile is achieved. As piling instability is most likely to occur during the soft start period, and soft start cannot commence till the Marine Warranty Supervisor has issued a Certificate of Approval that signals there is a current weather window of at least 6 hours, the likelihood is low for the pile to not achieve stability within the 6-hour window inclusive of stops and starts.

7.2.5.5 Pauses and Silent Periods

- The SZ and clearance zone must be continuously monitored by PSOs and PAM during any pauses in pile driving.

- If marine mammals are sighted within the SZ during a pause in piling, resumption of pile driving will be delayed until the animal(s) has moved outside the SZ or when 30 minutes have elapsed without redetection for whales, including the NARW, or 15 minutes have elapsed without redetection of dolphins, porpoises, and seals. Vessel Strike Avoidance
- The Project will follow vessel strike avoidance measures outlined previously in the *Vessel Strike Avoidance Policy* section (**Section 3.9**)

7.2.5.6 Vessel Speed Restrictions

- The Project will follow vessel strike avoidance measures outlined previously in the *Vessel Strike Avoidance Policy* section (**Section 3.9**)

7.2.6 Data Recording

- All data recording will be conducted using Mysticetus or similar software.
- Operations, monitoring conditions, observation effort, all marine mammal detections, and any mitigation actions will be recorded as well as any other reporting requirements prescribed by NMFS.
- Members of the monitoring team must consult NMFS' NARW reporting systems for the presence of NARWs in the Project Area.
    - Mysticetus will alert PSOs of any new sightings posted to the Mysticetus map. In addition, Mysticetus maintains "watch dogs" which will ensure the electronic link to NMFS-SAS and other 3rd party sources remains active.

7.3 Impact Pile Driving Reporting

- Revolution Wind will follow reporting measures as described in **Section 3.7 and Attachment 8**.

7.3.1 DMAs

- DMAs will be reported across all Project vessels.

7.3.2 Injured and Dead Protected Species

- The Project will follow reporting measures as described in **Section 3.7 and Attachment 8**.

7.4 Noise Attenuation for Impact Pile Driving

- The Project will use a NAS for all piling events and is committed to achieving the modeled ranges associated with 10 dB of noise attenuation (See **ITA Application Section 6.3.2**).

7.5 Sound Measurements during Impact Pile Driving

Received sound measurements will be collected during driving of the first three monopiles installed over the course of the Project using a NAS. The measurement plan is provided in **Attachment 7.**

- The goals of the field verification measurements using an NAS include: verification of modeled ranges and the distances to the Level A harassment and Level B harassment isopleths; and providing sound measurements of impact pile driving using International Organization for Standardization (ISO)-standard methodology to build data that are comparable among projects (ISO 2017).

7.5.1 Potential modification of Clearance Zones and SZs

- Based on the sound field measurement results the Project may request a modification of the clearance and/or SZs (see **Attachment 7**).

8 Construction Plan for Vibratory Pile Driving of Sheet Pile

The sea-to-shore transition will include a new onshore transition vault, cable installed using horizontal directional drilling under the beach and intertidal water. Construction activities may include the temporary installation of a casing pipe, supported by sheet pile "goal" posts. Installation of casing pipe would be completed using pneumatic pipe ramming equipment while installation of sheet pile for goal posts or a cofferdam would be completed using a vibratory pile driving hammer. If project conditions require a temporary cofferdam, it will be constructed as a sheet piled structure into the sea floor or a gravity cell structure placed on the sea floor.

8.1 Monitoring and Mitigation Zones

Table 18 provides the ranges to all thresholds and monitoring zones applied during vibratory sheet pile installation and removal of each goal post or cofferdam. No noise attenuation is proposed due to the short time period of the activities and relatively low source levels. No Level A exposures are expected from vibratory sheet pile installation or removal; however acoustic ranges were modeled for reference. The Level A ranges are acoustic ranges and therefore represent the maximum distance at which a stationary receiver (i.e., animal) could exceed SEL_{cum} thresholds over a 24-hour period. Exposure ranges (which were not modeled for vibratory pile driving) are expected to be small enough such that no Level A exposures are anticipated.

The Level A acoustic ranges, Level B acoustic range, Level B monitoring zone, mitigation zones, and vessel separation distances for vibratory sheet pile driving are provided in **Table 18**. To estimate distances to Level A and Level B thresholds acoustic modeling was recently performed for the Sunrise Wind project at that project's anticipated HDD exit pit location approximately 0.5 mi (800 m) offshore of Long Island, New York near Smith Point. This location has similar water depths and shallow substrate conditions as found at the landfall location in Narragansett Bay so the modeling results are expected to be applicable to the Revolution Wind project. Modeling methods were the same as those summarized above for impact pile driving of monopile foundations, including the use of GRLWEAP, PDSM and FWRAM models. Mitigation zones established for all species, including NARW, will be applied during all months of the year in which work is performed. Monitoring zones implemented during the Project may be modified, with NMFS approval based on measurements of the received sound levels during piling operations.

Table 18: Distances to Level A and Level B isopleths and mitigation and monitoring zones[1,2] during Project vibratory sheet pile driving.

Species	Level A Acoustic Range[3] (SEL_{cum}) (m)	Level A Acoustic Range (SPL_{pk}) (m)	Level B Acoustic Range/Monitoring Zone (m)	Pre-start Clearance Zone[4] (m)	Shutdown Zone[4] (m)	Vessel Separation Distance (m)
Low-Frequency Cetaceans						
Fin whale*	5	N/A	9,740	200	10	100
Minke whale	5	N/A	9,740	200	10	100
Sei whale*	5	N/A	9,740	200	10	100
Humpback whale	5	N/A	9,740	200	10	100
NARW*	5	N/A	9,740	200	10	500
Blue whale*	5	N/A	9,740	200	10	100
Medium-Frequency Cetaceans						
Sperm whale*	N/A	N/A	9,740	200	10	100
Atlantic white sided dolphin	N/A	N/A	9,740	200	10	50
Atlantic spotted dolphin	N/A	N/A	9,740	200	10	50
Short-beaked common dolphin	N/A	N/A	9,740	200	10	50
Risso's dolphin	N/A	N/A	9,740	200	10	50
Bottlenose dolphin, offshore	N/A	N/A	9,740	200	10	50
Long-finned pilot whale	N/A	N/A	9,740	200	10	50
High-Frequency Cetaceans						
Harbor porpoise	190	N/A	9,740	200	200	50
Pinnipeds in Water						
Gray seal	10	N/A	9,740	200	50	50
Harbor seal	10	N/A	9,740	200	50	50

* = denotes species listed under the Endangered Species Act; SEL_{cum} = cumulative sound exposure level; SPL_{pk} = peak sound pressure level; NA= not applicable (i.e., Level A take will be requested for these species so no shutdown will be implemented).

[1] Zone monitoring will be achieved using visual observation

[2] The Level A zone represents the acoustic ranges of species with no animal movement modelling applied

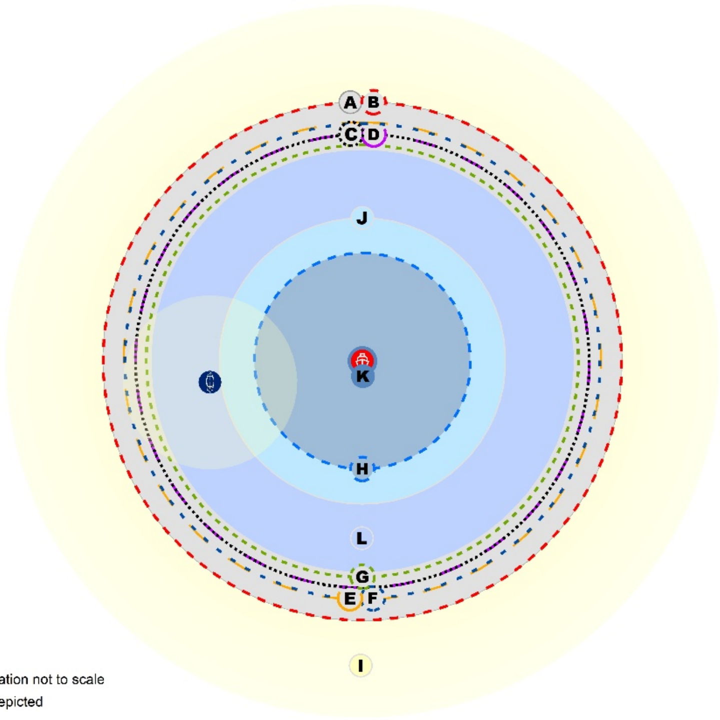
[3] The pre-start clearance zones for all marine mammals are based upon the maximum Level A zone (190 m) and rounded up for PSO clarity.

[4] The shutdown zones for large whales (including NARW) are based upon the maximum Level A zone for each group and rounded up for PSO clarity.

Revolution Wind Mitigation and Monitoring Zones

Vibratory Sheet Pile Driving

LGL Ecological Research Associates
CELEBRATING 50 YEARS



Range illustration not to scale
X = not depicted

Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Monitoring Platforms

●	Pile/Construction Vessel	
●	Secondary Vessel	

Mitigation and Monitoring Zones [1,2]

A	Large Whale Clearance Zone	100 m
B	Large Whale Shutdown Zone	100 m
C	Mid-Frequency Cetacean Clearance Zone	100 m
D	Mid-Frequency Cetacean Shutdown Zone	100 m
E	Harbor Porpoise Clearance Zone	100 m
F	Harbor Porpoise Shutdown Zone	100 m
G	Seal Clearance Zone	100 m
H	Seal Shutdown Zone	50 m

Monitoring Zones and Reporting

I	Level B Monitoring Zone	10,000 m
J	Low-Frequency Cetacean Level A Exposure	66.2 m
K	Mid-Frequency Cetacean Level A Exposure	5.9 m
L	High-Frequency Cetacean Level A Exposure	97.8 m
X	Level A Zone for HF Hearing Groups SPL_{PK}	N/A m

[1] All mitigation and monitoring zones are inclusive of combined visual and acoustic monitoring effort.
[2] Refer to the ***Table of mitigation and monitoring zones for vibratory sheet pile driving in (Table 13)*** for other zones.

	DAYTIME MONITORING								
	PERSONNEL	EQUIPMENT							
	PSOS on watch	Reticle binoculars	Mounted thermal/IR camera system	Mounted "big-eye" binocular	Hand-held or wearable NVDs	IR spotlights	Data collection software system	PSO-dedicated VHF radios	Digital single-lens reflex camera equipped with 300 mm lens
# on Construction Vessel	2	2	1	1	2	2	1	2	1

Figure 7: Marine Mammal Mitigation and Monitoring Zones during Vibratory Pile Driving.

8.2 Vibratory Sheet Pile Driving Project Monitoring and Mitigation Protocols

Visual monitoring protocols will be in place for all vibratory sheet pile installation and removal. All observations will take place from one of the construction vessels stationed at or near the sheet piling location. No PAM operations will be utilized due to the likelihood of masking effects of the vibratory pile driving activities which will result in ineffective acoustic monitoring opportunities. **Table 19** provides the list of the personnel on watch and monitoring equipment available onboard the construction vessel.

Table 19: Personnel and equipment compliment for monitoring vessels during vibratory pile driving.

Item	# on Construction Vessel
PSOs on watch	2
Reticle binoculars	2
Mounted thermal/IR camera system	1
Mounted "big-eye" binocular	1
Hand-held or wearable NVDs	2
IR spotlights	2
Data collection software system	1
PSO-dedicated VHF radios	2
Digital single-lens reflex camera equipped with 300-mm lens	1

IR = infrared; NVD = night vision device; PSO = protected species observer; VHF = very high frequency.

8.2.1 Visual Observation Protocols and Methods

8.2.1.1 Daytime Visual

- Visual monitoring will occur from the construction vessel to provide complete visual coverage of the marine mammal CZ and SZs during vibratory sheet pile installation and removal.
- Two PSOs will maintain watch on the construction vessel during the pre-start clearance period (**Section 7.2.1**), throughout vibratory pile installation and removal, and 30-minutes after piling is completed.
- Two PSOs will conduct observations concurrently. The total number of observers will be dictated by the personnel necessary to adhere to standard schedule and rest requirements while meeting Project mitigation monitoring requirements. A sample crew shift rotation is shown in **Attachment 2**.
- PSOs will visually monitor the CZ and SZs.
- One observer will monitor the CZ and SZs with the naked eye and reticle binoculars. One PSO will monitor in the same way but will periodically scan outside the SZ using the mounted big eye binoculars.

8.2.1.2 Daytime Visual during Periods of Low Visibility

- During daytime low visibility conditions, one PSO will monitor the CZ and SZs with the mounted IR camera while the other maintains visual watch with the naked eye / binoculars.

8.2.1.3 Nighttime Visual

- Construction at the landfall site will not occur at night.

8.2.2 Pre-Start Clearance

- PSOs will monitoring the clearance zone for 30 minutes prior to start of vibratory pile driving.
- If a marine mammal is observed entering or within the CZ piling cannot commence until the animal has exited the CZ or time has elapsed since the last sighting (30 minutes for large whales, 15 minutes for dolphins, porpoises, and pinnipeds).

8.2.3 Operations Monitoring

- PSOs will continue to survey the SZ using visual protocols throughout the vibratory pile driving and for a minimum of 30 minutes after piling has been completed.

8.2.4 Shutdown Protocols

- If a marine mammal is observed entering or within the respective SZs after sheet pile installation has commenced, a shutdown will be implemented as long as health and safety is not compromised.

8.2.5 Pauses and Silent Periods

- The SZ must be continuously monitored by PSOs during any pauses in vibratory pile driving
- If marine mammals are sighted within the respective SZ during a pause in vibratory pile driving, activities will be delayed until the animal(s) has moved outside the SZ or when 30 minutes have elapsed without redetection for whales, including the NARW, or 15 minutes have elapsed without redetection of dolphins, porpoises, and seals.

8.2.6 Vessel Strike Avoidance

- The Project will follow vessel strike avoidance measures outlined previously in the *Vessel Strike Avoidance Policy* section (**Section 3.9**).

8.2.6.1 Vessel Speed Restrictions

- The Project will follow vessel strike avoidance measures outlined previously in the *Vessel Strike Avoidance Policy* section (**Section 3.9**)

8.2.7 Data Recording

- All data recording will be conducted using Mysticetus software.
- Operations, monitoring conditions, observation effort, all marine mammal detections, mitigation actions, and any other recording requirements prescribed by NMFS.

- Members of the monitoring team must consult NMFS' NARW reporting systems for the presence of NARWs in the Project Area.

8.3 Reporting

- The Project will follow reporting measures as described in **Section 3.7 and Attachment 8**.

8.3.1 DMAs

DMAs will be reported across all vessels.

8.3.2 Injured and Dead Protected Species

- The Project will follow reporting measures as described in **Section 3.7 and Attachment 8**

8.4 Sound Measurements during Vibratory Pile Driving

Received sound measurements will be collected during vibratory pile driving at the landfall construction site. The measurement plan will be similar to that described for impact pile driving provided in **Attachment 7**, which is designed to collect data on approximate source levels, the directionality of the sounds produced, and transmission loss in at least one direction. The number and location of recorders may be reduced to measurements conducted in open water locations due to the presence of nearby land. The distances at which acoustic recorders are placed from the landfall construction will be determined based on the modeled distances to the acoustic thresholds for vibratory pile driving.

- The goals of the field verification measurements include: verification of modeled ranges to the harassment threshold isopleths and providing sound measurements of vibratory pile driving using International Organization for Standardization (ISO)-standard methodology (ISO 2017) for comparison among projects and informing future operations.

9 Operations Mitigation and Monitoring Protocols

Long-term visual and PAM efforts will be employed to assess the potential impacts of the Project on protected species in the Project area and support the *Vessel Strike Avoidance Plan*. Pre-construction surveys will provide a baseline set of data for comparison against the monitoring efforts during construction. Using the same monitoring methodologies during post-construction, surveys will provide for an assessment of the potential long-term impacts of the Project. Several different methodologies will be employed to assess Project-related impacts including vessel-based visual surveys as well as PAM efforts via both static and non-static deployment methodologies.

Activities occurring during operations that require monitoring for marine mammals will follow the protocols outlined in **Section 5**. HRG surveys will be monitored using the visual techniques outlined in **Section 6**.

9.1 Visual Monitoring for Operations

It is expected that during operations and maintenance phases of the Project, regular maintenance will occur. This will typically involve vessel movement. Crew transfer vessels (CTVs) will transport people and equipment continuously back and forth from Port to station, and service operation vessels (SOVs) will remain in the immediate vicinity of the operation and move crew in close transits around the area. During these two types of activities, visual monitoring will occur following protocols described in Sections **5.2.1**, **6.2.1**, and **6.2.2**. Mitigations will be in place to reduce the threat of ship strikes. These are described in detail in **Section 3.9**. In the event that there may need to be other than routine maintenance (e.g., blade replacement or nacelle work), the same visual methods and protocols will be applied as discussed in **Section 5**, as appropriate. Acoustic monitoring and appropriate mitigations will be implemented as warranted during operations.

9.2 Passive Acoustic Monitoring for Operations

Most operations-related, non-construction activities are expected to consist of maintenance, support, and transport vessels. Appropriate types of PAM for marine mammals during these activities may include the use of towed hydrophone arrays and static PAM buoys for activities that are fixed and restricted to a well-defined area. See Table 1 provided in **Attachment 4** for some examples of systems that could be used.

9.2.1 Autonomous Acoustic Recorders and Moored PAM Buoys

Operational monitoring using PAM requires systems that are intended to operate for relatively long periods of time (e.g., months to years) and are capable of monitoring marine mammals over relatively large areas (e.g., the entire Lease Area or possibly beyond). Examples of suitable hardware systems include autonomous recorder arrays, radio-linked PAM buoy, ASVs (e.g., wave-gliders), or some combination of these systems (e.g., "hybrid" systems). The relative costs and general advantages versus disadvantages of each of these are described below. As discussed previously, cabled systems are not considered here.

AARs are available in a variety of configurations and specifications (**Attachment 4**) (Sousa-Lima et al. 2013). Typically, AARs are deployed on the seafloor for a period of time ranging from several days, weeks, or months to up to 1 year. They are later retrieved from the seafloor, and the data are downloaded. An acoustic release device is typically used to release the recorder from the seafloor; however, grappling methods can also be used in some shallow water environments (usually 50 m or less). Some shallow water systems can also be retrieved by divers, but this approach is becoming less common with more reliable and low-cost release devices and also due to safety issues. Once retrieved, the recording devices can be serviced, the data downloaded, and the devices then re-deployed for additional missions. A major disadvantage of AARs over other systems is that because they record and store data internally, the recorders must be retrieved in order to access the data. Therefore, AARs are not capable of real-time monitoring. However, due to their autonomous nature, an advantage of these systems is that an infinite variety of deployment configurations is possible.

Most autonomous recorders consist of a single omni-directional hydrophone; therefore, it is not possible to obtain bearings or localizations to sound sources from this type of single device. However, other advanced systems utilize a directional (e.g., DIFAR) hydrophone/sensor, or multiple hydrophones connected to a single multi-channel recorder (e.g., a hydrophone array) and thus can localize. In some systems, multiple AAR units can be precisely time-synchronized (e.g., using an acoustic pinger or electronic cable) so that bearings can be obtained, and, in some deployment configurations, localization of sound sources is thus possible (**Attachment 4**).

One downside of autonomous recorder systems is that if a failure occurs (e.g., electronic malfunction, flooding, or a failure to retrieve them), significant volumes of data can be lost. This issue is of particular concern for long-term deployments. Also, the data storage and batteries required for extended deployment periods increase the sizes and costs of these systems. Finally, there is a cost associated with deployment and retrieval, which typically requires a vessel with a hoist, A-frame, or other heavy machinery. The size of vessel required depends on the size and ease of deployment of the AAR system. Some smaller systems can be deployed from a small boat or rigid-hulled inflatable boat, while others might require a large and costly research or other vessel with an A-frame. Finally, the fact that data must be post-processed results in an additional analysis expense. However, depending on the level of and type of processing, this approach is usually less expensive (per unit of data collected) than real-time monitoring, which typically requires experienced and relatively costly personnel working on vessels or platforms at sea.

Real-time (e.g., radio-linked) PAM buoys can be used for regional monitoring of large areas and have an advantage over AARs in that they can telemeter data to shore or a monitoring station nearby in real, or near real-time. Examples of real-time PAM buoys are provided in **Attachment 4**.

There are also hybrid systems that have some components of both real-time and autonomous systems. For example, many types of real-time systems also record data internally, so they can function both as real-time systems, and as autonomous recorders in case the radio or satellite link is not reliable. Some hybrid systems only send status reports or whale-call detection summaries to shore or a vessel nearby via the radio or satellite link. The optimal system will depend on cost considerations, the target species, the length of deployment desired, and a variety of other factors. The details of the operational monitoring system used will be determined once the goals, priorities, and requirements of the regional PAM are known. It is important to realize that there is no single system that is capable of mitigation and monitoring of all species of marine mammals for all areas and noise conditions, so it is possible that several systems, or combinations of systems, will be needed.

10 Regional Long-Term Monitoring Impacts

Regional monitoring systems are defined here as ones that are intended to operate for long periods of time (e.g., months to years in mission duration) and are capable of monitoring marine mammals in the entire Lease Area and possibly beyond. PAM-based systems can be deployed for periods of months to years, and, depending on the species and environments being monitored, can monitor relatively large areas (e.g., tens to hundreds of square kilometers for some of the larger species of whales). Examples of the types of hardware systems include AAR arrays, radio-linked PAM buoy arrays, autonomous underwater vehicles (AUV; e.g., Slocum glider), ASVs (e.g., wave-gliders), or some combination of these systems (e.g., “hybrid” systems) (Attachment 4). Although cabled PAM devices are a possible option for long-term PAM, they are not considered here (e.g., high installation and maintenance costs, environmental issues related to cable laying, permitting).

10.1 Bottom Deployed Autonomous Recorders

AARs are described in **Section 3.4.3** and are a good option for long-term monitoring. The type of system chosen will depend on the monitoring priorities (species and areas to be monitored), the environment (e.g., water depths), bottom fishing (e.g., trawling) in the area to be monitored, and other factors. Several systems and their capabilities are provided in **Attachment 4**, **Table 4-2**.

10.2 Autonomous Mobile PAM

Mobile systems are defined here as systems that are not fixed (e.g., moored or bottom deployed) at one location. Examples of mobile systems include AUVs, ASVs, and drifting PAM buoys. Examples of drifting PAM buoys include sonobuoys, the Que-phone, Drifting Autonomous Spar Buoy Recorders (DASBRS), and SonarPoint (in the drifter configuration). Due to their drifting nature, these systems are typically deployed in pelagic environments, or for very short periods (e.g., sonobuoys). Because the Lease Area is a fixed region that needs to be monitored for relatively long periods of time (months to years), drifting buoys are not considered a good option for PAM of marine mammals in this area. Therefore, drifting PAM buoys are not considered further. A review for ASVs and AUVs was recently conducted by Verfuss et al. (2019). If an autonomous mobile PAM system is selected to be used for long-term monitoring, details of the protocols will be provided along with the system's capabilities and specifications.

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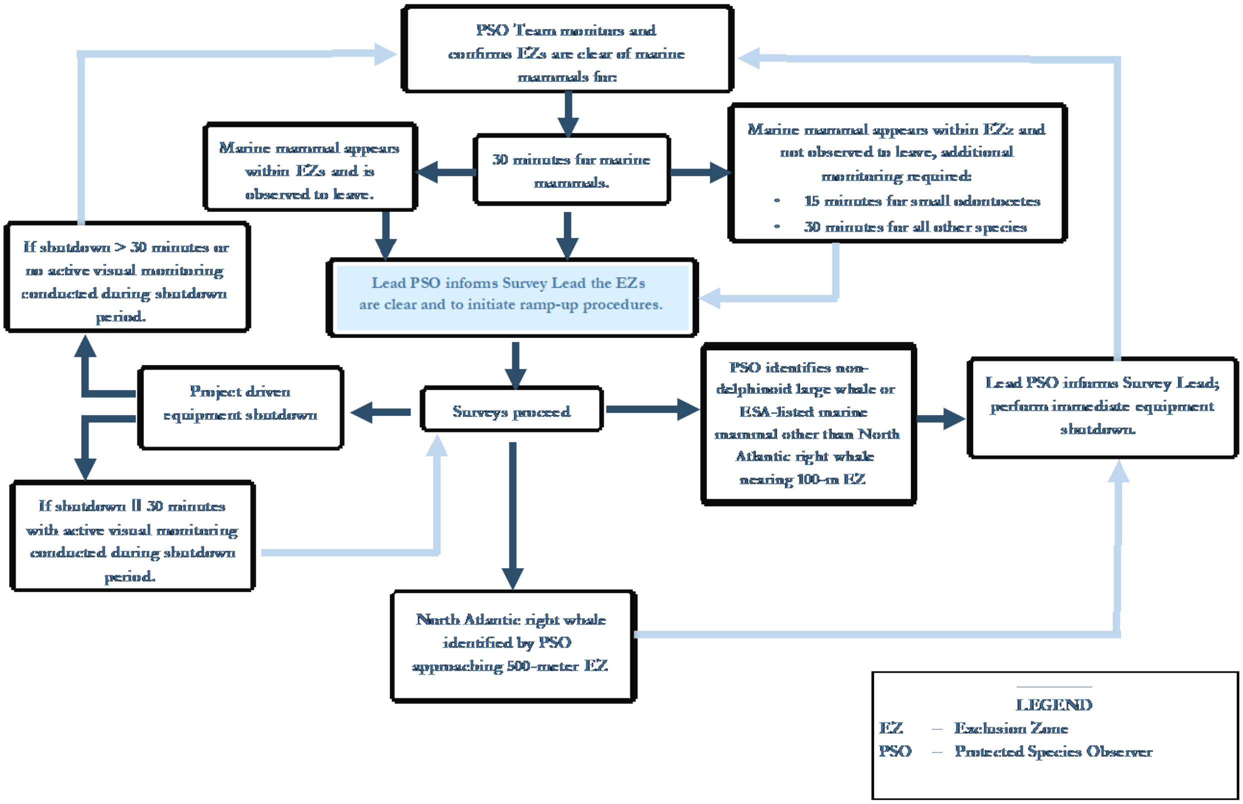
Attachment 1: PSO Communication Flow Diagram

Attachment 1: PSO Communication Flow Diagram



Attachment 2: Examples of Observation Zones and PSO/PAM Team Configurations

Attachment 2: Examples of Observation Zones and PSO/PAM Team Configurations

	Time of Day (Local)																							
	2400-0100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	1900-2000	2000-2100	2100-2200	2200-2300	2300-2400
Piling Vessel																								
PSO1	🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦														
PSO2			🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦												
PSO3					🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦										
PSO4															🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦
PSO5	🟦	🟦															🟦	🟦	🟦	🟦			🟦	🟦
PSO6													🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦		
PSO Vessel																								
PSO1	🟩	🟩	🟩	🟩			🟩	🟩	🟩	🟩														
PSO2			🟩	🟩	🟩	🟩			🟩	🟩	🟩	🟩												
PSO3					🟩	🟩	🟩	🟩			🟩	🟩	🟩	🟩										
PSO4															🟩	🟩	🟩	🟩			🟩	🟩	🟩	🟩
PSO5	🟩	🟩															🟩	🟩	🟩	🟩			🟩	🟩
PSO6													🟩	🟩	🟩	🟩			🟩	🟩	🟩	🟩		
PAM Station																								
PAM1	🟫	🟫			🟫	🟫			🟫	🟫														
PAM2			🟫	🟫			🟫	🟫			🟫	🟫												
PAM3													🟫	🟫			🟫	🟫			🟫	🟫		
PAM4															🟫	🟫			🟫	🟫			🟫	🟫
PAM Station version 2 (1 less PAM Operator)																								
PAM1	🟫	🟫	🟫	🟫									🟫	🟫	🟫	🟫								
PAM2					🟫	🟫	🟫	🟫									🟫	🟫	🟫	🟫				
PAM3									🟫	🟫	🟫	🟫									🟫	🟫	🟫	🟫

Example PSO and PAM operator schedules for monitoring during foundation installation pile driving.

	Time of Day (Local)																							
	2400-0100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	1900-2000	2000-2100	2100-2200	2200-2300	2300-2400
HRG Vessel																								
PSO1						■	■	■	■			■	■			■	■							
PSO2										■	■			■	■			■	■	■	■			
PSO3	■			■	■												▨	■	■			■	■	■
PSO4		■	■	■	■															■	■	■	■	
PSO5	■	■	■			■	▨																	■

Example PSO schedule for monitoring during HRG surveys.

	Time of Day (Local)																
	400-500	500-600	600-700	700-800	800-900	900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	1900-2000	2000-2100
Piling Vessel / PSO Vesel																	
PSO1		🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦						
PSO2				🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦				
PSO3		🟦	🟦			🟦	🟦	🟦	🟦			🟦	🟦				
PSO4	🟩													🟩	🟩	🟩	🟩
PSO5	🟩													🟩	🟩	🟩	🟩

Example PSO schedule for monitoring during pile driving at the landfall construction site. PSO observations indicated by green cells would only be necessary if pile driving occurred on days with longer daylight periods.

Attachment 3: Review of NVD Systems

Attachment 3: Review of NVD Systems

Table 3-1. Technical specifications of infrared (IR) systems selected for review (presented in alphabetical order).[1]

Model[1]	Field of View (Degrees; or Horizx Vert)	Detector Type[2]	IR Focal Length	Resolution	Pan/Tilt
AGM-HS Gen 3 Hand Select Night Vision Monocular	40°	Uncooled LW planar	26 mm	64-72 lp/mm[3]	N/A
Current Scientific Corporation Night Navigator 2526	8.3 - 52.5° Choice of multiple lenses available	Uncooled LW planar	25 - 75 mm 3X optical zoom	640 x 480 1280x1024 expected in year 2021	Variable 360° pan at 40° per second, tilt -90° / +30°
Current Scientific Corporation NN6056	1.7 - 32.2°	Cooled MW	22 X optical zoom	640x512	
Current Scientific Corporation NN8000	180/360° FOV	Uncool LW coupledwith Cooled MW	Uncooled – fixed 52.5° Cooled Varying	Uncooled 1280x1024 cooled up to 1280x1024	Uncooled 360° continuous Cooled 360° with a seek rate of 90° per second
FLIR M400 Thermal Machine Camera	6 - 18°	Uncooled LW planar	35 - 105 mm 4X optical & 4X digital zoom	640 x 480	variable 360°, +/- 90° tilt
FLIR Ocean Scout 640	18 x 14	Uncooled LW planar	4X digital zoom	640 x 512	N/A
FLIR MD625 Thermal Imager	25 x 20	Uncooled LW planar	25 mm 4X zoom	640 x 480	N/A
FLIR M324XP	24 x 18	Uncooled LW planar	19 mm 2X zoom	320 x 240	360° pan +/- 90° tilt
FLIR Armasight CommandPro 336	13 x 10	Uncooled LW planar	25 mm 4X zoom	640 x 480	N/A
FLIR ThermaCam Ex series	45 x 34	Uncooled LW planar	unknown, no zoom	120 x 90	N/A
NVTS Reliant 640HD	15.5 x 11.6	Uncooled LW planar	40 mm 4X digital zoom	640 x 480	360° pan -15x90 reversible

Model[1]	Field of View (Degrees; or Horizx Vert)	Detector Type[2]	IR Focal Length	Resolution	Pan/Tilt
NVTS Guardian 4HD	25.5 x 21	Uncooled LW Planar	15 – 300 mm 20X optical zoom	640 x 512	360° pan -60 x 70 reversible
Rheinmetall AIMMMS	360 x 18	Cooled LW rotating line scanner	unknown	640 x 480	rotating line scanner giving 360° FOV and 12° tilt
Seiche HD Thermal Camera	18°	Uncooled LW planar	4X digital zoom	640 x 480	120° pan
Seiche Dual Camera System (supersedes HD Thermal above)	Six options - 7.5 mm to 50 mm fixed	Uncooled LW planar	8 X digital zoom	640x480	+/- 168° pan -90 x 25
Xenics	4.2 - 42° range of lenses	Cooled MW planar	Up to 210 mm	640 x 480	fixed

[1] Listed is published information. Omissions are due to either manufacturer or research data not readily available.

[2] Most uncooled planar-based detectors are Vanadium Oxide (VoX) long–wavelength (*i.e.*, 7.5–14μm) microbolometer, thermal sensitivity of <0.05°C unless noted otherwise.

[3] lp/mm: a metric for resolution indicated as 'line pairs per millimeter'.

Source:(Smultea et al. 2021).

Table 3-2. Technical specifications of night vision device (NVD; i.e., low-light amplifying/enhancing) imaging systems known to be in use for detecting cetaceans at sea.

Model	FOV (Degrees)	Detector type	Focal length	Resolution	Pan/Tilt
ATN PVS7-3 night vision goggles	60°	Unknown	27 mm	64 lp/mm	N/A
Electrophysics Astroscope[1]	Depends on lens type used	Unknown	Depends on lens type used	Depends on lens type used	N/A

[1] Manufacturer data currently unavailable at the time of this writing. This device is mentioned here to acknowledge its recent use for sea-based mitigation work(e.g., Lee and Nenadovic, 2017).

Attachment 4: Review of PAM Systems

Attachment 4: Review of PAM Systems

Table 4-1. PAM Hardware Specifications and Capabilities.

PAM HARDWARE SPECIFICATIONS AND CAPABILITIES TABLE Last updated 9-Oct 2019																		
Manufacturer/Provider	System name/ Model(s)	System Type	Data Viewable in Real-Time?	Modular/ multiple hydrophone types?	Calibrated?	Type of Calibration	Multi- Channel (Y/N/UNK)	Max # of channels	Max Sample Rate (kHz)	Bitrate (resolution)	Dynamic Range (dB)	Max Storage Capacity (TB)	Max Battery Duration	Max Depth (m)	Form Factor	Dimensions	Battery Type	Deployment Vessel
WHOI (Baumgartner)	DMON Buoy	AAR, RTB	Y (near-r-t)	Y (LF, MF, HF)	Can be	NR	Y	3	500 kHz	16 bits	NR	32 GB	up to 18 months	200	NR	NR	Alkaline	>70 ft.
WHOI (Baumgartner)	Robots4whales Waveglider	ASV, RTB	Y (near-r-t)	Y (LF, MF, HF)	Can be	NR	Y	3	500 kHz	16 bits	NR	32 GB	up to 4 months	1,000	NR	NR	Lithium	Any
Cornell-BRP (Klinck)	Rockhopper (formerly MARU)	AAR	N	custom	Y	UNK	N	NA	380	24-bit	UNK	10.5 TB	6 months (@ 200 kHz sample rate)	3,500	Spherical	UNK	Lithium	Small Boat (RHIB)
Cornell-BRP (Klinck)	AutoBuoy	AAR, RTB	Y	UNK	UNK	UNK	UNK	NA	UNK	16-bit	UNK	NA	UNK	moored, so limited to shallow water	Large Buoy	UNK	UNK	Large ship
JASCO Applied Sciences	AMARG4	AAR	N	Y: 4	UNK	UNK	Y	4 acoustic, 7 oceanographic sensors	8-512 kHz	24-bit	UNK	10 TB	18 months	6,700	spherical	43.2 cm^3	D-cell	UNK
JASCO Applied Sciences	SPARBuoy	AAR, RTB	Y (near-r-t)	Y (LF, MF, HF)	Can be	NR	Y	16	512 kHz	24-bit	NR	10 TB	up to 6 months	200	cylindrical	NR	Alkaline or Lithium?	>70 ft
JASCO Applied Sciences	3M Observer Buoy	AAR, RTB	Y (near-r-t)	Y (LF, MF, HF)	Can be	NR	Y	16	512 kHz	24-bit	NR	10 TB	up to 18 months	200	NR	NR	Alkaline or Lithium?	>70 ft
JASCO Applied Sciences	0.6M Observer Buoy	AAR, RTB	Y (near-r-t)	Y (LF, MF, HF)	Can be	NR	Y	16	512 kHz	24-bit	NR	10 TB	up to 18 months	200	NR	NR	Alkaline or Lithium?	>70 ft
JASCO Applied Sciences	Datamaran Observer-Saildrone	USV, RTB	Y (near-r-t)	Y (LF, MF, HF)	Can be	NR	Y	16	512 kHz	24-bit	NR	6 TB	up to 4 months	1,000	Catamaran	NR	Alkaline or Lithium?	>70 ft
JASCO Applied Sciences	Waveglider Observer	USV, RTB	Y (near-r-t)	Y (LF, MF, HF)	Can be	NR	Y	16	512 kHz	24-bit	NR	6 TB	up to 4 months	200	Waveglider	NR	Alkaline or Lithium?	>70 ft
SMRU Consulting	CAB	AAR, RTB	Y	Y	Y	Individual	Y	Up to 3 per CAB Platform	500	UNK	UNK	1 TB	2-3 weeks	45	Cylndrical	110 cm × 56 cm	Lithium	Small Boat
RTSYs	Resea	AAR	N	Y	Y	Individual?	Y	4	3hz-500 kHz	24-bit	>100 dB	2 TB	UNK	700	cylindrical	12 cm × 32 cm	alkaline or Li-SOCI2	Small Boat
RTSYs	Multhy	AAR	N	Y	Y	Individual?	Y	16	3hz to 500 kHz	24-bit	>100 dB	2 TB	UNK	700	cylindrical	55 cm × 12 cm	rechargable battery pack	UNK
RTSYs	Sylence	AAR	N	Y	UNK	UNK	N	1	39 kHz to 1250 kHz	16 or 24-bit	UNK	128 GB	45 days, possibly more	200	cylindrical	12 cm × 55 cm	18 alkaline or Li-SoCI2 D cell	small boat
Seiche Ltd.	Autonaut PAM	ASV	Y	Y	Y	electro- acoustic (full system)	Y	4	500	16-bit	90	4 TB	months	20 (customizable tow cable length)	Vessel	5 m × 0.8 m	24 V lead- acid	ship / slipway / beach
Seiche Ltd.	Modular buoy system	RTB	Y	Y	Y	electro- acoustic (full system)	Y	4	500	16-bit	90	essentially unlimited as data recorded are at the telemetry receiver station	20 h (lead-acid), 80 h (lithium)	customizable cable length	Buoy		12 V lead- acid or lithium	ship
Seiche Ltd. / ASV Global	ASV PAM	USV (motorized)	Y	Y	Y	electro- acoustic (full system)	Y	4	500	16-bit	UNK	4 TB	several days; limited by fuel capacity of USV	220 (customizable tow cable length)	UNK	models available from 4-12 m LOA	110-240 V invertor	ship / slipway / beach
Greenridge Sciences	ASAR	AAR	N	UNK	UNK	1 omni-directional, 2 directional	Y	3	1 kHz	16-bit	UNK	60 GB	116 days, continuous recording, no data compression	100	UNK	26” × 26” square base, ~26” high (includes frame)	custom alkaline D- cell battery pack	UNK
Greeneridge Sciences	DASAR	AAR	N	UNK	UNK	1 omni-directional, 2 directional	Y	2	up to 96 kHz	16-bit	UNK	2 TB	200 days for 1-channel continuous recording @ 96 kHz sample rate, assuming 60% data compression; 100 days for 2-channel continuous recording @ 96 kHz sample rate, assuming 60% data compression	750 (2,100 without transponders)	UNK	35” × 8” (60” long with frame)	custom alkaline C- cell battery pack	UNK
Greeneridge Sciences	DASAR-CI	AAR	N	UNK	UNK	3 omni-directional	Y	3	5 kHz	16-bit	UNK	512 GB	145 days, continuous recording, no	100	UNK	triangular base w/57” sides, 20”	5 rechargeable batteries	UNK

PAM HARDWARE SPECIFICATIONS AND CAPABILITIES TABLE Last updated 9-Oct 2019

Manufacturer/Provider	System name/ Model(s)	System Type	Data Viewable in Real-Time?	Modular/ multiple hydrophone types?	Calibrated?	Type of Calibration	Multi- Channel (Y/N/UNK)	Max # of channels	Max Sample Rate (kHz)	Bitrate (resolution)	Dynamic Range (dB)	Max Storage Capacity (TB)	Max Battery Duration	Max Depth (m)	Form Factor	Dimensions	Battery Type	Deployment Vessel
													data compression			high (includes frame)		
Wildlife Acoustics	Song Meter 4 (SM4) Series	AAR	N	Y (hydrophones by HTI)	Y	UNK	Y	2	96 kHz	16-bit		1 TB (2x 512 SD cards)	400 days (duty cycled?)	UNK	Cylindrical	UNK	Alkaline or NiHM (4 D cell)	
DBV Technologies	Customized	AAR, RTB	P	UNK	Y	UNK	Y	UNK	User defined	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK
DesertStar Systems	SonarPoint / Multiple models& configurations	AAR, RTB**	Y*	Y	Y	Y	Y (units can be time-synchronized)	UNK	415 kHz	16-bit	95 dB	8 TB (up to 8 SD cards)	For -8 (eight slot/quad battery) version: 115 days @ 25kHz sample rate, 96 days @ 100kHz sample rate, 56 days @ 416 kHz sample rate	300 or 1,000	cylindrical	6.5"L x 2.5"D (-2 version), 15.7"L x 2.5"D (-8 version)	Rechargeable lithium ion	small boat
Ocean Instruments	SoundTrap ST300	AAR, RTB	N	UNK	Y	Factory OCR Calibration Certificate, self-calibration check, pistonphone coupler available	UNK	UNK	STD Model: 20 to 60 Hz; HF model: 20 to 150 Hz	16-bit	UNK	256 GB	70 days	500	Cylindrical	200mm x 60mm	D-cell batteries	UNK
Ocean Instruments	SoundTrap ST4300	AAR	N	Y	Yes	Self-calibration check	Y	4	288 kHz x 4; 20 Hz - 90 kHz ± 3 dB	4 x 16-bit SAR	UNK	128 GB	30 Days	500	Cylindrical	200mm x 60mm	D-cell batteries	UNK
Ocean Instruments	SoundTrap ST500	AAR	N	UNK	Yes	Factory calibration certificate	UNK	UNK	288 kS/sec; 20 Hz – 90 kHz	16-bit	UNK	1 TB	180 Days	500	Cylindrical	350mm x 100mm	D-cell batteries	UNK
SIO/UCSD	HARP	AAR	N	Y, custom	Y	UNK	Can Be	UNK	>400 kHz	UNK	UNK	>1 TB	Several months	>1000	Cylindrical	Depends on platform used	Lithium Batteries	Large Vessel with A- frame
MTE	AURAL-M2	AAR	N	UNK	UNK	UNK	UNK	UNK	10 to 16,384 kHz	16-bit	UNK	1 TB	365 days	300	Cylindrical	5.75” x 35.375” or 47.375” or 70”	12V Zinc	UNK
MTE	µAURAL	AAR	N	UNK	UNK	UNK	UNK	UNK	UNK	24-bit	UNK	32 GB	300 hours	100	Cylindrical	3" x 18"	Rechargeabl e NiMH	UNK
Thayer-Mahan	Outpost	ASV	Y		Y	J-9 Projector Calibration	Y	32 / 64 (1)	2.52 kHz	25.2	109	4 TB	>1 year (2)	183 (3)	Linear Array	38.4 / 76.8 m acoustic section	Li-ion	Various
Autonomous Marine Systems Inc. (AMS)	Datamaran	ASV	Yes	Y	Y	N/A	Y	No limit	Whatever the attached PAM equipment is capable of. The DM can transmit 4 channel, 24 bit, 100kHz sampled acoustic waveforms to shore when within 200 km	24 bit	Depends on specific hydrophone + pre-amp system selected	Practically unlimited. Tens of TBs	Unlimited as 1980Watt PV panel name-plate rating and 3072WHr battery capacity available	Can tow array at 100 ft	Catamaran (See website for dimensions of equipment that can be located inside hulls of Datamaran)	1m x 0.2m x 0.2 m?	N/A	UNK
RS Aqua	Orca	AAR, RTB	Y	1 to 5	Y	Multipoint frequency response	Y	5	384	16-bit	95.5	4 TB	155 days (continuous recording)	3,500	Cylindrical with cabled hydrophone option	17.8 cm diameter, 28 - 77.5 cm length, 6.7 - 39 kg	Alkaline or Lithium	UNK
RS Aqua	Porpoise	AAR, RTB	Y (both real time and autonomous options)	1	N	Single point frequency response	N	1		24 bit	110	4 TB	293 days continuous recording	2,000	Cylindrical with cabled hydrophone option	7 cm diameter x 23.3 cm length, 4.5 lbs	Alkaline or Lithium	UNK

PAM HARDWARE SPECIFICATIONS AND CAPABILITIES TABLE Last updated 9-Oct 2019

Manufacturer/Provider	System name/ Model(s)	System Type	Data Viewable in Real-Time?	Modular/ multiple hydrophone types?	Calibrated?	Type of Calibration	Multi- Channel (Y/N/UNK)	Max # of channels	Max Sample Rate (kHz)	Bitrate (resolution)	Dynamic Range (dB)	Max Storage Capacity (TB)	Max Battery Duration	Max Depth (m)	Form Factor	Dimensions	Battery Type	Deployment Vessel
Liquid Robotics/SMRU Instrumentation/Teledyne-Reson	Blackbeard (AWG)	ASV	Y (only spectral band metrics that are sent in small burst data report; wav audio files not available in real-time)	1	Y (possible to add more hydrophones)	calibration by Reson and SAIL	Yes	4	500 kHz	24-bit	UNK	512 GB	>1 month	10	liquid robotics waveglider towing decimus towbody		lithium-ion	small boat
Ocean Sonics	IcListen AF(L)	AAR	Y*	Y (Ocean Sonics Hydrophones)	Y	UNK	N	1	512 kHz	16 or 24 bit	106	128 GB	10 hr	200 or 3,500 (plastic or titanium housing)	Cylindrical	48 x 165 mm	UNK	small boat
Ocean Sonics	IcListen AF	AAR	Y*	Y (Ocean Sonics Hydrophones)	Y	UNK	N	1	512 kHz	16 or 24 bit	106	129 GB	10 hr	201 or 3,500 (plastic or titanium housing)	Cylindrical	49 x 165 mm	UNK	small boat
Ocean Sonics	IcListen HF(L)	AAR	Y*	Y (Ocean Sonics Hydrophones)	Y	UNK	N	1	512 kHz	16 or 24 bit	95	130 GB	10 hr	202 or 3,500 (plastic or titanium housing)	Cylindrical	50 x 165 mm	UNK	small boat
Ocean Sonics	IcListen HF	AAR	Y*	Y (Ocean Sonics Hydrophones)	Y	UNK	N	1	512 kHz	16 or 24 bit	95	131 GB	10 hr	203 or 3,500 (plastic or titanium housing)	Cylindrical	51 x 165 mm	UNK	small boat
Ocean Sonics	IcListen X2	AAR	Y*	Y (Ocean Sonics Hydrophones)	Y	UNK	N	1	512 kHz	16 or 24 bit	95	132 GB	10 hr	204 or 3,500 (plastic or titanium housing)	Cylindrical	52 x 165 mm	UNK	small boat
Ocean Sonics	IcListen R-Type	AAR	Y*	Y (Reson Hydrophone)	UNK	UNK	N	1	512 kHz	16 or 24 bit	90	133 GB	10 hr	900	Cylindrical	53 x 165 mm	UNK	small boat
Loggerhead Instruments	Snap	AAR	N	Y (3 hydrophone models from HTI)	Y	UNK	N	1	96 kHz	UNK	Depends on gain settings and hydrophones	128 GB	8 days (continuous); 190 days (10min on/off duty cycled)		Cylindrical	16 x 2.875"	3 alkaline D-cell batteries	small boat
Loggerhead Instruments	LS1 Multi-Card Recorder	AAR	N	Y (HTI Hydrophones)	Y	UNK	Y (Stero possible)	2	97 kHz	UNK	Depends on gain settings and hydrophones	256 GB (expandable)	50 days (continuous)	300	Cylindrical	17″x4.5″	12 alkaline D-cell batteries	small boat
Loggerhead Instruments	LS1x Multi-Card Recorder	AAR	N	Y (HTI Hydrophones)	Y	UNK	Y (Stero possible)	2	98 kHz	UNK	Depends on gain settings and hydrophones	256 GB (expandable)	100 days? (LS1X has 2x battery capacity of LS1)	3,000 (aluminum housing)	Cylindrical	25″x4.5″	24 alkaline D-cell batteries	small boat
Loggerhead Instruments	Medusa	RTB (noise calculations)	Y	UNK	UNK	UNK	N	1	44.1 kHz	UNK	UNK	64 GB	UNK	1m?	Cylindrical	24" x 3"	lithium ion (8x 5Ah; Rechargeable)	small boat
MSEIS	WISDOM Data	RTB	Y	Y, high and low sensitivity options	Upon request	Dependent on customer requirement	Y	4	1000 kHz	16 bit	Dependent on hydrophones used	120 GB (expandable)	40+ hours in darkness, indefinite when solar powered	TBC	Cylindrical buoy	1250mm diameter x 2.5m height above water	2x 12V SLA 22Ah	Deployment by crane

Legend/Abbreviations:	N	No	UNK	unknown or unavailable
	Y	Yes	AAR	Autonomous Acoustic Recorder
	P	Possible	RTB	Radio Telemetered (Moored, Acoustic) Buoy
	TR	Terabyte	GB	Gigabyte
	kHz	kilohertz	dB	decibel(s)
	NR	No response to request	AUV	Autonomous Underwater Vehicle
	NA	Not applicable or relevant	ASV/USV	Autonomous Surface Vehicle/Unmanned Surface Vehicle (e.g., waveglider)

Information compiled by Tom Norris, Biowaves Inc.

Table 4-2. PAM Technology monitoring types.

			Monitoring Type				
			Mitigation		Regional Long-Term	Tracking	
PAM Technology	Vehicle		Pile Driving	OTHER?		Local	Regional
PAM	Autonomous Recorders and Real-time Systems	Seafloor			X	X	P
		Moored	X	X	X	X	P
	Passively (buoyancy/ wind) powered AV	AUV		X	P		
		ASV	P	X	P	P	P
	Drifter		P	X	P	P	P

X = capable of monitoring

P = possible under certain conditions or circumstances (e.g., low currents or sea states, or if numerous devices are deployed and data can be integrated)

Attachment 5: Protected Species Reporting Contact Information for the Project

Attachment 5: Protected Species Reporting Contact Information for the Project

Table 5-2. National Marine Fisheries Service.

USCG District	Phone Numbers for Right Whale Sightings, or for Entangled, Stranded, Injured or Dead Marine Mammals	
US Coast Guard	TBD	TBD

Table 5-2. National Marine Fisheries Service.

NMFS Contact	Phone Number and email for Right Whale Sightings, or for Entangled, Stranded, Injured or Dead Marine Mammals	
Office of Protected Resources (OPR)	301-427-8401	TBD by agency
Greater Atlantic Regional Fisheries Office (GARFO)	TBD by agency	TBD by agency
Marine Mammal and Sea Turtle Stranding and Entanglement Hotline Program/Regional Stranding Coordinator **(New England)**	866-755-6622	TBD by agency

Table 5-3. BOEM.

NMFS Contact	Phone Number and email for Right Whale Sightings, or for Entangled, Stranded, Injured or Dead Marine Mammals	
BOEM Offshore Wind Division	TBD by agency	TBD by agency

Attachment 6: Vessel Strike Avoidance Plan

Attachment 6: Vessel Strike Avoidance Plan

To mitigate potential impacts of vessel strikes, Revolution Wind will adhere to the following *Base Conditions*.

Base Conditions:

- **Training***:* All personnel working offshore will receive training on marine mammal, sea turtle, and Atlantic sturgeon awareness and vessel strike avoidance measures.
- **Speed/Approach Constraints**: All vessels will adhere to current NOAA vessel guidelines for approach distances and mandatory measures stipulated in regulations governing the approach to North Atlantic Right Whales and the Right Whale Speed Rule. (Note: Voluntary measures within a DMA are addressed separately in the Standard and Adaptive Plan detailed below).
- **Approach Constraints**: Vessels will avoid marine mammals as described below:
  - All species
    - For all marine mammal observations, all vessels underway must not divert or alter course in order to approach.
    - Any vessel underway must avoid excessive speed or abrupt changes in direction.
    - When a marine mammal(s) is sighted while a vessel is underway, the vessel must take action as necessary to avoid violating the relevant separation distances (e.g., attempt to remain parallel to the animal's course).
    - Exceptions:
    - Limitations on approach do not apply where compliance would create an imminent and serious threat to a person, vessel, or aircraft
    - Limitations on approach do not apply when approaching to investigate an entanglement or injury, or to assist in the disentanglement or rescue of a whale, provided that permission is received from NMFS or a NMFS designee prior to the approach
    - Limitations on approach do not apply to the extent that a vessel is restricted in her ability to maneuver, and because of the restriction, cannot comply with the limitation on approach.
  - North Atlantic Right Whale
    - By regulation (50 CFR §224.103(c)), approach (including by interception) within 500 yards (460 m) of a right whale by vessel, aircraft, or any other means is prohibited.
    - If within 500 yards (460 m) of a right whale: (1) If underway, a vessel must steer a course away from the right whale and immediately leave the area at a slow safe speed;
    - Exceptions stated in the "All Species" section above are applicable for NARW.
  - Other Large Whales
    - Vessel speeds will immediately be reduced to 10 knots or less when any large whale,

        mother/calf pair, or large assemblage of non-delphinoid cetaceans is observed near (within 100 m) an underway vessel.

    - All vessels must maintain a minimum separation distance of 100 m from sperm whales and non-NARW baleen whales. If one of these species is sighted within 100 m of an underway vessel, that vessel must shift the engine to neutral. Engines must not be engaged until the whale has moved outside of the vessel's path and beyond 100 m.
    - Exceptions stated in the "All Species" section above are applicable for large whales.
  - Dolphins, porpoises, seals
    - All vessels must, to the maximum extent practicable, attempt to maintain a minimum separation distance of 50 m from all delphinoid cetaceans and pinnipeds. If a delphinoid cetacean or pinniped is sighted within 50 m of an underway vessel, that vessel must shift the engine to neutral. Engines must not be engaged until the animal(s) has moved outside of the vessel's path and beyond 50 m.
    - Exception to separation distance and shifting engines to neutral for delphinoid cetaceans and pinnipeds that approach the vessel (e.g., bow-riding dolphins).
    - Exceptions stated in the "All Species" section above are applicable for dolphins, porpoises and seals.

- **Monitoring/Mitigation**: Vessel operators and crew will maintain a vigilant watch for marine mammals and sea turtles, and slow down or maneuver their vessels as appropriate to avoid a potential intersection with a marine mammal or sea turtle.
- **Situational Awareness/Common Operating Picture**: Revolution Wind will establish a situational awareness network for marine mammal and sea turtle detections through the integration of sighting communication tools such as Mysticetus, Whale Alert, WhaleMap, etc. Sighting information will be made available to all project vessels through the established network. REV's Marine Coordination Center will serve to coordinate and maintain a Common Operating Picture. In addition, systems within the Marine Coordination Center, along with field personnel, will:
  - Monitor the NMFS North Atlantic right whale reporting systems daily;
  - Monitor Coast Guard VHF Channel 16 throughout the day to receive notifications of any sighting; and
  - Monitor any existing real-time acoustic networks.

In addition to the above *Base Conditions*, Revolution Wind will implement a *Standard Plan,* or an *Adaptive Plan* as presented below. Revolution Wind intends for these plans to be interchangeable and implemented throughout both the construction and operations phases of the project. Revolution Wind will submit a final *NARW Vessel Strike Avoidance Plan* at least 90 days prior to commencement of vessel use that details further the Adaptive Plan and specific monitoring equipment to be used. The plan will, at minimum, describe how PAM, in combination with visual observations, will be conducted to ensure the transit corridor is clear of NARWs. The plan will also provide details on the vessel-based observer protocols on transiting vessels.

Standard Plan:

- Implement *Base Conditions* described above.

- **Between November 1st and April 30th**: Vessels of all sizes will operate port to port (from ports in NY, CT, RI and MA) at 10 knots or less. Vessels transiting from other ports outside those described will operate at 10 knots or less when within any active SMA or within the Wind Development Area (WDA), including the lease area and export cable route.
- **Year Round:** Vessels of all sizes will operate at 10 knots or less in any DMAs.
- **Between May 1st and October 31st**: All underway vessels (transiting or surveying) operating at >10 knots will have a dedicated visual observer (or NMFS approved automated visual detection system) on duty at all times to monitor for marine mammals within a 180° direction of the forward path of the vessel (90° port to 90°starboard). Visual observers must be equipped with alternative monitoring technology for periods of low visibility (e.g., darkness, rain, fog, etc.). The dedicated visual observer must receive prior training on protected species detection and identification, vessel strike minimization procedures, how and when to communicate with the vessel captain, and reporting requirements. Visual observers may be third-party observers (i.e., NMFS-approved PSOs) or crew members.

Adaptive Plan:

The Standard Plan outlined above will be adhered to except in cases where crew safety is at risk, and/or labor restrictions, vessel availability, costs to the project, or other unforeseen circumstance make these measures impracticable. To address these situations, an *Adaptive Plan* will be developed in consultation with NMFS to allow modification of speed restrictions for vessels. Should Revolution Wind choose not to implement this *Adaptive Plan,* or a component of the *Adaptive Plan* is offline (e.g., equipment technical issues), Revolution Wind will default to the *Standard Plan* (described above). The *Adaptive Plan* will not apply to vessel subject to speed reductions in SMAs as designated by NOAA's Vessel Strike Reduction Rule.

Proposed measures may include:

Implement *Base Conditions* described above.

- **Year Round**: A semi-permanent acoustic network comprising near real-time bottom mounted and/or mobile acoustic monitoring platforms will be installed such that confirmed North Atlantic right whale detections are regularly transmitted to a central information portal and disseminated through the situational awareness network.
    - The transit corridor and WDA will be divided into detection action zones.
    - Localized detections of NARWs in an action zone would trigger a slow-down to 10 knots or less in the respective zone for the following 12 h. Each subsequent detection would trigger a 12-h reset. A zone slow-down expires when there has been no further visual or acoustic detection in the past 12 h within the triggered zone.
    - The detection action zones size will be defined based on efficacy of PAM equipment deployed and subject to NMFS approval as part of the *NARW Vessel Strike Avoidance Plan.*
- **Year Round**: All underway vessels (transiting or surveying) operating >10 knots will have a dedicated visual observer (or NMFS approved automated visual detection system) on duty at all times to monitor for marine mammals within a 180° direction of the forward path of the vessel (90° port to 90°starboard). Visual observers must be equipped with alternative monitoring technology for periods of low visibility (e.g., darkness, rain, fog, etc.). The dedicated visual observer must receive prior training on protected species detection and identification, vessel strike minimization procedures, how and when to communicate with the vessel captain, and reporting requirements. Visual observers may be third-party observers (i.e., NMFS-approved

PSOs) or crew members.

- **Year-round**: any DMA is established that overlaps with an area where a project vessel would operate, that vessel, regardless of size when entering the DMA, may transit that area at a speed of >10 knots. Any active action zones within the DMA may trigger a slow down as described above.
- If PAM and/or automated visual systems are offline, the *Standard Plan* measures will apply for the respective zone (where PAM is offline) or vessel (if automated visual systems are offline).

Attachment 7: Sound Field Verification Plan

Attachment 7: Sound Field Verification Plan

Introduction

This underwater noise measurement plan for sound field verification (SFV) is proposed in connection with the planned foundation installation activities for Revolution Wind.

Purpose

The aim of the proposed measurement exercise is to obtain a dataset that can be used to verify prognosed sound levels submitted in underwater noise assessment and used as input to predict ranges to acoustic thresholds that may result in injury or behavioral disruption of marine mammals, sea turtles and/or fish near the construction area. It is, therefore, necessary to conduct underwater noise measurements to verify the prognosed sound levels were comparable/lower than those measured in field and any estimated animal exposures were accurate/conservative enough. Impact pile driving is considered as the installation method for the proposed measurement plan. Amendments to the plan for other installation methods are discussed in the end of this document.

Specifics of the measurement plan

All measurements will be performed according to the ISO 18406:2017 standard. The foundation installation noise will be measured using omnidirectional hydrophones capable of measuring frequencies between 20 Hz and 20 kHz. The hydrophone signals will be verified before deployment and after recovery by means of a pistonphone calibrator on deck or similar method. Each measurement position will consist of two hydrophones at approximately mid depth and 2 m above the seafloor. Deployment will be made using a heavy weight as anchor - to prevent equipment drifting (typically total ballast weight exceeding 100 kg) – as depicted in **Figure 7-1**. Deployment and retrieval position of each hydrophone will be recorded using hand-held GPS equipment, or alternative precise method. The hydrophones will be placed at various distances from the installation location as depicted in **Figure 7-2**.

The equipment, methodology, placement, and analysis will be the same for all pile measurements. Output results will include sound pressure level and frequency context. Measurements will be conducted in a detailed configuration at the beginning of installation. An example of the measurement configuration is provided in **Figure 7-2.**

To validate the estimated sound field, SFV measurements will be conducted during pile driving of the first three monopiles installed over the course of the project, with noise attenuation activated. A SFV Plan will be submitted to NMFS for review and approval at least 90 days prior to planned start of pile driving. This plan will describe how Revolution Wind will ensure that the first three monopile installation sites selected for SFV are representative of the rest of the monopile installation sites and, in the case that they are not, how additional sites will be selected for SFV. This plan will also include methodology for collecting, analyzing, and preparing SFV data for submission to NMFS. The plan will describe how the effectiveness of the sound attenuation methodology will be evaluated based on the results.

In the event that Revolution Wind obtains technical information that indicates a subsequent monopile is likely to produce larger sound fields, SFV will be conducted for those subsequent monopiles. Revolution Wind will provide the initial results of the SFV measurements to NMFS in an interim report after each monopile installation for the first three piles as soon as they are available but no later than 48 hours after each installation.

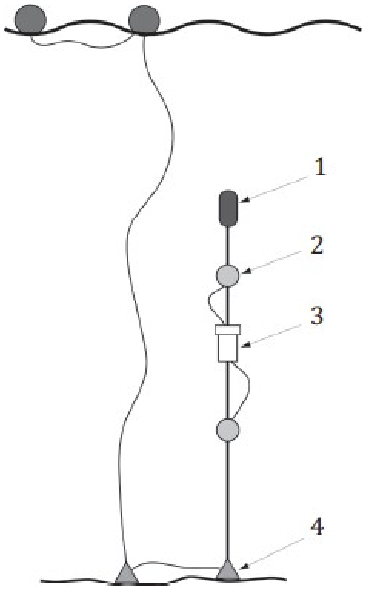


Figure 7-1. Principle sketch of hydrophone deployment. 1 is the float, 2 is the hydrophone, 3 is the recorder and 4 is the bottom weight(s). From ISO18406:2017.

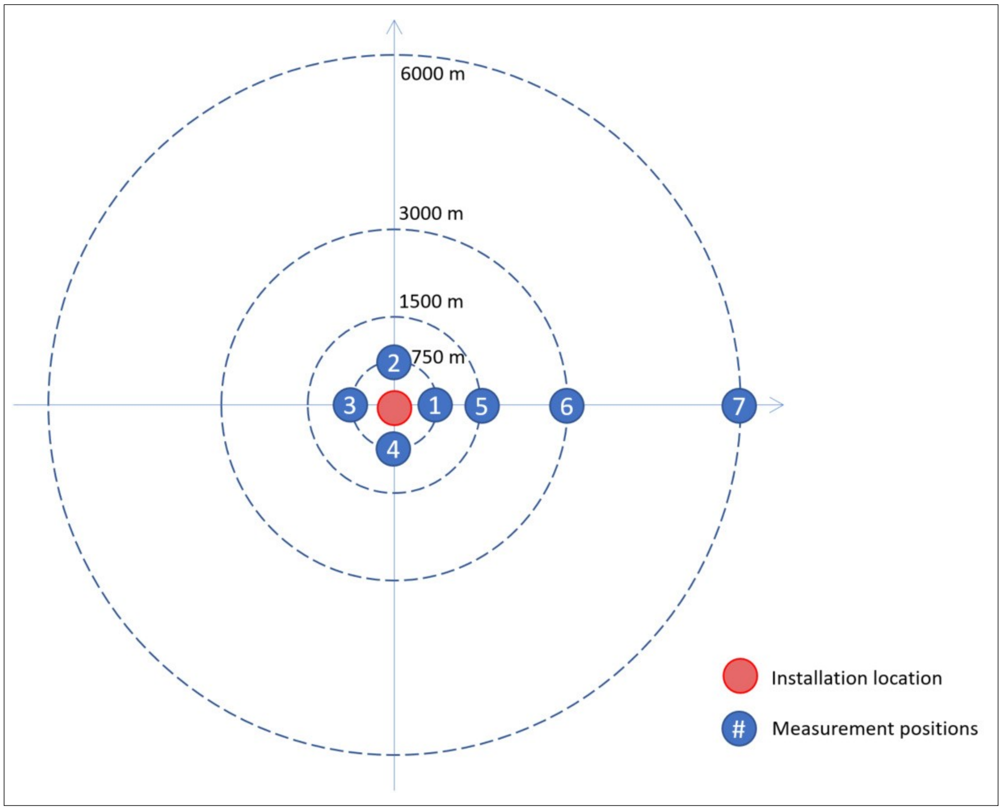


Figure 7-2 Sample sound field verification showing layout of proposed measurement locations. Specific locations are only examples and may change.

Level A Harassment and Level B Harassment Zone Distance Verification for impact pile driving of WTG foundations

Revolution Wind will conduct SFV under the following circumstances:

- Impact driving of the first three monopiles installed over the duration of the LOA;
- If Revolution Wind obtains technical information that indicates a subsequent monopile is likely to produce larger sound fields; and
- At least three monopiles of the same size if a reduction to the clearance and/or shutdown zones is requested.

Revolution Wind will conduct a SFV to empirically determine the distances to the isopleths corresponding to Level A harassment and Level B harassment thresholds, including at the locations corresponding to the modeled distances to the Level A harassment and Level B harassment thresholds, or as agreed to in the SFV Plan. As a secondary method, Revolution Wind may also estimate distances to Level A harassment and Level B harassment thresholds by extrapolating from in situ measurements at multiple distances from the monopile, including at least one measurement location at 750 m from the pile.

For verification of the distance to the Level B harassment threshold, Revolution Wind will report the measured or extrapolated distances where the received levels SPL_{rms} decay to 160 dB, as well as integration time for such SPL_{rms}. If initial SFV measurements indicate distances to the isopleths corresponding to Level A harassment and/or Level B harassment thresholds are greater than the distances predicted by modeling assuming 10 dB attenuation, Revolution Wind will implement additional sound attenuation measures prior to conducting additional pile driving. Initial additional measures may include improving the efficacy of the implemented noise attenuation technology and/or modifying the piling schedule to reduce the sound source. If modeled zones cannot be achieved by these corrective actions, Revolution Wind will install an additional NMS to achieve the modelled ranges. Each sequential modification will be evaluated empirically by SFV. Additionally, in the event that SFV measurements continue to indicate distances to isopleths corresponding to Level A harassment and Level B harassment thresholds are consistently greater than the distances predicted by modeling, NMFS may expand the relevant clearance and shutdown zones and associated monitoring measures.

If initial SFV measurements indicate distances to the isopleths corresponding to the Level A harassment and Level B harassment thresholds are less than the distances predicted by modeling assuming 10 dB attenuation, Revolution Wind may request a modification of the clearance and shutdown zones for impact pile driving. For a modification request to be considered by NMFS, Revolution Wind must have conducted SFV on at least 3 piles to verify that zone sizes are consistently smaller than predicted by modeling. If a subsequent piling location is selected that was not represented by previous locations (e.g., substrate composition, water depth), SFV will be conducted. Revolution Wind will request modifications of zones based on the SFV results as detailed in the following section.

Modification of shutdown and monitoring zones

Revolution Wind may request a modification to the size of shutdown and monitoring zones based on the results of pile measurements. The zones will be determined as follows:

- The large whale pre-start clearance zone will be calculated as the radius of the maximum Level A exposure range of any mysticete.
- The right whale pre-start clearance zone will be equal to the marine mammal Level B zone.
- The large whale, including right whale, shutdown zone will be calculated as the radius of the maximum Level A exposure range of any mysticete.

- The harbor porpoise and seal pre-start clearance zone and shutdown zone will be determined as the extent of the level A exposure range.
- For all mid-frequency cetaceans other than sperm whales, the pre-start clearance and shutdown zones will effectively be the perimeter of the NMS because the physical placement of the NMS will preclude take (i.e., the Level A zone is smaller than the distance of the NMS from the pile) (see **Table 7** of the PSMMP).

In the case of expanded clearance and shutdown zones, zone monitoring will be achieved through a combined effort of passive acoustic monitoring and visual observation. Based on the results of the SFV measurements, the secondary vessel will be placed at the outer limit of the subsequent Large Whale Shutdown Zone as displayed in **Figure 3** of the PSMMP. No additional PSOs or PSO vessels are proposed to visually monitor the expanded zones.

The placement of PAM will sufficiently cover any expanded clearance or shutdown zones. As described in the PSMMP, the total number of PAM stations and array configuration will depend on the size of the zone to be monitored, the amount of noise expected in the area, and the characteristics of the signals being monitored. Acoustic monitoring will include and extend beyond the Large Whale Pre-Start Clearance Zone. Orsted will be prepared to flex the PAM configuration to be capable of monitoring the resulting measured (SFV) zone up to the maximum potential Level B zone.

Attachment 8: Reporting Plan

Attachment 8: Reporting Plan

Introduction

The following tables provide a comprehensive schedule of reporting for various outputs of data collected for specified activities.

Table 1: Protected Species Reporting

Report	Content	Frequency	Method	Applicable Activity
Immediate/Within 24 -48 Hours				
Injured or Dead Marine Mammals (non-activity cause)	TBD	As soon as feasible; no longer than 24 hours	Via Whale Alert; NMFS SAS (phone); PR.ITP.MonitoringReports@noaa.gov	All
Injury/Death/Vessel Strike of Marine Mammals (caused by activity)	TBD	Immediate (and cease specified activity)	NMFS SAS (phone); PR.ITP.MonitoringReports@noaa.gov; NMFS OPR (301-427-8401)	All
NARW Visual Sighting	TBD	As soon as feasible; no longer than 24 hours	Via Whale Alert; NMFS SAS (phone); PR.ITP.MonitoringReports@noaa.gov	All
NARW Acoustic Detection (confirmed)	TBD	As soon as feasible; no longer than 24 hours	nmfs.pacmdata@noaa.gov or via Whale Alert; PR.ITP.MonitoringReports@noaa.gov	Piling and Detonation
Interim Sound Field Verification Report	TBD	Within 48 hours of each pile and detonation measured	PR.ITP.MonitoringReports@noaa.gov	Piling and Detonation
Weekly				
Weekly PSO/PAM Report	daily start and stop of all pile-driving activities, the start and stop of associated observation periods by PSOs, details on the deployment of PSOs, a record of all detections of marine mammals, any mitigation actions (or if mitigation actions could not be taken, provide reasons why), and details on the noise attenuation system(s) used and its performance; vessel transits; and piles installed	Wednesday following a Sun-Sat week.	PR.ITP.MonitoringReports@noaa.gov and nmfs.pacmdata@noaa.gov	Construction Activity Only

Report	Content	Frequency	Method	Applicable Activity
Final /Annual Reports				
Final (Draft) SFV Report	TBD	Within 90 days of completion of activities	PR.ITP.MonitoringReports@noaa.gov	Piling and Detonation
Final NARW Acoustic Detection Data	Detection data and metadata	90 days after completion of Piling activity	PR.ITP.MonitoringReports@noaa.gov and nmfs.pacmdata@noaa.gov	Piling and Detonation
Annual: Annual (Draft) Visual and Acoustic Monitoring Report	TBD; Summarized by activity type (e.g. piling, onshore installation works; Detonation and HRG)	April 1st of each year of the Rule, provide report of prior calendar year	PR.ITP.MonitoringReports@noaa.gov	All ITA Activity

Table 2: Administrative Reporting

Report	Frequency	Method	Applicable Activity
PSO CVs	Prior to initiation of project activities	TBD	All
Required Training Documentation	Prior to initiation of project activities	TBD	All