United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Draft Request for an Incidental Harassment Authorization to Allow the Non-Lethal Take of Marine Mammals Incidental to High-resolution Geophysical Surveys

January 2020

Submitted to:

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Acronyms and Abbreviations

AMAPPS	Atlantic Marine Assessment Program for Protected Species
ANSI	American National Standards Institute
BIA	Biologically Important Area
BOEM	Bureau of Ocean Energy Management
CeTAP	Cetacean and Turtle Assessment Program
CFR	Code of Federal Regulations
dB	decibel
DMA	Dynamic Management Area
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
ESP	electrical service platform
ft	feet
h	hour
HESS	High Energy Seismic Survey
HF	high frequency (cetacean hearing group)
HRG	high resolution geophysical
Hz	hertz
IEC	International Electrotechnical Commission
IHA	Incidental Harassment Authorization
in	inch
ISO	International Organization for Standardization
IWC	International Whaling Commission
JASCO	JASCO Applied Sciences
kg	kilogram
kHz	kilohertz
kJ	kilojoule
km	kilometer
L_E	cumulative sound exposure level
LF	low frequency (cetacean hearing group)
L_p	sound pressure level
L_{pk}	peak sound pressure level
m	meter
MA ESA	Massachusetts Endangered Species Act
MA WEA	Massachusetts Wind Energy Area
MF	mid-frequency (cetacean hearing group)
mi	mile
MMPA	Marine Mammal Protection Act

ms	milliseconds
μPa	micropascal
MBES	multibeam echosounder
m/s	meter per second
NARW	North Atlantic right whale
NEFSC	Northeast Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
nm	nautical mile
OCS	Outer Continental Shelf
OECC	Offshore Export Cable Corridor
OSP	Optimum Sustainable Population
PAM	passive acoustic monitoring
PBR	Potential Biological Removal
PK	peak sound pressure level
PSO	protected species observer
PTS	permanent threshold shift
PW	phocid in water (hearing group)
s	second
SBP	sub-bottom profiler
SEFSC	Southeast Fisheries Science Center
SEL	cumulative sound exposure level
SL	source level
SMA	Seasonal Management Area
SPL	sound pressure level
SPUE	sightings per unit effort
RI/MA & MA WEAs	Rhode Island/Massachusetts and Massachusetts Wind Energy Areas
rms	root mean square
TTS	temporary threshold shift
UME	Unusual Mortality Event
USBL	ultra-short baseline
U.S.C.	United States Code
USFWS	US Fish and Wildlife Service
Vineyard Wind	Vineyard Wind, LLC
WEA	Wind Energy Area
WTG	wind turbine generator

1. Description of Specified Activity

Vineyard Wind, LLC (Vineyard Wind) is proposing to conduct high-resolution geophysical (HRG) surveys in support of offshore wind development projects (the 'Project[s)]') in Federal and State waters that include Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0501 and Lease Area OCS-A 0522 (together the 'lease areas') and potential offshore export cable corridor (OECC) routes (Figure 1). Vineyard Wind submits this request for Incidental Harassment Authorization (IHA), pursuant to Section 101(a)(5) of the Marine Mammal Protection Act (MMPA (2015) 16 U.S.C. §§1361-1383b, 1401-1406, 1411-1421h) and 50 Code of Federal Regulations (CFR) § 216 Subpart I, allowing for the incidental harassment of small numbers of marine mammals resulting from exposure to regulatory defined sound levels during HRG survey activities.

The regulations set forth in Section 101(a)(5) of the MMPA and 50 CFR § 216 Subpart I allow for the incidental taking of marine mammals by a specific activity if the activity is found to have a negligible impact on the species or stock(s) of marine mammals and will not result in immitigable adverse impact on the availability of the marine mammal species or stock(s) for certain subsistence uses. In order for the National Marine Fisheries Service (NMFS) to consider authorizing the taking by United States (U.S.) citizens of small numbers of marine mammals incidental to a specified activity (other than commercial fishing), or to make a finding that incidental take is unlikely to occur, a written request must be submitted to the NMFS Office of Protected Resources. Vineyard Wind's request is detailed in the following sections.

1.1. HRG Survey Activities

The purpose of the HRG surveys described in this IHA application is to obtain a baseline assessment of seabed/sub-surface soil conditions in the lease areas and along potential OECC routes to support the siting and development of the Projects. Vineyard Wind proposes to conduct HRG survey activities within an area illustrated in Figure 1 (referred to as Potential Survey Area). The area includes Lease Area OCS-A 0501, located approximately 24 kilometers (km) (13 nautical miles [nm]) from the southeast corner of Martha's Vineyard and Lease Area OCS-A 0522, located approximately 46 km (25 nm) south of Nantucket. Additionally, OECC routes may also be surveyed within the area depicted in Figure 1.

Water depths across the lease areas range from approximately 35 to 63 meters (m) (115 to 207 feet [ft]); the OECC routes will extend from the lease areas to shallow water areas near potential landfall locations in Massachusetts, Rhode Island, Connecticut, and New York. HRG equipment will be deployed from multiple vessels acquiring data concurrently within the HRG survey area (Figure 1). HRG survey activities south of Cape Cod are anticipated to begin on April 1, 2020 and will last for up to one year. HRG survey activities planned for north and northeast of Cape Cod will be conducted exclusively during the months of August and September when North Atlantic right whales (NARWs; *Eubalaena glacialis*) are not anticipated to be present (Nichols et al. 2008).

Marine HRG surveys will include the following activities:

- Depth sounding (single and multibeam depth sounders) to determine site bathymetry and general bottom topography;
- Magnetic intensity measurements for detecting local variations in the regional magnetic field from geological strata and potential ferrous objects on and below the bottom;
- Seafloor imaging (sidescan sonar survey) for seabed sediment classification purposes, to identify natural and human-made acoustic targets resting on the bottom as well as any anomalous features;
- Shallow penetration sub-bottom profiler (chirper) to map the near surface stratigraphy (top 0 to 5 m [16 feet] of soils below seabed); and
- Medium penetration sub-bottom profiler (sparker) to map deeper subsurface stratigraphy as needed (soils down to 75 to 100 m [246 to 328 ft] below seabed).

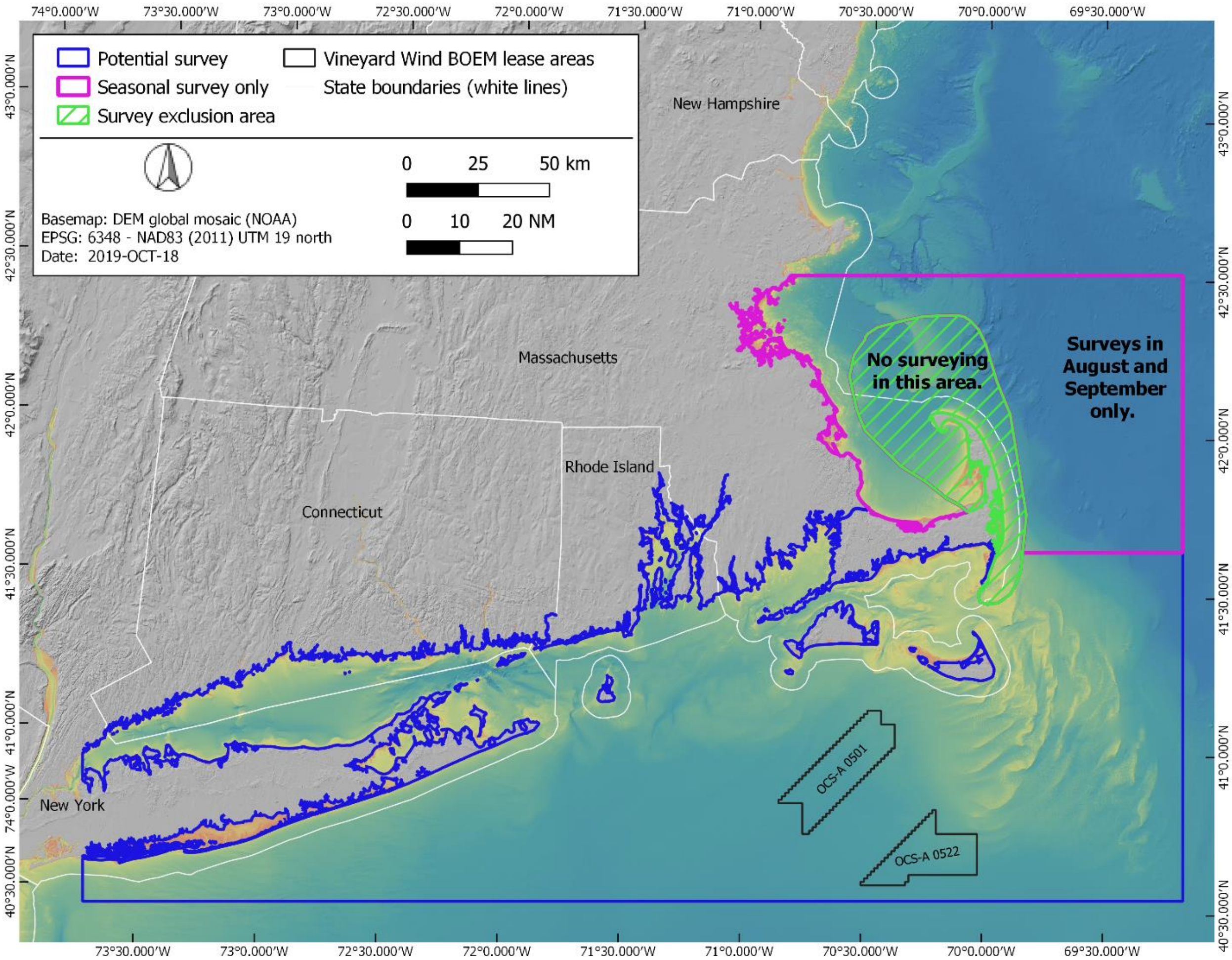

Figure 1. Potential high resolution geophysical (HRG) survey area. HRG surveys are proposed to take place within the boundaries shown. The area denoted in pink on the map illustrates an area where HRG survey activities will be restricted to periods of lower North Atlantic right whale (NARW) presence, i.e., August and September (Nichols et al. 2008).

1.2. Activities Considered in this Application

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 2014a).

HRG survey equipment that may be used includes:

- **Shallow Penetration Sub-bottom Profilers (SBP; Chirps)** to map the near-surface stratigraphy (top 0 to 5 m [0 to 16 ft]) of sediment below seabed). A chirp system emits sonar pulses that increase in frequency from about 2 to 20 kHz over time. The pulse length frequency range can be adjusted to meet project variables. Typically mounted on the hull of the vessel or from a side pole.
- **Medium Penetration SBPs (Boomers)** to map deeper subsurface stratigraphy as needed. A boomer is a broadband sound source operating in the 3.5 Hz to 10 kHz frequency range. This system is commonly mounted on a sled and towed behind the vessel.

- **Medium Penetration SBPs (Sparkers)** 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. These are typically towed behind the vessel with adjacent hydrophone arrays to receive the return signals.
- **Parametric SBPs**, also called sediment echosounders, for providing high data density in sub-bottom profiles that are typically required for cable routes, very shallow water, and archaeological surveys. Typically mounted on the hull of the vessel or from a side pole.
- **Multibeam Echosounders (MBESs)** to determine water depths and general bottom topography. MBES sonar systems project sonar pulses in several angled beams from a transducer mounted to a ship's hull. The beams radiate out from the transducer in a fan-shaped pattern orthogonally to the ship's direction.
- **Side-scan Sonar** for seabed sediment classification purposes and to identify natural and man-made acoustic targets on the seafloor. The sonar device emits conical or fan-shaped pulses down toward the seafloor in multiple beams at a wide angle, perpendicular to the path of the sensor through the water. The acoustic return of the pulses is recorded in a series of cross-track slices, which can be joined to form an image of the sea bottom within the swath of the beam. The sonar device is typically towed beside or behind the vessel or from an autonomous vehicle.
- **Ultra-Short Baseline (USBL) and Global Acoustic Positioning Systems** to provide high accuracy ranges by measuring the time between the acoustic pulses transmitted by the vessel transceiver and a transponder, or beacon, necessary to produce the acoustic profile. These are two component systems with a hull or pole-mounted transceiver and one to several transponders mounted on other survey equipment.

The operational parameters (e.g., operating frequency, source level [SL], pulse duration, repetition rate) for each piece of equipment, as well as the output parameters (e.g., sound pressure level [SPL]), propagation distance, frequency content) are generally similar within each category and therefore the overall magnitude of impact radii can often be predicted based on the equipment category (Crocker and Fratantonio 2016).

Vineyard Wind proposes to use multiple vessels to acquire the proposed HRG survey data. HRG survey activities will be conducted by vessels that can accomplish the survey goals in specific survey areas. Vessels will maintain both the required course and a survey speed required to cover approximately 100 km (54 nm) per day during line acquisition, with consideration to weather delays, equipment maintenance, and crew availability. Vessel survey speed is anticipated to be approximately 4 knots (2.1 meters per second [m/s]).

HRG Survey activities will occur in discrete segments corresponding to the following general areas:

- Lease Area OCS-A 0501 - Inclusive of potential wind turbine generator (WTG) locations, electrical service platform (ESP) location(s), and inter-array cable corridors;
- Lease Area OCS-A 0522 - Inclusive of potential WTG locations, ESP location(s), and inter-array cable corridors;
- OECC routes - Potential OECC routes through Federal and State waters located within the general survey area indicated in Figure 1.

The maximum survey length has been selected to provide operational flexibility and to cover the possibility of multiple landfall locations and associated OECC routes. Track line spacing for HRG survey activities will align with BOEM Guidelines for Providing Archaeological and Historic Property Information pursuant to 30 CFR § Part 585 (March 2017) and for Providing Geophysical, Geotechnical, and Geohazard Information pursuant to 30 CFR § Part 585 (July 2015) (BOEM 2015).

To maximize efficiency and minimize the duration of HRG survey activities and the period of potential impact on marine fauna, Vineyard Wind proposes to conduct HRG survey activities 24 hours per day, weather dependent, while acquiring data in both the lease areas and along OECC routes. HRG survey activities conducted north and northeast of Cape Cod will be conducted exclusively during the months of August and September. While the HRG survey activities are estimated to occur over the course of a full year, the actual survey duration will be shorter given the use of multiple vessels.

Survey vessels produce underwater sound from both dynamic positioning thruster and propulsion systems that may reach regulatory defined acoustic thresholds for behavioral disturbance. NMFS has previously determined that with the Standard Operating Conditions and the Reasonable and Prudent Measures, as defined in the Biological Opinion dated April 10, 2013 for Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic OCS in Massachusetts, Rhode Island, New York and New Jersey Wind Energy Areas resulting from BOEM Endangered Species Act (ESA; 16 U.S.C. § 1531 et seq.) Section 7 consultation (NMFS 2013), that the proposed activities may adversely affect but are not likely to jeopardize the continued existence of threatened or endangered species. Underwater sound from vessels used to acquire HRG survey data are not considered further in this application.

1.3. Acoustic Terminology

The publication of International Organization for Standardization (ISO) 18405 Underwater Acoustics–Terminology (ISO 2017) provided a dictionary of underwater bioacoustics (previous standards: IEC 1994, ANSI S1.1-2013 2013). In the remainder of this report, we follow the definitions and conventions of ISO (2017) except where stated otherwise. Table 1 provides a list of the acoustic units used in this document.

Table 1. Summary of relevant acoustic terminology and units used by US regulators and in this report.

Metric	NOAA (NMFS 2018)	This report (as per ISO 2017)		Unit
		Abbreviation in main text	Symbol in equations/tables	
Sound pressure level	n/a	SPL	L_p	decibel (dB) re 1 micropascal (μPa)
Peak sound pressure level	PK	PK	L_{pk}	dB re 1 μPa
Cumulative sound exposure level	SEL_{cum}	SEL	L_E	dB re 1 $\mu Pa^2 \cdot s$
Source level	SL	SL	SL	dB re 1 μPa·m

Notes: The SEL_{cum} metric as used by NOAA, describes the sound energy received by a receptor over a period of 24 hours. Accordingly, following the ISO standard, this will be denoted as SEL in this report, except for tables and equations where L_E will be used alongside SEL to account for its use in mathematical equations.

2. Dates, Duration, and Specified Geographic Region

2.1. Dates of the Proposed HRG Surveys

HRG survey activities south of Cape Cod are anticipated to begin on April 1, 2020 and will last for up to one year (blue survey area on Figure 1). Vineyard Wind plans to restrict the acquisition of HRG survey data in areas north and northeast of Cape Cod to the months of August and September to avoid anticipated periods of higher NARW presence in other months (Nichols et al. 2008). Survey operations are proposed to be conducted 24 hours per day to minimize the overall duration of survey activities and the associated period of potential impact on marine species.

2.2. Specific Geographical Region of Activity

HRG survey activities are planned to occur in both Federal offshore waters (Lease Area OCS-A 0501 and Lease Area OCS-A 0522) and along potential OECC routes in both Federal and State nearshore waters of Massachusetts, Rhode Island, New York, and Connecticut to various landfall locations. The proposed surveys will be acquired within the area illustrated in Figure 1. Water depths in the lease areas range from 35 to 63 m (115 to 207 ft). Water depths along the potential OECC routes range from 5 to greater than 200 m (16 to >656 ft).

3. Species and Number of Marine Mammals

All marine mammal species are protected under the MMPA. Some marine mammal stocks may be designated as Strategic under the MMPA (2015), which requires the jurisdictional agency (NMFS for the Atlantic offshore species considered in this application) to impose additional protection measures. A stock is considered Strategic if:

- Direct human-caused mortality exceeds its Potential Biological Removal (PBR) level (defined as the maximum number of animals, not including natural mortality, that can be removed from the stock while allowing the stock to reach or maintain its optimum sustainable population level);
- It is listed under the ESA;
- It is declining and likely to be listed under the ESA; or
- It is designated as depleted under the MMPA.

A depleted species or population stock is defined by the MMPA as any case in which:

- The Secretary, after consultation with the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals established under MMPA Title II, determines that a species or population stock is below its optimum sustainable population;
- A State, to which authority for the conservation and management of a species or population stock is transferred under Section 109 of the MMPA, determines that such species or stock is below its optimum sustainable population; or
- A species or population stock is listed as an endangered or threatened species under the ESA.

Some species are further protected under the ESA (2002). Under the ESA, a species is considered endangered if it is “in danger of extinction throughout all or a significant portion of its range.” A species is considered threatened if it “is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range” (ESA 2002).

3.1. Marine Mammals Likely to be Present in the HRG Survey Area

Thirty-nine marine mammal species (whales, dolphins, porpoise, seals, and manatees) comprising 40 stocks have been documented as present (some year-round, some seasonally, and some as occasional visitors) in the Northwest Atlantic Outer Continental Shelf (OCS) region (CeTAP 1982, USFWS 2014, Roberts et al. 2016, Hayes et al. 2018). All thirty-nine marine mammal species identified in Table 2 are protected by the MMPA and some are also listed under the ESA. The five ESA-listed marine mammal species known to be present year-round, seasonally, or occasionally in southern New England waters are the sperm whale (*Physeter macrocephalus*), NARW, fin whale (*Balaenoptera physalus physalus*), blue whale (*Balaenoptera musculus*), and sei whale (*Balaenoptera borealis borealis*). The humpback whale (*Megaptera novaeangliae*), which may occur year-round, has been delisted as an endangered species. These large whale species are generally migratory and typically do not spend extended periods of time in a localized area.

Southern New England waters (including the highlighted survey areas in Figure 1) are primarily used as seasonal feeding areas or habitat during seasonal migration movements that occur between the more northward feeding areas and the Southern Hemisphere breeding grounds typically used by some of the large whale species (although some winter breeding areas exist further offshore versus in the southerly latitudes). The mid-sized whale species (e.g., minke whale [*Balaenoptera acutorostrata acutorostrata*]), large baleen whales, and the sperm whale are present year-round in continental shelf and slope waters and may occur in the waters of the proposed HRG survey areas, though movements will vary based on prey availability and other habitat factors.

Along with cetaceans, seals are protected under the MMPA. The four species of phocids (true seals) that have ranges overlapping the Potential Survey Area, inclusive of the lease areas and the potential OECC routes, are harbor seals (*Phoca vitulina*), gray seals (*Halichoerus grypus*), harp seals (*Pagophilus groenlandicus*), and hooded seals (*Cystophora cristata*) (Hayes et al. 2019). One species of sirenian, the Florida manatee (*Trichechus manatus latirostris*) is an occasional visitor to the region during summer months (USFWS 2019). The manatee is listed as threatened under the ESA and is protected under the MMPA along with the other marine mammals.

The expected occurrence of each species in the Potential Survey Area is listed in Table 2, and is based on Hayes et al. (2019) and the Roberts et al. (2015, 2016, 2017, 2018) habitat models. Many of the marine mammal species that inhabit the Northwestern Atlantic are not likely to be found in the HRG survey area (Figure 1), as they do not commonly occur in this region of the Atlantic Ocean. Species considered rare are not expected to be incidentally taken by the HRG survey activities and are therefore not considered in this analysis. Species categories include:

- 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; and
- Rare - Records for some years but limited; range includes the HRG survey area but due to habitat preferences and distribution information, species are not expected to occur in the HRG survey area although records may exist for adjacent waters.

The protection status, stock identification, occurrence, and abundance estimates of the species listed in Table 2 that fall into the categories common, regular, and uncommon, are discussed in more detail in Section 4. The likelihood of incidental exposure for each species based on its presence, density, and overlap of proposed activities is described in Sections 6 and 7.

Table 2. Marine mammal species that may occur in the marine waters of Southern New England.

Common name	Scientific name	Stock	Regulatory status	Occurrence in Potential Survey Area	Abundance[a] (NMFS best available)
Baleen whales (Mysticeti)					
Blue whale	*Balaenoptera musculus*	W. North Atlantic	ESA; Endangered	Rare	440
Bryde's whale	*Balaenoptera edeni*	Northern Gulf of Mexico	MMPA; Strategic	Rare	33
Fin whale	*Balaenoptera physalus*	W. North Atlantic	ESA; Endangered	Common	1,618
Humpback whale	*Megaptera novaeangliae*	Gulf of Maine	MMPA	Common	896
Minke whale	*Balaenoptera acutorostrata*	Canadian East Coast	MMPA	Common	2,591
North Atlantic right whale	*Eubalaena glacialis*	W. North Atlantic	ESA; Endangered	Common	451
Sei whale	*Balaenoptera borealis*	Nova Scotia	ESA; Endangered	Common	357
Toothed Whales (Odontoceti)					
Atlantic spotted dolphin	*Stenella frontalis*	W. North Atlantic	MMPA	Rare	44,715
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	W. North Atlantic	MMPA	Common	48,819
Common bottlenose dolphin	*Tursiops truncatus*	W. North Atlantic, Offshore	MMPA;	Common	77,532[h]
		W. North Atlantic, Northern Migratory Coastal	MMPA; Strategic[b]	Common	6,639[h]
Clymene dolphin	*Stenella clymene*	W. North Atlantic	MMPA	Rare	Unknown
False killer whale	*Pseudorca crassidens*	W. North Atlantic	MMPA; Strategic	Rare	442
Fraser's dolphin	*Lagenodelphis hosei*	W. North Atlantic	MMPA	Rare	Unknown
Killer whale	*Orcinus orca*	W. North Atlantic	MMPA	Rare	Unknown
Long-finned pilot whale	*Globicephala malaena*	W. North Atlantic	MMPA	Uncommon	5,636[g]
Melon-headed whale	*Peponocephala electra*	W. North Atlantic	MMPA	Rare	Unknown
Pan-tropical spotted dolphin	*Stenella attenuata*	W. North Atlantic	MMPA	Rare	3,333
Pygmy killer whale	*Feresa attenuata*	W. North Atlantic	MMPA	Rare	Unknown
Risso's dolphin	*Grampus griseus*	W. North Atlantic	MMPA	Uncommon	18,250
Rough-toothed dolphin	*Steno bredanensis*	W. North Atlantic	MMPA	Rare	271
Short-beaked common dolphin	*Delphinus delphis*	W. North Atlantic	MMPA	Common	70,184
Short-finned pilot whale	*Globicephala macrorhynchus*	W. North Atlantic	MMPA	Rare	21,515[g]
Sperm whale	*Physeter macrocephalus*	North Atlantic	ESA; Endangered	Uncommon	2,288[e]
Spinner dolphin	*Stenella longirostris*	W. North Atlantic	MMPA	Rare	Unknown
Striped dolphin	*Stenella coeruleoalba*	W. North Atlantic	MMPA	Rare	54,807

Common name	Scientific name	Stock	Regulatory status	Occurrence in Potential Survey Area	Abundance[a] (NMFS best available)
Beaked whales					
Cuvier's beaked whale	*Ziphius cavirostris*	W. North Atlantic	MMPA	Rare	6,532
Blainville's beaked whale	*Mesoplodon densirostris*	W. North Atlantic	MMPA	Rare	7,092[c,f]
Gervais' beaked whale	*Mesoplodon europaeus*	W. North Atlantic	MMPA		
Sowerby's beaked whale	*Mesoplodon bidens*	W. North Atlantic	MMPA		
True's beaked whale	*Mesoplodon mirus*	W. North Atlantic	MMPA		
Northern bottlenose whale	*Hyperoodon ampullatus*	W. North Atlantic	MMPA	Rare	Unknown
Dwarf sperm whale	*Kogia sima*	W. North Atlantic	MMPA	Rare	3,785[d]
Pygmy sperm whale	*Kogia breviceps*	W. North Atlantic	MMPA		
Harbor porpoise	*Phocoena phocoena*	Gulf of Maine/ Bay of Fundy	MMPA	Common	79,833
Earless seals (Phocidae)					
Gray seal	*Halichoerus grypus*	W. North Atlantic	MMPA	Common	27,131[j]
Harbor seal	*Phoca vitulina*	W. North Atlantic	MMPA	Regular	75,834
Harp seal	*Pagophilus groenlandicus*	W. North Atlantic	MMPA	Rare	Unknown[i]
Hooded seal	*Cystophora cristata*	W. North Atlantic	MMPA	Rare	Unknown
Sirenia					
Florida manatee	*Trichechus manatus latirostris*	Florida	MMPA; Threatened /Depleted and Strategic	Rare	Unknown

[a] Best available population estimate is from NOAA Fisheries Stock Assessment Reports (Hayes et al. 2018).
Abundance estimates derived from habitat-based density modeling of the entire Atlantic Exclusive Economic Zone (EEZ) from Roberts et al. (2016), except for the fin whale, humpback whale, minke whale, North Atlantic right whale, sei whale, Cuvier's beaked whale, Mesoplodon beaked whales, pilot whale, sperm whale, and harbor porpoise whose abundances are updated values from Roberts et al. (2017). Seal abundance estimates are from Roberts et al. (2015, unpublished) and are for all seals in the U.S. Atlantic EEZ as a group.
[b] 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) which is declining and likely to be listed as threatened under the ESA; or 3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA (http://www.ncseonline. org/nle/crsreports/biodiversity/biodv-11.cfm).
[c] This estimate includes Gervais' and Blainville's beaked whales and undifferentiated Mesoplodon spp. beaked whales. Sources: Kenney and Vigness-Raposa (2009), Waring et al. (2011, 2013, 2015), Hayes et al. (2017, 2018), NOAA Fisheries (2012), and RI Ocean (2011).
[d] This estimate may include both the dwarf and pygmy sperm whales.
[e] Roberts et al. (2017) sperm whale abundance estimate consists of 223 for the continental shelf area and 3,976 for the slope and abyss.
[f] The four Mesoplodon beaked whale species are grouped in Roberts et al. (2017).
[g] Long-finned and short-finned pilot whales are grouped in Roberts et al. (2017).
[h] Common bottlenose dolphins occurring in the offshore Potential Survey Area likely belong to the Western North Atlantic Offshore stock. It is possible that some could belong to the Western North Atlantic Northern Migratory Coastal stock, but the northern most range of that stock is south of the Potential Survey Area. The Western North Atlantic Northern Migratory Coastal is considered Strategic by NOAA Fisheries because it is designated as depleted under the MMPA.
[i] Hayes et al. (2018) report insufficient data to estimate the population size of harp seals in U.S. waters; the best estimate for the whole population is 7.4 million.
[j] Estimate of gray seal population in U.S. waters. Data are derived from pup production estimates; Hayes et al. (2019) 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.

4. Affected Species Status and Distribution

There are 14 marine mammal species that are endangered, strategic, and/or can be reasonably expected to reside, traverse, or visit the HRG survey area (Figure 1), and thus may experience some level of exposure to sound from Vineyard Wind HRG survey activities. Species that are listed as uncommon or rare are considered extralimital to the HRG survey area and are not assessed in this IHA application. The NARW, fin whale, sei whale, and sperm whale are all considered endangered under the ESA. These four species, as well as the Northern Migratory Coastal bottlenose dolphin stock, are considered Strategic under the MMPA. The following subsections provide additional information on the biology, habitat use, abundance, distribution, and the existing threats to the non-ESA-listed and ESA-listed marine mammal species that are either common in southern New England waters or found regularly (i.e., have the likelihood of occurring at least seasonally) in the HRG survey area.

These species include the NARW, humpback whale, fin whale, sei whale, minke whale, bottlenose dolphin (two stocks), long-finned pilot whale, Risso's dolphin, short-beaked common dolphin, Atlantic white-sided dolphin, Atlantic spotted dolphin, harbor porpoise, gray seals, and harbor seals (BOEM 2014a). Beaked whales are likely to occur in regions farther offshore along the continental shelf-edge but not within 74 km (40 nm) of shore. While the potential for interactions with long-finned pilot whales and Atlantic spotted and Risso's dolphins is minimal, small numbers of these species may transit the Potential Survey Area and are therefore included in this analysis. In general, the remaining non-ESA mammal species listed in Table 2 range outside the HRG survey area, usually in deeper water, or are so rarely sighted that their presence in the HRG survey area is unlikely and therefore are no longer described in this application.

4.1. Mysticetes

4.1.1. Fin Whale (Balaenoptera physalus)–Endangered

Fin whales are the second largest species of baleen whale in the Northern Hemisphere with a maximum length of about 22.8 m (75 ft) (NOAA Fisheries 2018k). These whales have a sleek, streamlined body with a V-shaped head that makes them fast swimmers. Fin whales have a distinctive coloration pattern: the dorsal and lateral sides of their bodies are black or dark brownish-gray while 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 are the dominant large cetacean species during all seasons from Cape Hatteras to Nova Scotia, having the largest standing stock, the largest food requirements, and, therefore, the largest influence on ecosystem processes of any baleen whale species (Hain et al. 1992, Kenney et al. 1997).

Fin whales are low-frequency cetaceans producing short duration, down sweep calls between 15 and 30 hertz (Hz), typically termed “20-Hz pulses” as well as other signals up to 1 kHz (Southall et al. 2019). The SL of the fin whale vocalizations can reach 186 dB re 1 µPa, making it one of the most powerful biological sounds in the ocean (Charif et al. 2002).

4.1.1.1. Distribution

Fin whales off the eastern U.S., 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 named the Western North Atlantic stock.

Fin whales occur year-round in a wide range of latitudes and longitudes, but the density of individuals in any one area changes seasonally (NOAA Fisheries 2018k). Fin whales are the most commonly observed large whales in continental shelf waters from the mid-Atlantic coast of the U.S. to Nova Scotia (Sergeant 1977, Sutcliffe and Brodie 1977, CeTAP 1982, Hain et al. 1992). The fin whale's range in the western

North Atlantic extends from the Gulf of Mexico and Caribbean Sea to the southeastern coast of Newfoundland (Hayes et al. 2018). While fin whales typically feed in the Gulf of Maine and the waters surrounding New England, their mating and calving (and general wintering) areas are largely unknown (Hain et al. 1992, Hayes et al. 2018). Acoustic detections of fin whale singers augment and confirm these visual sighting conclusions for males. Recordings from Massachusetts Bay, New York bight, and deep-ocean areas have detected some level of fin whale singing from September through June (Watkins et al. 1987, Clark and Gagnon 2002, Morano et al. 2012). These acoustic observations from both coastal and deep-ocean regions support the conclusion that male fin whales are broadly distributed throughout the western North Atlantic for most of the year (Hayes et al. 2019). It is likely that fin whales occurring in the U.S. Atlantic EEZ undergo migrations into Canadian waters, open-ocean areas, and perhaps even subtropical or tropical regions. However, the popular notion that entire fin whale populations make distinct annual migrations like some other mysticetes has questionable support (Hayes et al. 2018). Based on an analysis of neonate stranding data, Hain et al. (1992) suggest that calving takes place during October to January in latitudes of the U.S. mid-Atlantic region.

Kraus et al. (2016) suggest that, compared to other baleen whale species, fin whales have a high multi-seasonal relative abundance in the Rhode Island/Massachusetts and Massachusetts Wind Energy Areas (RI/MA & MA WEAs) and surrounding areas. Fin whales were observed in the Massachusetts Wind Energy Area (MA WEA) in spring and summer. This species was observed primarily in the offshore (southern) regions of the RI/MA & MA WEAs during spring and was found closer to shore (northern areas) during the summer months (Kraus et al. 2016). Calves were observed three times and feeding was observed nine times during the Kraus et al. (2016) study. Although fin whales were largely absent from visual surveys in the RI/MA & MA WEAs in the fall and winter months (Kraus et al. 2016), acoustic data indicated that this species was present in the RI/MA & MA WEAs during all months of the year. Low-frequency vocalizing fin whales were acoustically detected in the MA WEA on 87% of survey days (889/1,020 days). Acoustic detection data indicated a lack of seasonal trends in fin whale abundance with slightly fewer detections from April to July (Kraus et al. 2016). As the detection range for fin whale vocalizations is more than 200 km (108 nm), detected signals may have originated from areas far outside of the RI/MA & MA WEAs; however, arrival patterns of many fin whale vocalizations indicated that received signals likely originated from within the Kraus et al. (2016) study area.

4.1.1.2. Abundance

Roberts et al. (2016) habitat-based density models suggest an abundance estimate of 4,633 fin whales in the U.S. Atlantic EEZ. The best available abundance estimate for the Western North Atlantic fin whale stock in U.S. waters from NMFS stock assessments is 1,618 individuals (Hayes et al. 2018).

4.1.1.3. Status

The status of this stock relative to its Optimum Sustainable Population (OSP) in the U.S. Atlantic EEZ is unknown, but the North Atlantic population is listed as endangered under the ESA and Massachusetts Endangered Species Act (MA ESA), and NMFS considers this a Strategic stock. No critical habitat areas have been established for the fin whale under the ESA. The lease areas are flanked by two Biologically Important Areas (BIAs) for feeding fin whales–the area to the northeast is considered a BIA year-round, while the area off the tip of Long Island to the southwest is a BIA from March to October (LaBrecque et al. 2015).

4.1.2. Humpback Whale (*Megaptera novaeangliae*)–Non-Strategic

Humpback whale females are larger than males and can reach lengths of up to 18 m (59 ft) (NOAA Fisheries 2018l). 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. This baleen whale species feeds 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).

Humpbacks whales are low-frequency cetaceans but have one of the most varied vocal repertoires of the baleen whales. Male humpbacks will arrange vocalizations into a complex, repetitive sequence to produce a characteristic "song". Songs are variable but typically occupy frequency bands between 300 and 3,000 Hz and last upwards of 10 minutes. Songs are predominately produced while on breeding grounds; however, they have been recorded on feeding grounds throughout the year (Clark and Clapham 2004, Vu et al. 2012). Typical feeding calls are centered at 500 Hz with some other calls and songs reaching 20 kHz. Common humpback calls also contain series of grunts between 25 and 1,900 Hz as well as strong, low frequency pulses (with SLs up to 176 dB re 1 µPa @ 1 m [3.3 ft]) between 25 and 90 Hz (Clark and Clapham 2004, Vu et al. 2012).

4.1.2.1. Distribution

In the North Atlantic, six separate humpback whale sub-populations have been identified based on their consistent maternally determined fidelity to different feeding areas (Clapham and Mayo 1987). These populations are found in the Gulf of Maine, Gulf of St. Lawrence, Newfoundland/Labrador, western Greenland, Iceland, and Norway (Hayes et al. 2018). Most humpback whales that inhabit the waters in the U.S. Atlantic EEZ belong to the Gulf of Maine stock.

Humpback whales in the Gulf of Maine stock typically feed in the waters between the Gulf of Maine and Newfoundland during spring, summer, and fall, but they have been observed feeding in other areas, such as off the coast of New York (Sieswerda et al. 2015). Some humpback whales from most feeding areas, including the Gulf of Maine, migrate to the West Indies (including the Antilles, Dominican Republic, Virgin Islands, and Puerto Rico) in winter, where they mate and calve their young (Katona and Beard 1990, Palsbøll et al. 1997). There have been several wintertime humpback sightings in coastal waters of the southeastern U.S., including 46 sightings of humpbacks in the New York-New Jersey Harbor Estuary documented between 2011 and 2016 (Brown et al. 2017). However, not all humpback whales from the Gulf of Maine stock migrate to the West Indies every winter because significant numbers of animals are observed in mid- and high-latitude regions at this time (Swingle et al. 1993).

Kraus et al. (2016) observed humpback whales in the RI/MA & MA WEAs and surrounding areas during all seasons. Humpback whales were observed most often during spring and summer months, with a peak from April to June. Calves were observed 10 times and feeding was observed 10 times during the Kraus et al. (2016) study. That study also observed one instance of courtship behavior. Although humpback whales were rarely seen during fall and winter surveys, acoustic data indicate that this species may be present within the MA WEA year-round, with the highest rates of acoustic detections in winter and spring (Kraus et al. 2016). Humpback whales were acoustically detected in the MA WEA on 56% of survey days (566/1,020 days). Acoustic detections do not differentiate between individuals, so detections on multiple days could be the same or different individuals. Humpback whales are low-frequency cetaceans with vocalizations that travel long distances in water. The mean detection range for humpback whales using passive acoustic monitoring (PAM) was 30 to 36 km (16.2 to 19.4 nm), with a mean radius of 36 km (22.3 nm) (95% confidence interval of 5 km [2.7 nm]) for the PAM system. Kraus et al. (2016) estimated that 63% of acoustic detections of humpback whales represented whales within their study area.

4.1.2.2. Abundance

The most recent ocean basin-wide estimate of the North Atlantic humpback whale population is 11,570 (Palsbøll et al. 1997). Roberts et al. (2016) habitat-based density models provide abundance estimates of 205 humpback whales in the U.S. Atlantic EEZ during winter months (December to March) and 1,637 during summer months (April to November). The best available population estimate for the Gulf of Maine stock from NOAA Fisheries stock assessments is 896 individuals and this population appears to be increasing (Hayes et al. 2018).

4.1.2.3. Status

The entire humpback whale species was previously listed as endangered under the ESA. However, in September 2016, NOAA Fisheries identified 14 Distinct Population Segments (DPSs) of humpback whales and revised the ESA listing for this species (DoC 2016a). Four DPSs were listed as endangered, one as threatened, and the remaining nine DPSs were deemed not warranted for listing. Humpback whales in the U.S. Atlantic EEZ belong to the West Indies DPS, which is considered not warranted for listing under the ESA (DoC 2016a). The Gulf of Maine stock is not considered depleted because it does not coincide with any ESA-listed DPS. The detected level of U.S. fishery-caused mortality and serious injury, derived from the available records, which is surely biased low, does not exceed the calculated PBR and, therefore, this is not a Strategic stock (if the recovery factor is set at 0.5) (Hayes et al. 2019). Humpback whales in the western North Atlantic have been experiencing an Unusual Mortality Event (UME) since January 2016 that appears to be related to a larger than usual number of vessel collisions (NOAA Fisheries 2018n). In total, 76 mortalities were documented through July 25, 2018, as part of this event (NOAA Fisheries 2018n). A BIA for humpback whales for feeding has been designated northeast of the lease areas from March through December (LaBrecque et al. 2015).

4.1.3. Minke Whale (*Balaenoptera acutorostrata*)–Non-Strategic

Minke whales are a baleen whale species reaching 10 m (33 ft) in length (NOAA Fisheries 2018r). This species has a cosmopolitan distribution in temperate, tropical, and high latitude waters (Hayes et al. 2018). The minke whale is common and widely distributed within the U.S. 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). This species has a dark gray-to-black back and a white ventral surface (NOAA Fisheries 2018r). 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 (NOAA Fisheries 2018r).

Minke whale recordings have resulted in some of the most variable and unique vocalizations of any marine mammal. Common calls for minke whales found in the North Atlantic include repetitive, low-frequency (100 to 500 Hz) pulse trains that may consist of either grunt-like pulses or thump-like pulses. The thumps are very short duration (50 to 70 milliseconds [ms]) with peak energy between 100 and 200 Hz. The grunts are slightly longer in duration (165 to 320 ms) with most energy between 80 and 140 Hz. In addition, minke whales will repeat a six to 14 minute-pattern of 40 to 60 second pulse trains over several hours (Risch et al. 2013). Minke whales produce a unique sound called the “boing”, which consists of a short pulse at 1.3 kHz followed by an undulating tonal call around 1.4 kHz. This call was widely recorded but unidentified for many years and had scientists widely speculating as to its source (Rankin and Barlow 2005).

4.1.3.1. Distribution

In the North Atlantic, there are four recognized populations: Canadian East Coast, West Greenland, Central North Atlantic, and Northeastern North Atlantic (Donovan 1991). Until better information becomes available, minke whales in the U.S. Atlantic EEZ are considered part of the Canadian East Coast stock, which inhabits the area from the western half of the Davis Strait (45°W) to the Gulf of Mexico. It is uncertain if separate sub-stocks exist within the Canadian East Coast stock.

Sighting data suggest that minke whale distribution is largely centered in the waters of New England and eastern Canada (Hayes et al. 2018). Risch et al. (2013) reported a decrease in minke whale calls north of 40°N in late fall with an increase in calls between 20° and 30°N in winter and north of 35°N during spring. Mating and calving most likely take place in the winter in lower latitude wintering grounds (NOAA Fisheries 2018r).

Kraus et al. (2016) observed minke whales in the RI/MA & MA WEAs and surrounding areas primarily from May to June. This species demonstrated a distinct seasonal habitat usage pattern that was consistent throughout the study. Though minke whales were observed in spring and summer months in the MA WEA, they were only observed in the lease areas in the spring. Minke whales were not observed between October and February, but acoustic data indicate the presence of this species in the offshore Potential Survey Area in winter months. Calves were observed twice, and feeding was also observed twice during the Kraus et al. (2016) study. Minke whales were acoustically detected in the MA WEA on 28% of survey days (291/1,020 days). Minke whale acoustic presence data also exhibited a distinct seasonal pattern; acoustic presence was lowest in the months of December and January, steadily increased beginning in February, peaked in April, and exhibited a gradual decrease throughout the summer months (Kraus et al. 2016). Although minke whales are low-frequency cetaceans, the acoustic detection range for this species during the study was small enough that over 99% of detections were limited to within the Kraus et al. (2016) study area. This species was not observed visually or detected acoustically in the OCS-A 0501 Lease Area during the 2016 or 2017 HRG surveys (Vineyard Wind 2016, 2017).

4.1.3.2. Abundance

Roberts et al. (2016) habitat-based density models provide abundance estimates of 740 minke whales in the U.S. Atlantic EEZ during winter months (November to March) and 2,112 during summer months (April to October). The best abundance estimate for the U.S. Atlantic EEZ is 2,591 from NOAA Fisheries stock assessments (Hayes et al. 2018). This estimate is likely biased low because it does not account for minke whales in Canadian waters or the availability bias due to submerged animals.

4.1.3.3. Status

Minke whales are not listed as threatened or endangered under the ESA and the Canadian East Coast stock is not considered Strategic under the MMPA. Minke whales in the western North Atlantic have been experiencing a UME since January 2017 with some evidence of human interactions as well as infectious disease (NOAA Fisheries 2018q). In total, 37 mortalities were documented through July 27, 2018 as part of this event (NOAA Fisheries 2018q). A BIA for minke whales for feeding has been designated east of OCS-A 0501 from March through November (LaBrecque et al. 2015).

4.1.4. North Atlantic Right Whale (*Eubalaena glacialis*)–Endangered/Strategic

NARWs are among the rarest of all marine mammal species in the Atlantic Ocean. They average approximately 15 m (50 ft) in length (NOAA Fisheries 2018p). Members of this species 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. 2018). They are slow-moving grazers that feed on dense concentrations of prey at or below the water’s surface, as well as at depth (NOAA Fisheries 2018p). Research suggests that NARWs must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx 1990).

NARWs are low-frequency cetaceans that vocalize using a number of distinctive call types, most of which have peak acoustic energy below 500 Hz. Most vocalizations do not go above 4 kHz (Matthews et al. 2014). One typical right whale vocalization is the “up call”, a short sweep that rises from roughly 50 to 440 Hz over a period of two seconds. These up calls are characteristic of the NARW and are used by research and monitoring programs to determine species presence. A characteristic “gunshot” call is believed to be produced by male NARWs. These pulses can have SLs of 174 to 192 dB re 1 µPa @ 1 m (3.3 ft) with frequency range from 50 to 2,000 Hz (Parks et al. 2005, Parks and Tyack 2005). Other tonal calls range from 20 to 1,000 Hz and have SLs between 137 and 162 dB re 1 µPa @ 1 m (3.3 ft).

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 U.S. East Coast to their calving grounds in the waters of the southeastern U.S. (Kenney and Vigness-Raposa 2010). 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).

NARWs are considered to be comprised of two separate stocks: Eastern North Atlantic and Western Atlantic stocks. The Eastern North Atlantic stock was largely extirpated by historical whaling (Aguilar 1986). NARWs in U.S. waters belong to the Western Atlantic stock. This stock ranges primarily from calving grounds in coastal waters of the southeastern U.S. to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence (Hayes et al. 2018).

Surveys indicate that there are seven areas where NARWs congregate seasonally: the coastal waters of the southeastern U.S., 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). 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 2016b). 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).

Kraus et al. (2016) observed NARWs in the RI/MA & MA WEAs in winter and spring and observed 11 instances of courtship behavior. The greatest sightings per unit effort (SPUE) in the RI/MA & MA WEAs by Kraus et al. (2016) took place in March, with a concentration of spring sightings in OCS-A 0501 and winter sightings in the area northeast of the lease areas. Seventy-seven unique individual NARWs were observed in the RI/MA & MA WEAs over the duration of the Northeast Large Whale Pelagic Survey (October 2011 to June 2015) (Kraus et al. 2016). No calves were observed. Kraus et al. (2016) acoustically detected NARWs with PAM within the MA WEA on 43% of survey days (443/1,020 days) and during all months of the year. NARW are low-frequency cetaceans. Acoustic detections do not differentiate between individuals, so detections on multiple days could be the same or different individuals. NARWs exhibited notable seasonal variability in acoustic presence, with maximum occurrence in winter and spring (January to March), and minimum occurrence in summer (July to September). The mean detection range for NARWs using PAM was 15 to 24 km (8.1 to 13.0 nm), with a mean radius of 21 km (11.3 nm) (95% confidence interval of 3 km [1.6 nm]) for the PAM system.

4.1.4.2. Abundance

Roberts et al. (2016) habitat-based density models provide abundance estimates of 535 NARWs in the U.S. Atlantic EEZ during winter (November to February), 416 during spring (March to April), 379 during summer (May to July), and 334 during fall (August to October) months. Hayes et al. (2018) report a minimum of 451 individuals in this stock. The best estimate of the NARW population size according the NARW Consortium is 451 (Pettis et al. 2017). This comes from the Pace et al. (2017) model, which also reported a 99.99% probability of NARW population decline from 2010 to 2015. This estimate does not consider that NARWs have been experiencing a UME since June 2017, with 19 documented deaths as of July 24, 2018 (NOAA Fisheries 2018g). This UME appears to be driven by entanglement in fishing gear and blunt force trauma associated with ship strikes mainly in the Gulf of St. Lawrence. Cause of death findings for the UME are based on seven necropsies of dead NARWs found in Canada in the Gulf of St. Lawrence (Daoust et al. 2017, NOAA Fisheries 2018g).

4.1.4.3. Status

The size of the Western Atlantic stock is considered extremely low relative to its OSP in the U.S. Atlantic EEZ (Hayes et al. 2018). The Western Atlantic Stock of NARWs is classified as a Strategic stock under the MMPA and is listed as endangered under the ESA and MA ESA. Historically, the population suffered severely from commercial overharvesting and has more recently been threatened by incidental fishery entanglement and vessel collisions (Knowlton and Kraus 2001, Kraus et al. 2005, Pace et al. 2017).

To protect this species from ship strikes, NOAA Fisheries designated Seasonal Management Areas (SMAs) in U.S. waters in 2008 (DoC 2008). All vessels greater than 19.8 m (65 ft) in overall length must operate at speeds of 10 knots (5.1 m/s) or less within these areas during specific time periods. The Block Island Sound SMA overlaps with the southern portion of Lease Area OCS-A 0501 and is active between November 1 and April 30 each year. The Great South Channel SMA lies to the northeast of Lease Area OCS-A 0501 and is active April 1 to July 31. Potential OECC routes lie within the Cape Cod Bay SMA, which is active between January 1 to May 15, and the Off Race Point SMA, which is active between March 1 to April 30. Vineyard Wind is committed to conduct HRG survey activities within the Cape Cod Bay SMA and Off Race Point SMA during the months of August and September to ensure sufficient buffer between the seasonal restrictions (January to May 15) and known seasonal occurrence of the NARW north and northeast of Cape Cod (fall, winter, and spring).

NOAA Fisheries may also establish Dynamic Management Areas (DMAs) when and where NARWs are sighted outside SMAs. DMAs are generally in effect for two weeks. During this time, vessels are encouraged to avoid these areas or reduce speeds to 10 knots (5.1 m/s) or less while transiting through these areas.

The lease areas included in the HRG survey area are encompassed by a NARW BIA for migration from March to April and from November to December (LaBrecque et al. 2015). To determine BIAs, experts were asked to evaluate the best available information and to summarize and map areas important to cetacean species' reproduction, feeding, and migration. The purpose of identifying these areas was to help resource managers with planning and analysis. The NARW BIA for migration includes the RI/MA & MA WEAs and beyond to the continental slope, extending northward to offshore of Provincetown, Massachusetts and southward to halfway down the Florida coast (LaBrecque et al. 2015).

4.1.5. Sei Whale (*Balaenoptera borealis*)–Endangered

Sei whales are a baleen whale in the same low-frequency hearing category as other mysticetes. They can reach lengths of about 12 to 18 m (39 to 59 ft) (NOAA Fisheries 2018o). This species has a long sleek body that is dark bluish-gray to black in color and pale underneath (NOAA Fisheries 2018o). 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 (NOAA Fisheries 2018o).

Like all baleen whales, sei whales are categorized as low-frequency cetaceans. There are limited confirmed sei whale vocalizations; however, studies indicate that this species produces several, mainly low-frequency (<1,000 Hz) vocalizations. Several calls attributed to sei whales include pulse trains up to 3 kHz, broadband "growl" and "whoosh" sounds between 100 and 600 Hz, tonal calls and upsweeps between 200 and 600 Hz, and down sweeps between 34 and 100 Hz (McDonald et al. 2005, Rankin and Barlow 2007, Baumgartner et al. 2008).

4.1.5.1. Distribution

The stock that occurs in the U.S. Atlantic EEZ is the Nova Scotia stock, which ranges along the continental shelf waters of the northeastern U.S. to Newfoundland (Hayes et al. 2017). Sighting data suggest sei whale distribution is largely centered in the waters of New England and eastern Canada (Roberts et al. 2016, Hayes et al. 2017). There appears to be a strong seasonal component to sei whale distribution. Sei whales are relatively widespread and most abundant in New England waters from spring to fall (April to July). During winter, the species is predicted to be largely absent (Roberts et al. 2016). This general offshore pattern of sei whale distribution is disrupted during episodic incursions into more shallow and inshore waters (Hayes et al. 2019). In years of reduced predation on copepods by other predators and thus greater abundance of this prey source, sei whales are reported in more inshore locations, such as the Great South Channel (in 1987 and 1989) and Stellwagen Bank (in 1986) areas (Payne and

Heinemann 1990, Hayes et al. 2019). An influx of sei whales into the southern Gulf of Maine occurred in summer 1986 (Schilling et al. 1992). Such episodes, often punctuated by years or even decades of absence from an area, have been reported for sei whales from various places worldwide.

Kraus et al. (2016) observed sei whales in the RI/MA & MA WEAs and surrounding areas only between the months of March and June. The number of sei whale observations was less than half that of other baleen whale species in the two seasons in which sei whales were observed (spring and summer). This species demonstrated a distinct seasonal habitat use pattern that was consistent throughout the study. Calves were observed three times and feeding was observed four times during the Kraus et al. (2016) study. Sei whales are expected to be present but much less common than fin whales, minke whales, humpback whales, and NARWs based on Kraus et al. (2016) sighting rates.

4.1.5.2. Abundance

Roberts et al. (2016) habitat-based density models provide abundance estimates of 98 sei whales in the U.S. Atlantic EEZ during winter (December to March), 627 during spring (April to June), 717 during summer (July to September), and 37 during fall (October to November). The best available abundance estimate for the Nova Scotia stock of sei whales from NMFS stock assessments is 357 individuals. This estimate is considered an underestimate because the full known range of the stock was not surveyed, the estimate did not include availability-bias correction for submerged animals, and there was uncertainty regarding population structure (Hayes et al. 2017). Abundance data for sei whales from Roberts et al. (2016) were used in this assessment.

4.1.5.3. Status

Sei whales are listed as endangered under the ESA and MA ESA and the Nova Scotia stock is considered Strategic by NMFS. No critical habitat areas are designated for the sei whale under the ESA. A BIA for feeding for sei whales occurs east of the lease areas from May through November (LaBrecque et al. 2015).

4.2. Odontocetes

4.2.1. Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*)–Non-Strategic

Atlantic white-sided dolphins are found in cold temperate and subpolar waters of the North Atlantic (Cipriano 2002). 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 (NOAA Fisheries 2018e). They feed mostly on small schooling fishes, shrimps, and squids, and they are often observed feeding in mixed-species groups with pilot whales and other dolphin species (Cipriano 2002, Jefferson et al. 2008).

Atlantic white-sided dolphins are in the mid-frequency functional hearing group with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Their vocalizations range from 6 to 15 kHz (DoN 2008). Because calls produced by many delphinid species are highly variable and overlap in frequency characteristics, it is challenging to identify to individual species (Oswald et al. 2007) during acoustic studies.

4.2.1.1. Distribution

Atlantic white-sided dolphins observed off the eastern U.S. coast are part of the Western North Atlantic stock. This stock inhabits waters from central West Greenland to North Carolina (about 35°N), primarily in continental shelf waters to the 100 m (328 ft) depth contour (Doksæter et al. 2008). Sighting data indicate seasonal shifts in distribution (Northridge et al. 1997). During January to May, low numbers of Atlantic white-sided dolphins are found from Georges Bank to Jeffreys Ledge (off New Hampshire). From June through September, large numbers of Atlantic white-sided dolphins are found from Georges Bank to the lower Bay of Fundy. From October to December, they occur at intermediate densities from southern Georges Bank to the southern Gulf of Maine (Payne and Heinemann 1990). No critical habitat areas are designated for the Atlantic white-sided dolphin.

Kraus et al. (2016) suggest that Atlantic white-sided dolphins occur infrequently in the RI/MA & MA WEAs and surrounding areas. Effort-weighted average sighting rates for Atlantic white-sided dolphins could not be calculated, because this species was only observed on eight occasions throughout the duration of the study (October 2011 to June 2015). No Atlantic white-sided dolphins were observed during the winter months, and this species was only sighted twice in fall and three times in spring and summer. It is possible that the Northeast Large Pelagic Survey may have underestimated the abundance of Atlantic white-sided dolphins, as this survey was designed to target large cetaceans and the majority of small cetaceans were not identified to species.

4.2.1.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 37,180 Atlantic white-sided dolphins in the U.S. Atlantic EEZ. There are insufficient data to determine seasonal abundance estimates of Atlantic white-sided dolphins off the eastern US coast or their status in the U.S. Atlantic EEZ. The best available abundance estimate for the Western North Atlantic stock of Atlantic white-sided dolphins is 48,819 individuals, estimated from data collected during a 2011 summer survey (Hayes et al. 2018).

4.2.1.3. Status

The Atlantic white-sided dolphin is not listed as threatened or endangered under the ESA or MA ESA, and the Western North Atlantic stock of Atlantic white-sided dolphins is not classified as Strategic.

4.2.2. Common Bottlenose Dolphin (*Tursiops truncates truncatus*)– Strategic (Coastal)/Non-Strategic (Offshore)

Bottlenose dolphins are one of the most well-known and widely distributed species of marine mammals. These dolphins reach 2 to 4 m (7 to 13 ft) in length and are light gray to black in color (NOAA Fisheries 2018f). Bottlenose dolphins are commonly found in groups of two to 15 individuals, though aggregations in the hundreds are occasionally observed (NOAA Fisheries 2018f). They are considered generalist feeders and consume a wide variety of organisms, including fish, squid, and shrimp and other crustaceans (Jefferson et al. 2008).

Coastal and offshore stocks of bottlenose dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Bottlenose dolphin vocalization frequencies range from 3.4 to 130 kHz (DoN 2008).

4.2.2.1. Distribution

The common bottlenose dolphin is a cosmopolitan species that occurs in temperate and tropical waters worldwide. Common bottlenose dolphins are found in estuarine, coastal, continental shelf, and oceanic waters of the western North Atlantic. Distinct morphological forms have been identified in offshore and coastal waters of the western North Atlantic off the U.S. east coast: a smaller morphotype present in estuarine, coastal, and shelf waters from Florida to approximately Long Island, New York, and a larger, more robust morphotype present further offshore in deeper waters of the continental shelf and slope from Florida to Canada (Mead and Potter 1995). The Northern Migratory Coastal stock is one such stock and one of only two (the other being the Southern Migratory Coastal stock) thought to make broad-scale, seasonal migrations in coastal waters of the western North Atlantic (Hayes et al. 2019). During warm water months, this stock occupies coastal waters from the shoreline to approximately the 20 m (66 ft) isobath between Assateague, Virginia, and Long Island, New York (Garrison et al. 2017). In addition to inhabiting coastal nearshore waters, the coastal morphotype of common bottlenose dolphin also inhabits inshore estuarine waters along the U.S. East Coast and Gulf of Mexico (Wells et al. 1987, Scott et al. 1990, Wells et al. 1996, Weller 1998, Zolman 2002, Speakman et al. 2006, Stolen et al. 2007, Balmer et al. 2008, Mazzoil et al. 2008). Offshore common bottlenose dolphin sightings occur from Cape Hatteras to the eastern end of Georges Bank (Kenney 1990). There are 17 coastal, offshore, bay, and estuarine stocks of common bottlenose dolphins in the U.S. Atlantic EEZ. During HRG surveys, the Northern Migratory Coastal stock may be encountered while surveying potential OECC routes in the nearshore. Bottlenose dolphins encountered in the HRG survey area would likely belong to the Western North Atlantic Offshore stock (Hayes et al. 2018). It is possible that a few animals could be from the Northern Migratory Coastal stock, but they generally do not range farther north than New Jersey.

Kraus et al. (2016) observed common bottlenose dolphins during all seasons within the RI/MA & MA WEAs. Common bottlenose dolphins were the second most commonly observed small cetacean species and exhibited little seasonal variability in abundance. They were observed in the MA WEA in all seasons and observed in Lease Area OCS-A 0501 in fall and winter. One sighting of common bottlenose dolphins in the Kraus et al. (2016) study included calves, and one sighting involved mating behavior. It is possible that the Northeast Large Whale Pelagic Survey underestimated the abundance of common bottlenose dolphins because this survey was designed to target large cetaceans and most small cetaceans were not identified to species (Kraus et al. 2016).

4.2.2.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 97,476 common bottlenose dolphins in the U.S. Atlantic EEZ. The best available population estimate for the Western North Atlantic Offshore stock of bottlenose dolphins is 77,532 (Hayes et al. 2017). This estimate is from summer 2011 surveys covering waters from central Florida to the lower Bay of Fundy (Hayes et al. 2017). The best available estimate for the North Atlantic Northern Migratory Coastal stock is 6,639 (Hayes et al. 2018). This estimate was derived from aerial surveys conducted in summer 2016 covering coastal and shelf waters from Assateague, Virginia, to Sandy Hook, New Jersey (Hayes et al. 2018).

4.2.2.3. Status

Common bottlenose dolphins of the western North Atlantic are not federally listed as threatened or endangered under the ESA or MA ESA. The Western North Atlantic Offshore stock is not considered Strategic (Hayes et al. 2017). However, the western North Atlantic Northern Migratory Coastal stock of common bottlenose dolphins is considered Strategic by NOAA Fisheries because it is listed as depleted under the MMPA (Hayes et al. 2018). From 1995 to 2001, NMFS recognized only the western North Atlantic Coastal stock of common bottlenose dolphins in the western North Atlantic, and this stock was listed as depleted as a result of a UME that took place from 1988 to 1989 (64 FR 17789, April 6, 1993). The stock structure was revised in 2008, 2009, and 2010 to recognize resident estuarine stocks and migratory and resident coastal stocks (Hayes et al. 2018). The Northern Migratory Coastal stock retains the depleted designation as a result of its origin from the Western North Atlantic Coastal stock (Hayes et al. 2018).

4.2.3. Pilot Whales (*Globicephala* spp.)–Non-Strategic

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 visually and acoustically due to similarity in appearance at the surface and vocalizations that overlap in frequency range. Consequently, the two species cannot be reliably distinguished (Rone and Pace 2012, Hayes et al. 2017); unless otherwise stated, the descriptions below refer to both species. Pilot whales have bulbous heads, are dark gray, brown, or black in color, and can reach approximately 7.3 m (24 ft) in length (NOAA Fisheries 2018c). These whales form large, relatively stable aggregations that appear to be maternally determined (American Cetacean Society 2018). Pilot whales feed primarily on squid, although they also eat small to medium-sized fish and octopus when available (NOAA Fisheries 2018c, 2018a). Occurrence of long-finned pilot whale is considered rare in the proposed HRG survey area, while the short-finned pilot whale is considered uncommon.

Pilot whales are acoustic mid-frequency specialists with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Pilot whales echolocate and produce tonal calls. The primary tonal calls of the long-finned pilot whale range from 1 to 8 kHz with a mean duration of about one second. The calls can be varied with seven categories identified (level, falling, rising, up-down, down-up, waver, and multi-hump) and are likely associated with specific social activities (Vester et al. 2014).

4.2.3.1. Distribution

Within the U.S. Atlantic EEZ, both species are categorized into Western North Atlantic stocks. In U.S. Atlantic waters, pilot whales are distributed principally along the continental shelf edge off the northeastern U.S. coast in winter and early spring (CeTAP 1982, Payne and Heinemann 1993, Abend and Smith 1999, Hamazaki 2002). In late spring, pilot whales move onto Georges Bank, into the Gulf of Maine, and into more northern waters, where they remain through late fall (CeTAP 1982, Payne and Heinemann 1993). Short-finned pilot whales are present within warm temperate to tropical waters and long-finned pilot whales occur in temperate and subpolar waters. Long-finned and short-finned pilot whales overlap spatially along the mid-Atlantic shelf break between New Jersey and the southern flank of Georges Bank (Payne and Heinemann 1993, Hayes et al. 2017). Long-finned pilot whales have occasionally been observed stranded as far south as South Carolina, and short-finned pilot whale have stranded as far north as Massachusetts (Hayes et al. 2017). The latitudinal ranges of the two species therefore remain uncertain. However, south of Cape Hatteras, most pilot whale sightings are expected to be short-finned pilot whales, while north of approximately 42° N, most pilot whale sightings are expected to be long-finned pilot whales (Hayes et al. 2017). Based on the distributions described in Hayes et al. (2017), pilot whale sightings in OCS-A 0501 and OCS-A 0522 would most likely be long-finned pilot whales.

Kraus et al. (2016) observed pilot whales infrequently in the RI/MA & MA WEAs and surrounding areas. Effort-weighted average sighting rates for pilot whales could not be calculated. No pilot whales were observed during fall or winter, and these species were only observed 11 times in spring and three times in summer. Two of these sightings included calves. It is possible that the Northeast Large Whale Pelagic Survey underestimated the abundance of pilot whales, as this survey was designed to target large cetaceans and most small cetaceans were not identified to species (Kraus et al. 2016).

4.2.3.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 18,977 pilot whales in the U.S. Atlantic EEZ. This estimate includes both long-finned and short-finned pilot whales. The best available population estimates in the U.S. Atlantic EEZ are 5,636 for long-finned pilot whales and 21,515 for short-finned pilot whales (Hayes et al. 2017). These estimates are from summer 2011 aerial and shipboard surveys covering waters from central Florida to the lower Bay of Fundy (Hayes et al. 2017).

4.2.3.3. Status

Total annual estimated average fishery-related mortality or serious injury during 2010 to 2014 was 38 for long-finned pilot whales and 192 for short-finned pilot whales (Hayes et al. 2017). Neither pilot whale species is listed as threatened or endangered under the ESA or the MA ESA, and the Western North Atlantic stock is not considered strategic under the MMPA.

4.2.4. Risso's dolphin (*Grampus griseus*)–Non-Strategic

Risso's dolphins are located worldwide in both tropical and temperate waters (Jefferson et al. 2008, Jefferson et al. 2014). The Risso's dolphin attains a body length of approximately 2.6 to 4 m (9 to13 ft) (NOAA Fisheries 2018b). This dolphin has a narrow tailstock and whitish or gray body. The Risso's dolphin forms groups ranging from 10 to 30 individuals (NOAA Fisheries 2018b). Risso's dolphins feed primarily on squid, but they also eat fish such as anchovies (*Engraulidae*), krill, and other cephalopods (NOAA Fisheries 2018b).

Risso's dolphins are in the mid-frequency functional hearing group, with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al. 2007). Vocalizations range from 400 Hz to 65 kHz (DoN 2008).

4.2.4.1. Distribution

Risso's dolphins in the U.S. 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). 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). In 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).

Kraus et al. (2016) results suggest that Risso's dolphins occur infrequently in the RI/MA & MA WEAs and surrounding areas. Effort-weighted average sighting rates for Risso's dolphins could not be calculated. No Risso's dolphins were observed during summer, fall, or winter, and this species was only observed twice in spring. It is possible that the Northeast Large Whale Pelagic Survey underestimated the abundance of Risso's dolphins, as this survey was designed to target large cetaceans and most small cetaceans were not identified to species.

4.2.4.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 7,732 Risso's dolphins in the U.S. Atlantic EEZ. The best available abundance estimate for Risso's dolphins in the Western North Atlantic stock from NOAA Fisheries stock assessments is 18,250, which is estimated from data collected during 2011 surveys (Hayes et al. 2018).

4.2.4.3. Status

Risso's dolphins are not listed as threatened or endangered under the ESA and this stock is not considered Strategic.

4.2.5. Short-Beaked Common Dolphin (*Delphinus delphis delphis*)–Non-Strategic

The short-beaked common dolphin is one of the most widely distributed cetaceans and occurs in temperate, tropical, and subtropical regions (Jefferson et al. 2008). 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" (NOAA Fisheries 2018d). This species feeds on schooling fish and squid found near the surface at night (NOAA Fisheries 2018d). They have been known to feed on fish escaping from fishermen's nets and fish that are discarded from boats (NOAA 1993). These dolphins can gather in schools of hundreds or thousands, although groups generally consist of 30 or fewer individuals (NOAA 1993).

Short-beaked common dolphins are in the mid-frequency functional hearing group. Their vocalizations range from 300 Hz to 44 kHz (Southall et al. 2007).

4.2.5.1. Distribution

Short-beaked common dolphins in the U.S. 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 U.S. Atlantic EEZ, this species is distributed along the continental shelf between the 100 to 2,000 m (328 to 6,562 ft) isobaths and is associated with Gulf Stream features (CeTAP 1982, Selzer and Payne 1988, 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 (Selzer and Payne 1988). 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 with females estimated to have a calving interval of two to three years (Hayes et al. 2018).

Kraus et al. (2016) suggested that short-beaked common dolphins occur year-round in the RI/MA & MA WEAs and surrounding areas. Short-beaked common dolphins were the most frequently observed small cetacean species within the Kraus et al. (2016) study area. Short-beaked common dolphins were observed in the RI/MA & MA WEAs in all seasons and observed in the Lease Area OCS-A 0501 in spring, summer, and fall. Short-beaked common dolphins were most frequently observed during the summer months; observations of this species peaked between June and August. Two sightings of short-beaked common dolphins in the Kraus et al. (2016) study included calves, two sightings involved feeding behavior, and three sightings involved mating behavior. Sighting data indicate that short-beaked common dolphin distribution tended to be farther offshore during the winter months than during spring, summer, and fall. It is possible that the Northeast Large Whale Pelagic Survey underestimated the abundance of short-beaked common dolphins, because this survey was designed to target large cetaceans and the majority of small cetaceans were not identified to species (Kraus et al. 2016).

4.2.5.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 86,098 short-beaked common dolphins in the U.S. Atlantic EEZ. The best population estimate in the U.S. Atlantic EEZ for the Western North Atlantic short-beaked common dolphin is 70,184 (Hayes et al. 2018).

4.2.5.3. Status

The short-beaked common dolphin is not listed as threatened or endangered under the ESA and the Western North Atlantic stock of the short-beaked common dolphins is not considered Strategic.

4.2.6. Sperm Whale (*Physeter macrocephalus*)–Endangered

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 US tons) (Whitehead 2009). Sperm whales have extremely large heads, which account for 25 to 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 (1,312 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 (3,281 ft) (Watwood et al. 2006). Sperm whales have a worldwide distribution in deep water and range from the equator to the edges of the polar pack ice (Whitehead 2002). 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, 2003).

The IWC recognizes only one stock of sperm whale for the North Atlantic, and Reeves and Whitehead (1997) and Dufault et al. (1999) suggest that sperm whale populations lack clear geographic structure.

Current threats to the sperm whale population include ship strikes, exposure to anthropogenic sound and toxic pollutants, and entanglement in fishing gear (though entanglement risk for sperm whales is relatively low compared to other, more coastal whale species) (Waring et al. 2015, NOAA Fisheries 2018i).

Sperm whales are in the mid-frequency hearing group, with an estimated auditory range of 150 Hz to 160 kHz (Southall et al., 2007). Sperm whales produce short-duration repetitive broadband clicks used for communication and echolocation. These clicks range in frequency from 0.1 to 30 kHz, with dominant frequencies between the 2 to 4 kHz and 10 to 16 kHz ranges (DoN 2008). Echolocation clicks from adult sperm whales are highly directional clicks and have a SL estimated at up to 236 dB re 1 µPa.

4.2.6.1. Distribution

Sperm whales mainly reside in deep-water habitats on the OCS, along the shelf edge, and in mid-ocean regions (NOAA Fisheries, 2010). However, this species has been observed in relatively high numbers in the shallow continental shelf areas off the coast of Southern New England (Scott and Sadove 1997). Sperm whale migratory patterns are not well-defined, and no obvious migration patterns have been observed in certain tropical and temperate areas. However, general trends suggest that most populations move poleward during summer months (Waring et al. 2015). In U.S. Atlantic EEZ waters, sperm whales appear to exhibit seasonal movement patterns (CeTAP 1982, Scott and Sadove 1997). During winter, sperm whales are concentrated to the east and north of Cape Hatteras. This distribution shifts northward in spring, when sperm whales are most abundant in the central portion of the mid-Atlantic bight to the southern region of Georges Bank. In summer, this distribution continues to move northward, including the area east and north of Georges Bank and the continental shelf to the south of New England. In fall months, sperm whales are most abundant on the continental shelf to the south of New England and remain abundant along the continental shelf edge in the mid-Atlantic bight.

Kraus et al. (2016) observed sperm whales four times in the RI/MA & MA WEAs during summer and fall from 2011 to 2015. Sperm whales, traveling singly or in groups of three or four, were observed three times in August and September 2012, and once in June 2015. One sperm whale was observed on the northwestern border of the OCS-A 0501 lease and one was observed between OCS-A 0501 and Nantucket Island. The frequency of sperm whale clicks exceeded the maximum frequency of PAM equipment used in Kraus et al. (2016), so no acoustic data are available for this species from that study. Sperm whales are expected to be present but uncommon in the Offshore Project Area based on Kraus et al. (2016) sightings.

4.2.6.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 5,353 sperm whales in the U.S. Atlantic EEZ. Though there is currently no reliable estimate of total sperm whale abundance in the entire western North Atlantic, the most recent best available population estimate for the U.S. Atlantic EEZ is 2,288 (Waring et al. 2015). This estimate was generated from the sum of surveys conducted in 2011, and is likely an underestimate of total abundance, because these surveys were not corrected for sperm whale dive time.

4.2.6.3. Status

Sperm whales are listed as endangered under the ESA and MA ESA, and the North Atlantic stock is considered Strategic by NMFS. Total annual estimated average human-caused mortality to this stock during the period from 2008 to 2012 was 0.8 sperm whales (Waring et al. 2015). No critical habitat areas have been designated for the sperm whale under the ESA.

4.2.7. Harbor Porpoise (*Phocoena phocoena*)–Non-Strategic

The harbor porpoise is abundant throughout the coastal waters of the Northern Hemisphere and the only porpoise species found in the Atlantic Ocean. This species is a small, stocky cetacean with a blunt, short-beaked head, dark gray back, and white underside (NOAA Fisheries 2018m). Harbor porpoises reach a maximum length of 1.8 m (6 ft) and feed 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).

The harbor porpoise is considered a high-frequency cetacean. The dominant component of harbor porpoise echolocation signals are narrowband high-frequency clicks within 130 to 142 kHz (Villadsgaard et al. 2007).

4.2.7.1. Distribution

The harbor porpoise is usually found in shallow waters of the continental shelf, although they occasionally travel over deeper offshore waters. They are commonly found in bays, estuaries, harbors, and fjords less than 200 m (656 ft) deep (NOAA Fisheries 2018m). Hayes et al. (2018) report that harbor porpoises are generally concentrated along the continental shelf within the northern Gulf of Maine and southern Bay of Fundy region during summer months (July through September). During fall (October through December) and spring (April through June), they are more widely dispersed from New Jersey to Maine. In winter (January to March), intermediate densities of harbor porpoises can be found in waters off New Jersey to North Carolina with lower densities found in waters off New York to New Brunswick, Canada (Hayes et al. 2019). There are four distinct populations of harbor porpoise in the Western Atlantic: Gulf of Maine/Bay of Fundy, Gulf of St. Lawrence, Newfoundland, and Greenland (Hayes et al. 2018). Harbor porpoises observed in the U.S. Atlantic EEZ are considered part of the Gulf of Maine/Bay of Fundy stock.

Kraus et al. (2016) indicate that harbor porpoises occur within the RI/MA & MA WEAs in fall, winter, and spring. Harbor porpoises were observed in groups ranging in size from three to 15 individuals and were primarily observed in the Kraus et al. (2016) study area from November through May, with very few sightings during June through September.

4.2.7.2. Abundance

Roberts et al. (2016) habitat-based density models provide an abundance estimate of 17,651 harbor porpoise in the U.S. Atlantic EEZ during winter (November to May) and 45,089 during summer (June to October) months. The best current abundance estimate of the Gulf of Maine/Bay of Fundy harbor porpoise stock is 79,883 individuals, based upon data collected during a 2011 line-transect sighting survey (Hayes et al. 2018).

4.2.7.3. Status

Harbor porpoises are not listed as threatened or endangered under the ESA or the MA ESA. The Gulf of Maine/Bay of Fundy stock of harbor porpoises is not considered Strategic. The total annual estimated average human-caused mortality is 307 (Hayes et al. 2018).

4.3. Pinnipeds

Four species of pinnipeds are known to occur or are potentially occurring in the Atlantic Ocean near the HRG survey area: the harbor seal, gray seal, harp seal, and hooded seal. Like all pinnipeds, these animals have an amphibious lifestyle and are found nearshore (especially near their haul-out/ breeding sites) as well as in offshore waters. All four seal species in the HRG survey area are phocids, or true seals, having no external ears.

4.3.1. Gray Seal (*Halichoerus grypus atlantica*)–Non-Strategic

Gray seals are the second most common pinniped in the U.S. Atlantic coast (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 to 3 m (7 to 10 ft) in length, and have a silver-gray coat with scattered dark spots (NOAA Fisheries 2018h). 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 OCS (Lesage and Hammill 2001, Jefferson et al. 2008). These opportunistic feeders primarily consume fish, crustaceans, squid, and octopus (Bonner 1971, Reeves 1992, Jefferson et al. 2008). They often co-occur with harbor seals because their habitat and feeding preferences overlap (NOAA Fisheries 2018h).

Gray seals, as with all pinnipeds, are assigned to functional hearing groups based on the medium (air or water) through which they are detecting the sounds, for an estimated auditory bandwidth of 75 Hz to 75 kHz (Southall et al. 2007).Vocalizations range from 100 Hz to 3 kHz (DoN 2008).

4.3.1.1. Distribution

The gray seal ranges from Canada to New York; however, there are stranding records as far south as Cape Hatteras, North Carolina (Gilbert et al. 2005). 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, Lesage and Hammill 2001). There are three breeding concentrations in eastern Canada: Sable Island, Gulf of St. Lawrence, and along the east coast of Nova Scotia (Lavigueur and Hammill 1993). In U.S. waters, gray seals primarily pup at four established colonies: Muskeget and Monomoy islands in Massachusetts, and Green and Seal Islands in Maine. Since 2010, pupping has also been observed at Noman’s Island in Massachusetts and Wooden Ball and Matinicus Rock in Maine (Hayes et al. 2019). Although white-coated pups have stranded on eastern Long Island beaches in New York, no pupping colonies have been detected in that region. Gray seals have been observed using the historic pupping site on Muskeget Island in Massachusetts since 1988 (Hayes et al. 2019). Pupping has taken place on Seal and Green Islands in Maine since at least the mid-1990s (Hayes et al. 2019). 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. Gray seals are expected to occur year-round in at least some potential OECC routes, with seasonal occurrence in the offshore areas from September to May (Hayes et al. 2018).

Kraus et al. (2016) observed gray seals in the RI/MA & MA WEAs and surrounding areas, but this survey was designed to target large cetaceans so locations and numbers of seal observations were not included in the study report (Kraus et al. 2016).

4.3.1.2. Abundance

The gray seal is found on both sides of the North Atlantic, with three major populations: Northeast Atlantic, Northwest Atlantic, and the Baltic Sea (Haug et al. 2013). The Western North Atlantic stock is equivalent to the Northwest Atlantic population, and ranges from New Jersey to Labrador (Mansfield 1966, Scott et al. 1990, Katona et al. 1993, Lesage and Hammill 2001). For U.S. waters alone, Hayes et al. (2018) estimated an abundance of 27,131.

4.3.1.3. Status

Gray seals are not listed as threatened or endangered under the ESA or the MA ESA and are not considered Strategic under the MMPA.

4.3.2. Harbor Seal (*Phoca vitulina vitulina*)–Non-Strategic

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). This species is approximately 2 m (7 ft) in length and has a blue-gray back with light and dark speckling (NOAA Fisheries 2018j).

(NOAA Fisheries 2018j). Harbor seals complete both shallow and deep dives during hunting, depending on the availability of prey (Tollit et al. 1997). This species consumes a variety of prey, including fish, shellfish, and crustaceans (Bigg 1981, Reeves 1992, Burns 2002, Jefferson et al. 2008). Harbor seals commonly occur in coastal waters and on coastal islands, ledges, and sandbars (Jefferson et al. 2008).

Male harbor seals produce underwater vocalizations during mating season to attract females and defend territories. These calls are comprised of "growls" or "roars" with peak energy at 200 Hz (Sabinsky et al. 2017). Captive studies have shown that harbor seals have good (>50 %) sound detection thresholds between 0.1 and 80 kHz, with primary sound detection between 0.5 and 40 kHz (Kastelein et al. 2009).

4.3.2.1. Distribution

Harbor seals are year-round inhabitants of the coastal waters of eastern Canada and Maine (Richardson and Rough 1993) and occur seasonally from southern New England to New Jersey coasts between September and late May (Schneider and Payne 1983, Barlas 1999, Schroeder 2000). In the western North Atlantic, they are distributed from eastern Canada to southern New England and New York, and occasionally as far south as the Carolinas (Payne and Selzer 1989). A general southward movement from the Bay of Fundy to southern New England occurs in fall and early winter (Rosenfeld et al. 1988, Whitman and Payne 1990, Barlas 1999, Jacobs and Terhune 2000). A northward movement from southern New England to Maine and eastern Canada occurs prior to the pupping season, which takes place from mid-May through June along the Maine coast (Richardson 1976, Wilson 1978, Whitman and Payne 1990, Kenney 1994).

Kraus et al. (2016) observed harbor seals in the RI/MA & MA WEAs and surrounding areas, but this survey was designed to target large cetaceans so locations and numbers of seal observations were not included in the study report (Kraus et al. 2016). Harbor seals have five major haul-out sites in and near the RI/MA & MA WEAs: Monomoy Island, the northwestern side of Nantucket Island, Nomans Land, the north side of Gosnold Island, and the southeastern side of Naushon Island (Payne and Selzer 1989). Increased abundance of seals in the northeast region has also been documented during aerial and boat surveys of overwintering haul-out sites from the Maine/New Hampshire border to eastern Long Island and New Jersey (Payne and Selzer 1989, Rough 1995, Barlas 1999, Hoover et al. 1999, Slocum et al. 1999, deHart 2002).

4.3.2.2. Abundance

Although the stock structure of the Western North Atlantic population is unknown, it is thought that harbor seals found along the eastern U.S. and Canadian coasts represent one population that is termed the Western North Atlantic stock (Temte et al. 1991, Andersen and Olsen 2010). The best estimate of abundance for harbor seals in the Western North Atlantic stock is 75,834 (Hayes et al. 2018). This estimate was derived from a coast-wide survey along the Maine coast during May and June 2012.

4.3.2.3. Status

The Western North Atlantic stock of harbor seals is not listed as threatened or endangered under the ESA or the MA ESA and is not considered Strategic under the MMPA.

5. Type of Incidental Taking Authorization Requested

Vineyard Wind is requesting an IHA pursuant to section 101(a)(5)(D) of the MMPA for incidental take by Level B harassment of small numbers of marine mammals during the HRG surveys described in Section 1. Potential takes would occur as a result of marine mammal exposure to regulatory-defined sound levels from HRG sources listed in Section 1 and described in detail in Section 6.

For impulsive and non-impulsive intermittent sources, the maximum range to a regulatory-defined Level A threshold is 60 m (197 ft) for high-frequency (HF) cetaceans. Potential exposure of marine mammals to sound levels associated with Level A thresholds may be estimated using this horizontal impact distance from a source and an exposure calculation. Consistent with the conclusions of the BOEM Atlantic OCS G&G Programmatic EIS (BOEM 2014b), no permanent hearing loss or physiological damage (such as permanent threshold shift [PTS]) or injury is expected to occur to marine mammals by the survey equipment or vessels during proposed HRG surveys, and therefore Level A take is not anticipated during HRG surveys. The calculations for Level A (and Level B) exposures assume that HRG surveys conducted during the survey window will use the source producing the largest acoustic isopleths. This assumption is conservative and provides a cautious approach to predicting active survey operations and their potential impact on marine mammal species.

The most likely Level B take is expected to result from minor or moderate behavioral reactions, such as avoidance and temporary displacement, for some individuals or groups of marine mammals near the proposed activities. It is expected that the severity of behavioral effects will vary with the duration of operations, the behavior of the animal at the time of reception of the sound, and the distance and received SPL of the sound. The Level B take is unlikely to be manifested as a temporary threshold shift (TTS) (Southall et al. 2007) but in the immediate vicinity (several meters) of the sound source, where the received SPLs might be high enough, has the potential to cause a temporary loss of hearing sensitivity (Holt 2008). Potential Level B impacts will be mitigated through a visual monitoring program and associated vessel activity management program, both of which are fully described in Section 11.

6. Take Estimates for Marine Mammals

Vineyard Wind is seeking authorization for the potential “taking” of small numbers of marine mammals under the jurisdiction of NMFS in the proposed region of the Projects, as described in Section 2. The 14 species that are estimated to potentially experience sound exposure levels associated with Level A and Level B harassment are described in Section 4. Each species has a geographic distribution that encompasses the HRG survey area and has at least a minimal potential to occur (categorized as common, regular, or uncommon). Authorization for Level B harassment is sought for the following species:

1. Fin whale;
2. Humpback whale;
3. Minke whale;
4. North Atlantic right whale;
5. Sei whale;
6. Atlantic white-sided dolphin;
7. Common bottlenose dolphin;
8. Pilot whale (mainly long-finned pilot whale);
9. Risso’s dolphin;
10. Short-beaked common dolphin;
11. Sperm whale;

12. Harbor porpoise;
13. Gray seal; and
14. Harbor seal.

The only anticipated impacts to marine mammals are associated with anthropogenic sound from the HRG survey equipment. The proposed HRG surveys are not expected to take more than a small number of marine mammals or have more than a negligible effect on their populations based on their seasonal density and distribution and their known reactions to exposure to impulsive, intermittent sound sources. Monitoring and mitigation will further reduce the potential for impact as described further in Section 11.

6.1. Acoustic Criteria–Level A and Level B Harassment Regulatory Criteria

The 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 HRG operations. These are:

- Level A: any act of pursuit, torment, or annoyance which 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 Project-associated HRG sound sources, it is necessary to first establish acoustic exposure criteria at which takes could result. In 2016, 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. All sources are also categorized as moving.

NOAA Fisheries 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 peak (unweighted/flat) sound level metric (PK) 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) that species are assigned to, based on their respective hearing ranges. The acoustic analysis applies the most recent sound exposure criteria utilized by NMFS to estimate acoustic harassment (NMFS 2018).

Sound levels thought to elicit disruptive behavioral response are described using the SPL metric (NMFS and NOAA 2005). NMFS currently uses behavioral response thresholds of 160 dB re 1 µPa for impulsive sounds and 120 dB re 1 µPa for non-impulsive sounds for all marine mammal species (NMFS 2018), based on observations of mysticetes (Malme et al. 1983, Malme et al. 1984, Richardson et al. 1986, Richardson et al. 1990). 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).

6.1.1. 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 of hearing (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, direct measurements of many odontocetes and all mysticetes do not exist. As a result, hearing ranges 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 (NMFS 2018).

Southall et al. (2019) published an updated set of Level A sound exposure criteria (i.e., for onset of TTS and 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 NMFS (2018). The new hearing groups proposed by Southall et al. (2019) have not yet been adopted by NOAA. The NOAA (2018) hearing groups presented in Table 3 are used in this analysis.

Table 3. Marine mammal hearing groups (Sills et al. 2014, NMFS 2018).

Hearing group	Generalized hearing range*
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 (PW)	50 Hz to 86 kHz
Phocid pinnipeds in air (PA)†	50 Hz to 36 kHz

* The generalized hearing range is for all species within a group. Individual hearing will vary.
† Based on the distance from shore (23 km [12.4 nm] offshore of Martha's Vineyard and Nantucket), sound will not reach NOAA thresholds for behavioral disturbance of seals in air (90 dB root mean square [rms] re 20 µPa for harbor seals and 100 dB [rms] re 20 µPa for all other seal species) at land-based sites where seals may spend time out of the water and thus in-air hearing is not considered further.

6.1.2. Marine Mammal Auditory Weighting Functions

The potential for anthropogenic sounds 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 (Section 6.1.1). Auditory (frequency) weighting functions reflect an animal's ability to hear a sound. Sound spectra are weighted at particular frequencies in a manner that reflects an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007). Auditory weighting functions have been proposed for marine mammals, specifically associated with thresholds for onset of TTS and PTS; they are expressed in metrics that consider what is known about marine mammal hearing (e.g., SEL) (Southall et al. 2007, Erbe et al. 2016, Finneran 2016). Marine mammal auditory weighting functions for all hearing groups (Table 3) published by Finneran (2016) are included in the NMFS (2018) Technical Guidance document for use in conjunction with corresponding SEL PTS (Level A) onset acoustic criteria.

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

6.1.3. Level A Harassment 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 the hearing apparatus independent of duration, so an additional metric of PK is needed to assess acoustic exposure injury risk. PTS is 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 TTS occurs, so PTS onset is typically extrapolated from TTS onset level and an assumed growth function (Southall et al. 2007). NOAA Fisheries (2018) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy accumulated over 24 hours (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 4). 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 4. Summary of relevant PTS onset acoustic thresholds (received level; dB) for marine mammal hearing groups (NMFS 2018).

Hearing group	Impulsive		Non-impulsive
	Unweighted L_{pk} (dB re 1 µPa)	M-weighted $L_{E,24h}$ (dB re 1 µPa²s)	M-weighted $L_{E,24h}$ (dB re 1 µPa²s)
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

6.1.4. Level B Harassment 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. However, 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 and Frankel 2012). Because of the complexity and variability of marine mammal behavioral responses to acoustic exposure, NMFS has not yet released technical guidance on behavior thresholds for use in calculating animal exposures. For impulsive sounds, NMFS is currently using an unweighted SPL of 160 dB re 1 µPa as behavioral response threshold for all cetacean species (NMFS and NOAA 2005). This criterion was derived from the High Energy Seismic Survey (HESS) Review Process (1999) report which, in turn, was based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1983, Malme et al. 1984). The HESS team recognized that behavioral responses to sound may occur at lower levels, but substantial responses were only likely to occur above a 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 a 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 dose-response functions. Absence of controls, precise measurements, appropriate metrics, and context dependency of responses (including the activity state of the animal) all contribute to variability.

Wood et al. (2012) proposed a graded probability of response for impulsive sounds using a frequency-weighted (i.e., M-weighted; Southall et al. 2007) SPL metric. The authors also designated behavioral response categories for sensitive species, including harbor porpoise and beaked whales, and for migrating mysticetes.

NOAA Fisheries currently considers marine mammals exposed above 160 dB re 1 µPa to have experienced a Level B behavior take, therefore this threshold is used in this analysis.

6.2. Acoustic Impact Analysis Methods Overview

To estimate the potential effects (i.e., Level A and Level B harassment) to marine mammals from exposure to anthropogenic sound generated during the Project, the following steps were performed:

- Calculate radial distances of various HRG sources to regulatory defined Level A and Level B acoustic thresholds;
- Calculate species-specific densities derived from the Roberts et al. (2016, 2017, 2018) habitat-based density model for the proposed HRG survey area. In order to determine marine mammal densities for take estimates, the density was averaged across the entire HRG survey area for all survey months;
- Determine the zone of influence (ZOI) for each survey equipment type;
- Estimate the number of potential marine mammal exposures without mitigation for each equipment type by multiplying the ZOI, species-specific density and proposed number of survey days; and
- Estimate Level A and Level B takes once monitoring and mitigation is applied.

6.3. Predicted Radial Distances to Exposure Thresholds

The sound a source produces is characterized in time, spectral content, and space. As sound travels away from a source, it is shaped by interactions with the environment in which it propagates. For this reason, the sound field produced by a source is specific to the source and the location. Understanding the potential for sound exposure to impact animals requires an understanding of the sound field to which they could be exposed. Though not directly used for exposure estimates, ranges to exposure criteria thresholds are often reported and useful for informing monitoring and mitigation zones.

The sound sources of potential concern during HRG surveys are the moving impulsive HRG sources. The final equipment used during the proposed HRG survey activities will vary depending on the final survey design, vessel availability, and survey contractor selection. A selection of HRG equipment was used in this assessment to estimate potential horizontal impact distances to regulatory defined Level A and B harassment thresholds. A list of HRG sound sources that may be used during the HRG surveys that were assessed for potential acoustic impacts are included in Table 5. All the source parameters used to calculate horizontal impact distances are also provided in Table 5 and further detailed in Appendix A and Appendix B.

Operational parameters (e.g., SL, beam width, repetition rate, etc.) will vary during a survey depending on location and geophysical objectives, and therefore operational knowledge is required to select appropriate parameters and source levels to estimate the distances to regulatory thresholds. Where there is uncertainly, a precautionary and conservative approach is taken. A detailed explanation of the sources of parameter information is provided in Appendix A and Appendix B. In summary, the following hierarchy was used to select input into horizontal impact distance calculations, as directed by NMFS:

- For equipment that was measured in Crocker and Fratantonio (2016), the reported SL for the most likely operational parameters was selected;
- For equipment not measured in Crocker and Fratantonio (2016) manufacturer specifications, or personal communications with manufacturers were used. Manufacturer specifications typically represent the maximum output of any source and do not always represent the most likely operational settings. These should be considered conservative and are likely to overestimate the horizontal impact distance for that equipment; and
- For equipment that was not measured in Crocker and Fratantonio (2016) and where manufacturer specifications were not available or did not contain the required calculation inputs, the closest proxy source measured in Crocker and Fratantonio (2016) was used.

Table 5 identifies the proposed survey equipment expected to operate at and below 200 kHz, and lists the relevant acoustic parameters considered in the acoustic assessment of these sources. Equipment that will be operated at frequencies higher than 200 kHz (e.g., multibeam echosounders and side scan sonars) are not included in this application as they operate at frequencies outside of the hearing range of marine mammals. The final make and model of the listed HRG equipment is dependent on availability and will be determined during survey preparations and contract negotiations with a yet-to-be-determined survey contractor, however, equipment utilized will be the same or similar as that proposed in Table 5. The proposed HRG survey activities will not result in the disturbance of bottom habitat in the HRG survey area.

The primary operating frequency, and other relevant acoustic parameters (e.g., power level, pulse duration and repetition, beamwidth, etc.) are often made available by the HRG equipment manufacturer and provided in publicly available manufacturer specifications. This generally represents the most conservative settings of the equipment, while configuration of the equipment is specific to the proposed survey.

Table 5. List of proposed HRG sound sources that produce underwater sound at frequencies equal to or less than 200 kHz, and their acoustic characteristics. Details on calculation of out-of-beam levels can be found in Appendix A.

Equipment	System	Frequency (kHz)	Beam width (°)	Pulse duration (ms)	Repetition rate (Hz)	In-beam		Correction (dB)	Out-of-beam	
						Source level (dB re 1 μPa m)	Peak source level (dB re 1 μPa m)		Source level (dB re 1 μPa m)	Peak source level (dB re 1 μPa m)
Shallow subbottom profiler	EdgeTech Chirp 216	2–10	65	2	3.75	178	182	-8.10	169.9	173.9
	Innomar SES 2000 Medium	85–115	2	2	40	241	247	-36.3	204.7	210.7
Deep seismic profiler	Applied Acoustics AA251 Boomer	0.2–15	180	0.9	2	205	212	0.0	205	212
	GeoMarine Geo Spark 2000 (400 tip)	0.25–5	180	2.8	1	206	214	0.0	206	214
Underwater positioning (USBL)	SonarDyne Scout Pro	35–50	180	Unknown	Unknown	188	191	0.0	188	191
	ixBlue Gaps	20–32	180	1	10	191	194	0.0	191	194

6.3.1. Level A Harassment Criteria Radii

Table 6 lists the geophysical survey sources and the horizontal impact distances to the Level A criteria. Sources with a repetition rate greater than 10 Hz were assessed based on the non-impulsive SEL thresholds due to the relatively high repetition rate (see Appendix A for more details).

Table 6. Horizontal distance to Level A impact threshold.

Equipment	System	Level A horizontal impact distance (m)					Impulsive source
		LF	MF	HF	PW	OW	(Y/N)
Shallow subbottom profilers	EdgeTech Chirp 216	<1	<1	<1	<1	<1	Y
Shallow subbottom profilers	Innomar SES 2000 Medium	<1	<1	60	<1	<1	N
Deep seismic profilers	Applied Acoustics AA251 Boomer	<1	<1	60	<1	<1	Y
Deep seismic profilers	GeoMarine Geo Spark 2000 (400 tip)	<1	<1	6	<1	<1	Y
Underwater positioning (USBL)	SonarDyne Scout Pro	*	*	*	*	*	*
Underwater positioning (USBL)	ixBlue Gaps	<1	<1	55	<1	<1	Y

*Unable to compute distance due to unavailable source parameters. No manufacturer specifications available. Assume that the horizontal impact distance is similar to those reported for the ixBlue Gaps.

6.3.2. Level B Harassment Criteria Radii

Table 7 presents the geophysical survey sources and the horizontal impact distances to Level B thresholds reported with source levels computed over the duration of the pulse, and over a 100 ms integration period (see Appendix B for more details). As per NMFS guidance, the horizontal impact distance used to calculate the Zone of Influence (ZOI) and estimated exposures does not include the 100 ms hearing integration period. It is shown for comparison purposes only. The source levels computed over the pulse length are used in the ZOI and exposure calculations.

Table 7. Estimated horizontal distances to Level B threshold criteria (160 dB SPL) with and without adjustment for marine mammal hearing integration time.

Equipment	System	Frequency (kHz)	Beam width (°)	Source level (dB re 1 µPa m)	Level B horizontal impact distance (m)	Adjusted source level for 100 ms averaging time (dB re 1 µPa m)	Level B horizontal impact distance using adjusted source level (m)
Shallow subbottom profilers	EdgeTech Chirp 216	2–10	65	178	4	161	1
	Innomar SES 2000 Medium	85–115	2	241	116	230	42
Deep seismic profilers	Applied Acoustics AA251 Boomer	0.2–15	180	205	178	184.5	17
	GeoMarine Geo Spark 2000 (400 tip)	0.25–5	180	206	195	190.5	33
Underwater positioning (USBL)	SonarDyne Scout Pro	35–50	180	188	24	188	24
	ixBlue Gaps	20–32	180	191	35	171	4

6.4. Marine Mammal Densities

Marine mammal density estimates (animals per 100 square kilometers [animals/100 km^2] Table 8) used in this assessment were obtained using the Duke University Marine Geospatial Ecological Laboratory model results (Roberts et al. 2016, 2018) and a model that provides updated densities for the fin whale, humpback whale, minke whale, NARW, sei whale, sperm whale, pilot whales, and harbor porpoise (Roberts et al. 2017). This model incorporates more sighting data than Roberts et al. (2016), including sightings from AMAPPS 2010 to 2014 surveys, which included some aerial surveys over the RI/MA & MA WEAs (NEFSC & SEFSC, 2011, 2012, 2014a, 2014b, 2015, 2016). Density estimates for pinnipeds were calculated using Roberts et al. (2018) density data.

The mean density for each month was determined by calculating the unweighted mean of all 10 x 10 km (6.2 x 6.2 mi) grid cells partially or fully within the analysis polygon. Densities were computed for the entire year to coincide with possible planned activities. In cases where monthly densities were unavailable, annual mean densities were used instead. Table 8 shows the monthly marine mammal density estimates for each species evaluated in the acoustic analysis.

Table 8. Mean monthly marine mammal density estimates for the proposed HRG survey area from Roberts et al. (2015, 2016, 2017, 2018).

Species of interest	Monthly densities (animals/100 km²)[a]												Annual mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Fin whales[b]	0.139	0.125	0.142	0.252	0.321	0.370	0.361	0.359	0.298	0.178	0.128	0.130	0.234
Humpback whales	0.042	0.023	0.045	0.178	0.298	0.328	0.178	0.156	0.236	0.206	0.140	0.077	0.159
Minke whales	0.049	0.059	0.060	0.192	0.398	0.317	0.188	0.141	0.127	0.122	0.027	0.037	0.143
North Atlantic right whales[b]	0.027	0.028	0.404	0.559	0.113	0.048	0.020	0.004	0.005	0.010	0.021	0.025	0.105
Sei whales[b]	0.002	0.002	0.002	0.039	0.047	0.019	0.005	0.003	0.004	0.004	0.003	0.003	0.011
Atlantic white sided dolphins	2.102	1.430	1.510	3.107	6.528	6.717	4.594	3.128	2.826	3.259	3.511	3.431	3.512
Bottlenose dolphins	0.585	0.087	0.033	0.761	1.367	4.062	7.504	6.903	5.747	3.535	1.911	1.470	2.830
Pilot whales[c]	0.493	0.493	0.493	0.493	0.493	0.493	0.493	0.493	0.493	0.493	0.493	0.493	0.493
Risso's dolphins	0.012	0.006	0.003	0.003	0.008	0.014	0.030	0.050	0.035	0.015	0.021	0.029	0.019
Short beaked dolphins	9.533	2.331	1.050	1.758	3.181	4.716	6.621	9.561	11.006	11.138	8.719	15.238	7.071
Sperm whales[b]	0.001	0.002	0.002	0.007	0.019	0.015	0.037	0.040	0.016	0.012	0.007	0.002	0.013
Harbor porpoises	4.335	5.899	8.169	6.132	4.880	1.374	1.106	1.305	1.259	0.754	2.454	5.882	3.629
Gray seals	17.235	17.235	17.235	17.235	17.235	4.472	4.472	4.472	17.235	17.235	17.235	17.235	14.044
Harbor seals	17.235	17.235	17.235	17.235	17.235	4.472	4.472	4.472	17.235	17.235	17.235	17.235	14.044

[a] Density estimates are from habitat-based density modeling of the entire U.S. Atlantic EEZ from Roberts et al. (2016).
[b] Listed as endangered under the ESA.
[c] Long- and short-finned pilot whales are grouped together as a guild.

6.5. Zone of Influence

The ZOI is a representation of the maximum extent of the ensonified area around a sound source over a 24-hour period. The ZOI for each piece of equipment operating at or below 200 kHz was calculated using the following equation:

$$\text{Mobile sources:} \quad ZOI = (\text{Distance/day} \times 2r) + \pi r^2$$

where *r* is the linear distance from the source to the isopleth for Level A or Level B thresholds and day = 1.

The estimated potential daily active survey distance of 100 km (54 nm) was used as the estimated areal coverage over a 24-hour period. This distance accounts for the vessel traveling at roughly 4 knots (2.1 m/s) and includes non-active survey periods. The NMFS (2018) Level A harassment thresholds use dual metrics (SEL and PK). The largest horizontal impact distance from the two metrics was used to determine the ZOI for exposure estimation. The corresponding Level A and Level B ZOI for each HRG equipment type for a 24-hour period are provided in Table 9.

Table 9. Estimated ZOI for Level A and Level B exposure thresholds for each hearing group.

Source	ZOI Level A (km^2)				ZOI Level B (km^2)
	Hearing group[a]				
	LF[a]	MF[a]	HF[a]	PW[a]	All
EdgeTech Chirp 216	0.20[b]	0.20[b]	0.20[b]	0.20[b]	0.80
Innomar SES 2000 Medium	0.20[b]	0.20[b]	12.01	0.20[b]	23.24
Applied Acoustics AA251 Boomer	0.20[b]	0.20[b]	12.01	0.20[b]	35.70
GeoMarine Geo Spark 2000 (400 tip)	0.20[b]	0.20[b]	1.20	0.20[b]	39.12
SonarDyne Scout Pro	n/a	n/a	n/a	n/a	4.80
ixBlue Gaps	0.20[b]	0.20[b]	11.01	0.20[b]	7.00

[a] As defined in NMFS (2018): LF= low-frequency; MF = mid-frequency; HF = high-frequency; PW = phocid pinnipeds in water.
[b] Estimated distance was <1 m (3.3 ft); ZOI calculated based on 1 m (3.3 ft).

6.6. Estimated Numbers of Marine Mammals That Might Be Exposed to Level A and B Harassment Sound Levels

Vineyard Wind is requesting approval for the incidental harassment of marine mammals associated with sound exposure from HRG survey activities. Marine mammal exposures were estimated using habitat-based species' densities, equipment-specific sound source propagation calculations and a proposed maximum survey duration. Note that the maximum number of days used in exposure calculations is the number of estimated vessel days required to complete the survey (736 vessel days). The number of survey vessels and weather limitations will affect the actual length of survey time, but it is expected that the total active acquisition time will be less than the maximum time allocated.

Take estimates are based on a number of conservative assumptions including but not limited to: the estimation calculation method recommended by NMFS is conservative in that it does not consider all environmental variables, the estimates assume the equipment with the largest radial distance is active at all times for the entire duration of survey when all sound sources may not be operated at all times, and the estimates assume the maximum number of survey days when the number of actual survey days may be less.

6.6.1. Estimated Level A Harassment of Marine Mammals

Horizontal impact distance calculations (Table 6 and described in Appendix A) assume the sparker and boomer sources (e.g., GeoMarine Geo Spark 2000, Applied Acoustics AA251) are omnidirectional. This assumption, which is made because the beam pattern is unknown, results in precautionary estimates of received levels generally, and in particular, is likely to overestimate both SPL and PK. In situations for which the Level A horizontal impact distances are determined by PK (and not SEL), this likely overestimation of PK would lead to a conservative estimate of the number of Level A exposures. With these assumptions, the maximum potential Level A exposures without mitigation are expected to be >1 only for the abundant delphinid and pinniped species as well as the harbor porpoise as the only representative of the HF hearing group. Level A exposure estimates are provided in Table 10. As the maximum linear distance for Level A thresholds is 60 m (197 ft) for harbor porpoise while <6 m (20 ft) for all other species, monitoring and mitigation is expected to be effective in eliminating Level A takes.

Table 10. Maximum potential Level A exposures for each equipment category operating (no mitigation).

Species	Abundance	Geophysical Equipment Category						Maximum potential Level A exposure	Max. % population
		EdgeTech Chirp 216	Innomar SES 2000	Applied Acoustics Boomer	GeoMarine Geo Spark 2000	SonarDyne Scout Pro	ixBlue Gaps		
Fin whales*	1618	0.34	0.34	0.34	0.34	n/a	0.00	0.34	0.02
Humpback whales	896	0.23	0.23	0.23	0.23	n/a	0.00	0.23	0.03
Minke whales	2591	0.21	0.21	0.21	0.21	n/a	0.00	0.21	0.01
North Atlantic right whales*	451	0.16	0.16	0.16	0.16	n/a	0.00	0.16	0.03
Sei whales*	357	0.02	0.02	0.02	0.02	n/a	0.00	0.02	0.00
Atlantic white-sided dolphins	48819	5.17	5.17	5.17	5.17	n/a	0.00	5.17	0.01
Common bottlenose dolphins	6639	4.17	4.17	4.17	4.17	n/a	0.00	4.17	0.06
Pilot whales†	5636	0.73	0.73	0.73	0.73	n/a	0.00	0.73	0.01
Risso’s dolphins	18250	0.03	0.03	0.03	0.03	n/a	0.00	0.03	0.00
Short-beaked common dolphins	70184	10.41	10.41	10.41	10.41	n/a	0.00	10.41	0.01
Sperm whales*	2288	0.02	0.02	0.02	0.02	n/a	0.00	0.02	0.00
Harbor porpoises	79833	5.34	320.82	320.82	32.05	n/a	294.06	320.82	0.40
Gray seals	27131	20.67	20.67	20.67	20.67	n/a	0.00	20.67	0.08
Harbor seals	75834	20.67	20.67	20.67	20.67	n/a	0.00	20.67	0.03

* Listed as endangered under the ESA.
† Long- and short-finned pilot whales are grouped together as a guild.

6.6.2. Estimated Level B Harassment of Marine Mammals

Level B exposures were estimated by multiplying the average annual density of each species (Table 8) by the daily ZOI area (Table 9) based on an SPL threshold of 160 dB re 1 µPa, multiplied by the maximum number of vessel days estimated for the survey (736 days).

It is assumed that an animal will only be exposed once over a 24-hour period; however, an activity may result in multiple exposures of the same animal over a period of time if they remain within the ZOI. Therefore, both the number of estimated exposures and the affected population percentages represent the maximum potential take numbers. In reality, a limited number of marine mammals may demonstrate behavioral harassment. The numbers of individuals in the take calculations range from 0 to 431.

Table 11 summarizes the Level B exposure estimates for all species that were considered common, uncommon, or regular in the proposed HRG survey area. As described previously, NMFS has defined the Level B thresholds for impulsive and non-impulsive sound sources using the SPL metric. A marine mammal exposed to the Level B thresholds regardless of the exposure duration (unlike Level A takes where the SEL includes an exposure duration) are considered exposures for the purpose of this assessment.

Since the estimated Level B horizontal impact distances are all well within the proposed exclusion zone, mitigation is expected to be effective in eliminating virtually all Level B takes. Vineyard Wind is using a conservative approach for this IHA application and will assume that takes are equivalent to the maximum number of estimated Level B exposures (Table 11).

For species that have habitat densities for only a single guild (i.e., pilot whales, common bottlenose dolphin) (Roberts et al. 2015, 2016; Roberts, 2018), take estimates were computed for each guild and applied to the individual species or stocks within each guild. For estimated takes of pilot whales, an equal probability of either species being encountered is assumed and therefore, requested the total estimated takes for each species within the guild. For the common bottlenose dolphin, the offshore stock is primarily found in waters >34 m (112 ft); while the Northern Migratory Coastal stock is primarily found in waters <25 m (82 ft) (Hayes et al. 2018). The water depth in the lease areas range from 35 to 63 m (115 to 207 ft); it is expected that bottlenose dolphin takes will be from the offshore stock, with minimal takes from the Northern Migratory Coastal stock.

As described in Appendix B, the calculations assume the sparker and boomer sources (e.g., GeoMarine Geo Spark 2000, Applied Acoustics AA251) are omnidirectional. This assumption, which is made because the beam pattern is unknown, results in precautionary estimates of received levels generally, and in particular is likely to overestimate both SPL and PK. This overestimation of the SPL probably leads to an overestimation of the number of Level B takes for these equipment types.

Table 11. Maximum potential Level B exposures for each equipment category operating without mitigation applied.

Species	Abundance	Geophysical Equipment Category						Maximum potential Level B exposures	Max. % population
		EdgeTech Chirp 216	Innomar SES 2000	Applied Acoustics Boomer	GeoMarine Geo Spark 2000	SonarDyne Scout Pro	ixBlue Gaps		
Fin whales*	1618	1.38	39.97	61.40	67.28	8.26	12.05	67.28	4.16
Humpback whales	896	0.94	27.17	41.73	45.73	5.61	8.19	45.73	5.10
Minke whales	2591	0.84	24.48	37.59	41.20	5.06	7.38	41.20	1.59
North Atlantic right whales*	451	0.62	18.02	27.67	30.32	3.72	5.43	30.32	6.72
Sei whales*	357	0.07	1.92	2.95	3.23	0.40	0.58	3.23	0.90
Atlantic white-sided dolphins	48819	20.68	600.78	922.79	1011.19	124.12	181.04	1011.19	2.07
Common bottlenose dolphins‡	6639	16.67	484.17	743.67	814.91	100.03	145.90	814.91	12.27
Pilot whales†	5636	2.90	84.36	129.57	141.98	17.43	25.42	141.98	2.52
Risso's dolphins	18250	0.11	3.20	4.92	5.39	0.66	0.97	5.39	0.03
Short-beaked common dolphins	70184	41.64	1209.58	1857.89	2035.87	249.90	364.50	2035.87	2.90
Sperm whales*	2288	0.08	2.27	3.49	3.82	0.47	0.68	3.82	0.17
Harbor porpoises	79833	21.37	620.80	953.53	1044.87	128.26	187.07	1044.87	1.31
Gray seals	27131	82.70	2402.49	3690.17	4043.67	496.35	723.97	4043.67	14.90
Harbor seals	75834	82.70	2402.49	3690.17	4043.67	496.35	723.97	4043.67	5.33

* Listed as endangered under the ESA.
† Long- and short-finned pilot whales are grouped together as a guild.
‡ For the purposes of this assessment the same density is assumed for both bottlenose dolphin stocks.

6.7. Marine Mammal Mean Group Size

Density estimates inherently account for group size because the mean group size is a factor in the density estimate calculation. As described in a previous section (6.6.2) Level B exposures were estimated based on the average annual density. Correcting the number of animal exposures by the mean group size for each species is therefore not required since this adjustment would represent an unreasonable overestimation of the number of animals exposed (by a factor equal to the mean group size, e.g. 1.8 for fin whales and 34.9 for short-beaked common dolphins). Density surfaces like those produced by Roberts et al. (2015, 2016, 2017, and 2018) account for populations distributed in space whether they occur as individuals or groups.

It is reasonable to expect that exposure estimates for species occurring in small groups represent the mean exposure for all group members of the modelled 24-hour period as they often change their position within the group. For species occurring in large groups (e.g. >100-1000s animals per group) this assumption could lead to a bias, i.e. not reflecting the true sound level exposure individual animals would encounter within a large group. Group sizes for the species considered in the IHA only reach a maximum of 34.9 animals per group, so no correction is required.

When calculating Level B takes, in cases where the exposure estimate is less than the mean group size, it is assumed that if one group member was exposed, then it is likely that all animals in the same group also receive a similar sound level exposure. For this project, modeled Level B exposures exceed the mean group size for all species, therefore the requested number of takes are the same as the calculated Level B exposures. For requested takes, the number of predicted exposures equals one mean group size rounded up to the nearest integer. Mean group sizes for species were derived from Kraus et al. (2016) and AMAPPS survey data (Palka et al. 2017). Though pinnipeds congregate in large numbers on land, at sea they are generally foraging alone or in small groups. For harbor and gray seals, Palka et al. (2017) report sightings of seals at sea during 2010–2013 spring, summer, and fall NE AMAPPS aerial surveys. Those sightings include both harbor and gray seals, as well as unknown seals, and thus a single group size estimate was calculated for these two species.

As stated above, the take numbers listed in Table 12 are based on a number of conservative assumptions including but not limited to: the estimation calculation method recommended by NMFS is conservative in that it does not consider all environmental variables, the estimates assume the equipment with the largest radial distance is active at all times for the entire duration of survey when all sound sources may not be operated at all times, and the estimates assume the maximum number of survey days when the number of actual survey days may be less.

Table 12. Number of Level B takes requested. Take numbers are equivalent to the unmitigated estimated exposures since take requests exceed species' group size. Any portion of an animal is rounded to 1. Calculated exposure numbers are shown for reference.

Species	Calculated Level B exposures	Mean group size	Requested Level B takes**	Max. % population
Fin whales*	67.28	1.8	68	4.16
Humpback whales	45.73	2.0	46	5.10
Minke whales	41.20	1.2	42	1.59
North Atlantic right whales*	30.32	2.4	31	6.72
Sei whales*	3.23	1.6	4	0.90
Atlantic white-sided dolphins	1011.19	27.9	1012	2.07
Common bottlenose dolphins‡	814.91	7.8	815	12.27
Pilot whales†	141.98	8.4	142	2.52
Risso's dolphins	5.39	5.3	6	0.03

Species	Calculated Level B exposures	Mean group size	Requested Level B takes**	Max. % population
Short-beaked common dolphins	2035.87	34.9	2036	2.90
Sperm whales*	3.82	1.5	4	0.17
Harbor porpoises	1044.87	2.7	1045	1.31
Gray seals	4043.67	1.4	4044	14.90
Harbor seals	4043.67	1.4	4044	5.33

* Listed as endangered under the ESA.
† Long- and short-finned pilot whales are grouped together as a guild.
‡ For the purposes of this assessment the same density is assumed for both bottlenose dolphin stocks
** Take estimates are based on a number of conservative assumptions including but not limited to: the estimation calculation method recommended by NMFS is conservative in that it does not consider all environmental variables, the estimates assume the equipment with the largest radial distance is active at all times for the entire duration of survey when all sound sources may not be operated at all times, and the estimates assume the maximum number of survey days when the number of actual survey days may be less.

7. Anticipated Impact of the Activity

The effects of anthropogenic sound on marine mammals depend on the characteristics of that sound (level, spectrum, duration, rise time, duty cycle, etc.), the range of the sound, the context within which it occurs, including the sound propagation environment, and the activity of the animal under consideration. Marine mammals exposed to anthropogenic sound may experience impacts ranging in severity from minor disturbance to non-auditory injury (Southall et al. 2007, Wood et al. 2012, NMFS 2018, Southall et al. 2019). The potential exists for small numbers of marine mammals to be exposed to regulated levels of underwater sound associated with HRG survey activities. These impacts may affect individuals but have only negligible effects on marine mammal stocks or populations.

7.1. Characteristics of Sources

Geophysical surveys use sound sources that output acoustic signals within frequency bandwidths and amplitudes best suited for the desired survey product. The acoustic signals often are impulsive, tonal, or chirp pulses (short duration signals that sweep through many frequencies). HRG sources proposed for HRG surveys can be grouped into three categories: (1) impulsive signals (e.g., boomers and sparkers) that are broadband with most energy at low frequencies; (2) chirp sonars, which are high-frequency sweeps with most energy at high frequencies; and (3) sonars (e.g., side-scan, multibeam), which are high-frequency tones or chirp signals (Halvorsen and Heaney 2018). The source level, beamwidth, pulse duration, and pulse repetition rate of such sources typically are adjustable. Where such parameters are adjustable, precautionary values have been selected.

7.2. Potential Effects of HRG sources on Marine Mammals

All marine mammals use sound as a critical way to carry out life-sustaining functions, such as foraging, navigating, communicating, and avoiding predators. Marine mammals also use sound to learn about their surrounding 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). Marine mammals exposed to natural or anthropogenic sound may experience non-auditory and auditory impacts, which range in severity (Southall et al. 2007, Southall et al. 2019, NMFS 2018a, Wood et al. 2012). The potential exists for small numbers of marine mammals to be exposed to underwater sound associated with HRG survey activities. These impacts are likely to affect individual species but have only negligible effects on the marine mammal stocks and, therefore, will not adversely affect the population of any species. A previous analysis by BOEM (2014) on the effects of HRG survey noise on marine mammals in the Mid- and South-Atlantic Planning Areas concluded that impacts are expected to be minor with the implementation of mitigation measures such as those described by Vineyard Wind (Table 13).

7.3. Mitigation and Aversion

Mitigation and aversion are not considered in the exposure estimates. The inclusion of mitigation and aversion reduce the exposures and therefore the take requests. Although the proposed mitigation (Section 11) is implemented to eliminate the potential for Level A takes, it will also serve to reduce the exposure of animals to SLs that could constitute Level B takes. In the BOEM RI-MA EA (2013), the modeled area of ensonification for some geophysical survey equipment showed potential Level B thresholds at distances beyond what BOEM considered could be effectively visually monitored for the presence of marine mammals. However, NMFS determined that with standard operating conditions and reasonable and prudent measures, the proposed geophysical surveys may adversely affect but are not likely to jeopardize the continued existence of NARW, humpback whale, fin whale, sei whale, or sperm whale. This suggests that geophysical survey operations would not jeopardize the sustainability of other cetaceans that occupy the same acoustic habitat.

7.4. Multiple Exposures and Seasonality

The estimated exposures to most species' stocks are expected to be a significant over-estimate of the actual proportion of the stock potentially affected by the HRG survey activities. For example, in the case of the offshore common bottlenose dolphin stock, Level B exposures likely include the same individuals across multiple days and not exposures to the entire stock; therefore, they can be considered instances of exposure rather than a discrete count of individuals that have received regulatory-level sound exposures. The acoustic metrics used to establish Level A or B isopleths (PK, SPL) do not consider a duration of exposure (SEL) in the calculations. PK and SPL thresholds assume that an animal within calculated horizontal impact distances, regardless of the length of time, are taken by exposure. The exposure estimates assume that an animal will only be exposed to a certain sound level once over a 24-hour period; however, an activity may result in multiple exposures of the same animal over a time period. Multiplying exposures to the same animal over 736 vessel days is a conservative approach to estimating population-level exposure.

7.5. Negligible Impacts

Animals in an area of exposure may move location depending on their acoustic sensitivity, life stage, and acclimation (Wood et al., 2012) and may or may not demonstrate behavioral responses. Therefore, while the number of exposures and the affected population percentages represent the maximum potential take numbers, in actuality, a limited number of marine mammals may realize behavioral modification. Under the requirements of 50 CFR § 216.104, NMFS has defined negligible impact as an impact that is not reasonably expected to adversely affect a species or stock through effects on annual rates of recruitment or survival. The small numbers requirement is not based on take estimates alone; rather, for NMFS to make a negligible impact determination, small numbers must denote that the portion of a marine mammal species or stock in the take estimates will have a negligible impact on that species or stock.

As discussed in Sections 9 and 10, physical auditory effects, vessel strikes, PTS or TTS, and long-term impacts to habitat or prey species are not expected to occur. Temporary masking may occur in localized areas for short periods of time when an animal is in proximity to survey activities. Masking occurs when an animal's acoustic "space" (i.e., auditory perception and discrimination) is covered up by noise of similar frequency but at higher amplitudes of biologically important sounds. However, due to movement of the sources, masking effects are expected to be negligible and not contribute significantly to other noise sources operating in the region. The primary potential impact on marine mammals from exposure to survey-related underwater sound is behavioral responses, which do not necessarily constitute significant changes in biologically important behaviors. The National Research Council (2005) noted that an action or activity becomes biologically significant to an individual animal when it affects the ability of the animal to grow, survive, and reproduce, wherein an impact on individuals can lead to population-level consequences and affect the viability of the species. The reasonably expected impacts from the proposed activities are based on noise exposure thresholds that can potentially elicit a behavioral response and are categorized as Level B takes under the MMPA.

Based upon best available data regarding the marine mammal species (including density, status, and distribution) that are likely to occur in the HRG survey area, exposure to marine mammal species and stocks during HRG surveys would result in short-term minimal effects and would not affect the overall annual recruitment or survival for the following reasons:

- As detailed in Section 6, potential acoustic exposures from HRG survey activities are within the non-injurious behavioral effects zone (Level B harassment);
- The potential for take as estimated in Section 6 represents a highly conservative estimate of harassment based upon typical HRG survey scenarios without taking into consideration the effects of standard mitigation and monitoring measures; and
- The mitigation measures as described in Section 11 are designed to avoid and/or minimize the potential for interactions with and exposure to marine mammals.

Marine mammals are mobile free-ranging animals and have the capacity to exit an area when noise-producing survey activities are initiated. Based on the conservative take estimations, survey activities may disturb more than one individual for some species (mainly dolphins), but in conjunction with other aforementioned factors, the proposed HRG survey activities are not expected to result in population-level effects and individuals will return to normal behavioral patterns after activities have ceased or after the animal has left the area under survey.

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 proposed HRG survey area. As such, there are no relevant subsistence uses of marine mammals implicated by this action.

9. Anticipated Impacts on Habitat

No bottom disturbance from seabed placement of equipment is planned during the proposed HRG survey. The proposed HRG survey equipment does not contact the seafloor. The HRG survey activities have the potential to affect marine mammal water column habitat primarily through short-term impacts from increases in ambient sound levels from HRG survey activities. These impacts arise from a variety of impact producing factors (i.e., noise, discharges, physical presence, lights, turbidity) with the potential to temporarily affect marine mammal prey availability. Various pelagic and benthic fish species, cephalopods, and crustaceans are expected to occur in the HRG survey area. Impacts to these prey species are expected to be limited to short-term avoidance of the area or changes in behavior in the vicinity of the HRG survey activities. Since displaced individuals are expected to return shortly after a survey vessel passes an area, population-level effects on prey species are not anticipated.

The HRG survey area is quite large, and although multiple vessels will be contracted to complete the survey activities in a timely manner, surveys will be spaced to avoid geophysical interference with one another, and therefore barriers to passage by marine mammals are not anticipated.

HRG surveys will begin on April 1, 2020 and will last for up to one year. Impacts that extend beyond the period of the survey are not expected. In summary, anticipated impacts on habitat that may result from the HRG survey are considered negligible.

10. Anticipated Effects of Habitat Impacts on Marine Mammals

The anticipated impacts on habitat that may result from HRG survey activities (described in Section 9) are considered negligible and limited to short-term avoidance of the area or changes in behavior in the vicinity of the HRG survey activities. Since displaced individuals are expected to return shortly after survey vessels passes an area, the anticipated effects on marine mammals from negligible habitat impacts are also considered negligible. Additionally, surveys in NARW critical habitat will be limited to August and September. Potential impacts to habitat are considered negligible and will not overlap with the time of year when NARW are expected to be present (Nichols et al. 2008).

11. Mitigation Measures

Mitigation measures implemented during the HRG survey for sources operating at or below 200 Hz can decrease the potential impacts to marine mammals from sound exposure by reducing the ZOI and therefore the likelihood of Level A and Level B sound exposures. Vineyard Wind will comply with all applicable monitoring and mitigation regulations and any lease or permit conditions (e.g., mitigation measures prescribed in Lease OCS-A 0522 Appendix B to Addendum C) placed on the Projects by regulatory agencies. Stipulations provided in Lease OCS-A 0522 are the most stringent of both leases (Lease OCS-A 0501 and OCS-A 0522) and were thus chosen as the mitigation and monitoring measures for the HRG survey activities. In addition to regulatory compliance, Vineyard Wind is applying various mitigation measures to the Projects to reduce the potential for negative impacts to marine mammals during survey acquisition. The selection of appropriate mitigation techniques will consider safety, practical application, and effectiveness for the Projects.

The estimated horizontal impact distances (Section 6, Appendix A, and Appendix B) for the proposed HRG survey equipment are well within the proposed exclusion zones. These zones are anticipated to fully encompass the Level A and Level B harassment radii for all marine mammal species. Table 13 details the suite of planned monitoring activities and mitigation measures. While protection of marine mammals is a top priority, environmental and human health and safety is the very highest priority in working in the offshore environment; therefore, exceptions to mitigation may be made under certain circumstances.

Table 13. Monitoring and mitigation measures planned for the HRG survey activities.

Monitoring & mitigation measure	Description
Seasonal Restrictions[1]	▪ HRG survey activities will take place in the Cape Cod Bay SMA and Off Race Point SMA (included in Figure 1) **only during the months of August and September** to ensure sufficient buffer between the SMA restrictions (January to May 15) and known seasonal occurrence of the NARW north and northeast of Cape Cod (fall, winter, and spring). ▪ Vineyard Wind will not operate more than three concurrent HRG survey vessels, with HRG survey equipment operating at or below 200kHz, from March through June within a lease area or an export cable corridor, but not including coastal and bay waters.
Exclusion zone	▪ Exclusion zone(s) will be monitored around the center of the sources for marine mammals. ▪ Exclusion zone(s) must be clear of marine mammals for the following clearance timing prior to any HRG source emission: – 60 minutes for NARW; – 30 minutes for non-delphinoid cetaceans; and – 15 minutes for delphinoid cetaceans, pinnipeds, and other protected marine species. ▪ The following exclusion zones are employed during all HRG survey activities: – 500 m (1,640 ft) North Atlantic right whale exclusion zone; and – 100 m (328 ft) exclusion zone for all other marine mammals. ▪ The source will be immediately shutdown if marine mammals are visually observed or acoustically detected within the exclusion zones.
Protected Species Observers (PSOs)	▪ A minimum of two PSOs will maintain watch during daylight hours when the sources are active. ▪ PSOs will use night vision technology during nighttime surveys when the sources are active. ▪ PSOs may not perform another duty while on watch. ▪ A shift schedule of PSO/PAM Operators employed such that PSOs may not exceed four consecutive watch hours; must have a minimum two-hour break between watches; and may not exceed combined watch schedule of more than 12 hours in a 24-hour period.
Visual Monitoring	▪ PSOs will conduct visual monitoring of the exclusion zone(s) during daylight and nighttime when HRG survey activities are intended to be conducted. ▪ PSOs will observe exclusion zones and monitoring zones during all HRG survey activities. ▪ Observations of the zones will continue throughout the survey activity and/or while equipment operating at or below 200 kHz are in use. ▪ PSOs will be responsible for visually monitoring and identifying marine mammals approaching or entering the established zones during HRG survey activities. – It will be the responsibility of the lead PSO on duty to communicate the presence of marine mammals as well as to communicate and enforce the action(s) that are necessary to ensure mitigation and monitoring requirements are implemented as appropriate. – PSOs will be equipped with reticule binoculars and other suitable equipment observer to adequately perceive and monitor protected marine species and to estimate distances to marine mammals within the exclusion zone. – During night operations or when visual observation is otherwise impaired, PSOs will be supplemented with night vision technology and a passive acoustic monitoring system to monitor the exclusion zone. ▪ Observations will take place from the highest available vantage point on all survey vessels, allowing for 360-degree scanning. ▪ PSOs will record all sightings of marine mammals. ▪ Prior to initiation of survey work, all crew members will undergo environmental training, a component of which will focus on the procedures for sighting and protection of marine mammals.

Monitoring & mitigation measure	Description
Vessel strike avoidance	▪ All vessel operators and crews will maintain a vigilant watch for marine mammals at all times, and slow down or stop their vessel to avoid striking these protected species. ▪ All vessel operators will reduce vessel speed to 10 knots (5.1 m/s) or less when mother/calf pairs, pods, or larger assemblages of marine mammals are observed near an underway vessel. ▪ All vessel operators will comply with 10 knots (5.1 m/s) speed restrictions in any DMA. ▪ All vessels 19.8 m (65 ft) or greater operating from November 1 through May 14 will operate at speeds of 10 knots (5.1 m/s) or less, except while in Nantucket Sound. ▪ Vineyard Wind will ensure that vessel operators monitor NMFS NARW reporting systems from November 1 through May 14 and whenever a DMA is established within the HRG survey area. **North Atlantic right whales:** ▪ Vineyard Wind will ensure all vessels maintain a separation distance of 500 m (1,640 ft) or greater from any sighted NARW or unidentified large marine mammal. ▪ Vineyard Wind will ensure that the following avoidance measures are taken if a vessel comes within 500 m (1,640 ft) of any NARW. – If underway, any vessel will steer a course away from any NARW at 10 knots (5.1 m/s) or less until the 500 m (1,640 ft) minimum separation distance has been established, unless: – If a NARW is sighted within 100 m (328 ft) to an underway vessel the vessel operator must immediately reduce speed and promptly shift the engine to neutral. The vessel operator must not engage the engines until the NARW has moved beyond 100 m (328 ft), at which point Vineyard Wind will ensure that the vessel will steer a course away from any NARW at 10 knots (5.1 m/s) or less until the 500 m (1,640 ft) minimum separation distance has been established. – If a vessel is stationary, the vessel will not engage engines until the NARW has moved beyond 100 m (328 ft), at which point Vineyard Wind will ensure that the vessel will steer a course away from any NARW at 10 knots (5.1 m/s) or less until the 500 m (1,640 ft) minimum separation distance has been established. **Large whales other than the North Atlantic right whale:** ▪ Vineyard Wind will ensure that all vessels maintain a separation distance of 100 m (328 ft) or greater from any sighted ESA-listed whales or humpback whales. ▪ The following avoidance measures are taken if a vessel comes within 100 m (328 ft) of whale: – If underway, the vessel must reduce speed and shift the engine to neutral and must not engage the engines until the whale has moved beyond 100 m (328 ft). – If stationary, the vessel must not engage engines until the whale has moved beyond 100 m (328 ft). **Small cetaceans (dolphins and porpoises):** ▪ Vineyard Wind will ensure that: – All vessels underway do not divert to approach any small cetacean or seal. – All vessels maintain a separation distance of 50 m (164 ft) or greater from any sighted small cetacean or seal, except when a small cetacean or seal approaches the vessel (see below). ▪ If a small cetacean or seal approaches any vessel underway, the vessel underway must avoid excessive speed or abrupt changes in direction to avoid injury to the animal. ▪ Vineyard will report sightings of injured or dead protected species to BOEM, NMFS, and NMFS Greater Atlantic (Northeast) Region's Stranding Hotline (866-755-622 or current) within 24 hours of sighting, regardless of whether the injury/death was caused by the vessel. As requested by NMFS, if the survey vessel was responsible for the injury or death, Vineyard Wind will ensure that the vessel assists with any salvage effort.

Monitoring & mitigation measure	Description
Ramp-up for HRG sources	▪ HRG survey equipment must not be initiated if: – A NARW is observed within a 500 m (1,640 ft) radius of geophysical survey equipment during the pre-clearance period; or – Any other marine mammals are observed within a 100 m (328 ft) exclusion zone. ▪ PSOs will ensure exclusion zones are clear of marine mammals for a minimum 60 minutes prior to commencement of ramp-up procedures. ▪ The ramp-up procedure will not be initiated during periods of inclement conditions or if the exclusion zones cannot be adequately monitored by the PSOs, using the appropriate visual technology. ▪ Ramp-up may be used during dark periods or in poor visibility only if PAM is used to clear the exclusion zone for the respective clearance timing, listed above. ▪ A ramp-up begins with the powering up of the smallest acoustic HRG equipment at its lowest power output. When technically feasible the power is then gradually turned up and other acoustic sources added such that the source level increases gradually. ▪ If a marine mammal is observed within an exclusion zone during the pre-clearance period, ramp-up may not begin until the exclusion zone has been clear.
Pauses in HRG sources	▪ If the acoustic source is shut down for reasons other than mitigation (e.g., mechanical difficulty) for less than 20 minutes, it may be activated again without ramp-up only if PSOs have maintained constant observation and no detections of any marine mammal have occurred within the respective exclusion zones. ▪ Any shutdown exceeding 20 minutes must be followed by full ramp-up procedures.
Passive Acoustic Monitoring (PAM)	▪ Trained PAM operators will monitor for acoustic detections of marine mammals. ▪ A PAM system will be used to acoustically monitor for marine mammals during nighttime HRG survey activities. ▪ PAM operators will communicate nighttime detections to the lead PSO on duty who will ensure the implementation of the appropriate mitigation measure. ▪ If PAM is not used or is deemed non-functional at any time during the survey, the survey will be shut down until PAM is restored.
Shutdowns	▪ An immediate shut down of the HRG survey equipment will be required if a marine mammal is visually observed or acoustically observed at or within its respective exclusion zone. ▪ The vessel operator must comply immediately with any call for shutdown by the PSO. ▪ Any disagreement between the PSO and vessel operator should be discussed only after shutdown has occurred. ▪ HRG survey equipment may be allowed to continue operating if marine mammals voluntarily approach the vessel (e.g., to bow ride) when the sound sources are at full operating power. ▪ After shutdown, ramp-up can be initiated once the exclusion zone(s) are visually (acoustically during times of poor visibility or darkness, see Ramp-up for HRG survey above) clear for the respective clearance timing. ▪ Submit reports of NARW sightings) to NOAA and BOEM within 24 hours of shutdown.

[1] This restriction minimizes the amount of HRG survey activity that occurs when NARW is likely to be in the HRG survey area and thus limits sound exposure for this species. Roberts et al. (2016) density data and survey data (both visual and acoustic) from Kraus et al. (2016) suggest that the highest density of NARWs in the WEA occurs annually in March. Over 93% of the sightings in the Kraus et al. (2016) study occurred from January through April, with no NARWs sighted from May through August.

12. Arctic Plan of Cooperation

Not applicable.

The proposed HRG survey will be located off the U.S. northeast coast in the Atlantic Ocean, and no activities will take place in or near a traditional Arctic subsistence hunting area. Therefore, there are no relevant subsistence uses of marine mammals implicated by this action.

13. Monitoring and Reporting

13.1. Visual Monitoring

Vineyard Wind will ensure that PSOs record all observations of protected species using standard marine mammal observer data collection protocols. The required data elements for these reports are:

- Vessel name
- PSO's names and affiliations
- Date, time, location (latitude/longitude) when survey begins and ends
- Average environmental conditions during visual surveys, including:
  - Wind speed and direction
  - Sea state and swell
  - Overall visibility
  - Species (or identification to lowest possible taxonomic level)
  - Certainty of identification
  - Total number of animals and juveniles
  - Description of animals observed
  - Direction of animal's travel relative to the vessel
  - Behavior when first sighted and after initial sighting
  - Activity of vessel when sighting occurred

13.2. Reporting

During proposed HRG surveys, Vineyard Wind will report the following:

13.2.1. Reporting Injured or Dead Species

Vineyard Wind will ensure that sightings of any injured or dead marine mammals are reported to the Greater Atlantic (Northeast) Region Marine Mammal and Sea Turtle Stranding & Entanglement Hotline (866-755-NOAA [6622]) within 24 hours of a sighting, regardless of whether the injury or death is caused by a vessel. In addition, if the injury or death was caused by a collision with a survey-related vessel. The notification of a vessel 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.

13.2.2. Reporting Observed Impacts to Species

PSOs will report any observations concerning impacts on marine mammals to NMFS within 48 hours. Any observed takes of listed marine mammals resulting in injury or mortality must be reported within 24 hours to NMFS.

13.2.3. Report of Activities and Observations

Vineyard Wind will provide NMFS with a report within 90 calendar days following the commencement of survey activities, including a summary of the survey activities and an estimate of the number of marine mammals taken during these survey activities.

14. Suggested Means of Coordination

In addition to the monitoring and reporting measures discussed in this application and as described in Section 13, marine species sightings data will be collected during all HRG survey activities by PSO monitors and acoustic detection data will be collected using PAM. Monitoring will be conducted 24 hours per day. These data will be shared with NOAA Fisheries, thereby contributing to the knowledge on these protected species, which may provide insights for future projects.

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Appendix A. Vineyard Wind HRG Distance from Source Level A Technical Memo

A.1. Methods

This section describes the methods used to estimate the horizontal distances to the National Marine Fisheries Service (NMFS) injury criteria (Table A-1). Sources that operate with a repetition rate greater than 10 Hz were assessed with the non-impulsive source criteria, Sources with a repetition rate equal to or less than 10 Hz were assessed with the impulsive source criteria.

Table A-1. Peak sound pressure level (PK; dB re 1 µPa) and sound exposure level (SEL; dB re 1 µPa²·s) thresholds for injury (PTS onset) for marine mammals for impulsive and non-impulsive sound sources (NMFS 2018).

Functional hearing group	Impulsive source		Non-impulsive source
	PK	Weighted SEL_{24h}	Weighted SEL_{24h}
Low-frequency cetaceans (LF)	219	183	199
Mid-frequency cetaceans (MF)	230	185	198
High-frequency cetaceans (HF)	202	155	173
Phocid pinnipeds in water (PW)	218	185	201
Otariid pinnipeds in water (OW)	232	203	219

NMFS provides a spreadsheet to calculate these distances, but it is not designed for high-resolution geophysical survey sources and does not consider seawater absorption or beam patterns, both of which can substantially influence received sound levels. To account for these effects, we model sound levels using Equations A-1 to A-9, as follows.

The sonar equation is used to calculate the sound pressure level:

$$\mathrm{SPL}(r) = SL - PL(r) \ , \tag{A-1}$$

where *SPL* is the sound pressure level (dB re 1 µPa), *r* is the distance from the source (m), *SL* is the source level (dB re 1 µPa m), and *PL* is the propagation loss as a function of distance. Propagation loss is calculated using:

$$PL(r) = 20\log_{10}\left(\frac{r}{1\ m}\right)\ \mathrm{dB} + \alpha(f)\cdot r/1000 \ , \tag{A-2}$$

where $\alpha(f)$ is the absorption coefficient (dB/km) and f is frequency (kHz). The absorption coefficient is approximated by discarding the boric acid term from Ainslie (2010, p 29 equation 2.2):

$$\alpha(f) \approx 0.000339f^2 + 48.5f^2/(75.6^2 + f^2)\ . \tag{A-3}$$

When a range of frequencies is produced by a source, we use the lowest frequency for determining the absorption coefficient.

The source level is either its in-beam value (for angles within the −3 dB beamwidth) or a single representative out-of-beam value. This representative value is estimated by first calculating upper and lower bounds and then taking the average of these. We assume the beam pattern $b(u)$ is that of an unshaded circular transducer:

$$b(u) = (2\ J_1(u)/u)^2, \tag{A-4}$$

where $J_1(u)$ is a first order Bessel function of the first kind, whose argument is a function of off-axis angle θ and beamwidth (full width at half maximum) $\delta\theta$

$$u = u_0 \frac{\sin\theta}{\sin\frac{\delta\theta}{2}}\,, \tag{A-5}$$

where $u_0 = 1.614$.

For the upper limit we choose the highest sidelobe level of the beam pattern, given by Ainslie (2010 p 265 Table 6.2):

$$B_{\max} = -17.6\ dB. \tag{A-6}$$

For the lower limit we consider the asymptotic behavior of the beam pattern in the horizontal direction

$$J_1(u) \sim \sqrt{\frac{2}{\pi u}} \cos\left(u - \frac{3\pi}{4}\right)\,, \tag{A-7}$$

where

$$u = \frac{u_0}{\sin\frac{\delta\theta}{2}}\,. \tag{A-8}$$

In this way we obtain the lower limit as

$$B_{\min} = 10\log_{10}\left(\frac{8}{\pi\, u_0^3}\sin^3\frac{\delta\theta}{2}\right)\mathrm{dB}\,. \tag{A-9}$$

The out-of-beam source level is found by adding the arithmetic mean of $B_{\min}$ and $B_{\max}$ to the in-beam source level.

For broad beam sources (beamwidths larger than 90°), we assumed the source was omnidirectional. For intermediate beam sources (beamwidths between 36° and 90°), we interpolated the correction between the two methods. The resulting correction as a function of beamwidth is shown in Figure A-1.

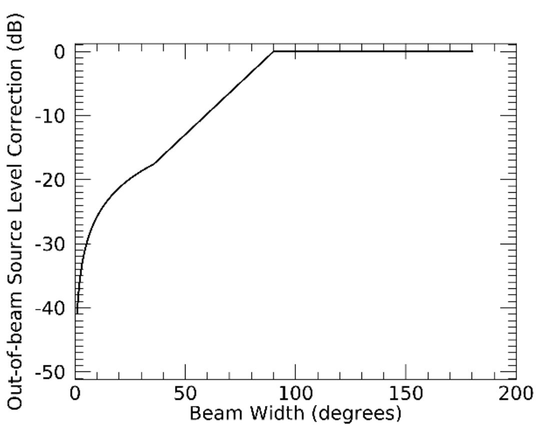


Figure A-1. Correction for calculating out-of-beam source level (i.e., in the horizontal direction) from in-beam source level, as a function of source beamwidth.

Separate impact ranges are calculated using the in-beam source level at the angle corresponding to the −3 dB half-width and the out-of-beam source level in the horizontal direction. The higher of the two sound levels was then selected for assessing impact distance.

Distances to peak thresholds were calculated using the peak source level and applying propagation loss from Equation A-2

Equation A-2. Peak levels were assessed for both in-beam and out-of-beam levels (the latter was assessed using the out-of-beam source level correction described previously).

For the weighted SEL thresholds, we performed the following steps:

1. Calculated weighted broadband source levels by assuming a flat spectrum between the source minimum and maximum frequency, weighted the spectrum according to the marine mammal hearing group weighting function (NMFS 2018), and summing across frequency. A 0.5 dB correction is added to the energy source level (ESL) because the 90 % energy pulse duration usually used to evaluate SL contains only 90 % of the pulse energy. The 0.5 dB correction ensures that all of the energy in the pulse is included.
2. Modeled propagation loss as a function of oblique range using Equation A-2.
3. Modeled per-pulse SEL for a stationary receiver at a fixed distance off a straight survey line, using a vessel transit speed of 3.5 knots and source-specific pulse length and repetition rate. The off-line distance is referred to as the closest point of approach (CPA) and was performed for CPA distances between 1 m and 10 km. The survey line length was modeled as 10 km long (analysis showed longer survey lines increased SEL by a negligible amount). SEL is calculated as $SPL + 10\log_{10}\frac{T}{1\,\mathrm{s}}\ \mathrm{dB}$, where T is the pulse duration. For equipment where SEL was known, we used SEL directly in the calculations and provide the corresponding pulse duration in Appendix A.2.
4. Calculated the SEL for each survey line to produce curves of weighted SEL as a function of CPA distance.
5. Used the curves from Step 4 to estimate the CPA distance to the impact criteria.

This method accounts for the hearing sensitivity of the marine mammal group, seawater absorption, and beamwidth for downwards-facing transducers.

A.2. Sources

A.2.1. Overview of Source Properties

Table A-2 lists the geophysical survey sources that produce underwater sound at frequencies less than 200 kHz, and their acoustic characteristics. Table A-3 provides the accompanying data source reference.

Table A-2. Considered geophysical survey sources.

Equipment	System	Frequency (kHz)	Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)	Beam width (°)	Pulse duration (ms)	Repetition rate (Hz)
Shallow subbottom profiler	EdgeTech Chirp 216	2–10	178	182	65	2	3.75
	Innomar SES 2000 Medium	85–115	241	247	2	2	40
Deep seismic profiler	Applied Acoustics AA251 Boomer	0.2–15	205	212	180	0.9	2
	GeoMarine Geo Spark 2000 (400 tip)	0.25–5	206	214	180	2.8	1
Underwater positioning (USBL)	SonarDyne Scout Pro	35–50	188	191	180	Unknown	Unknown
	ixBlue Gaps	20–32	191	194	180	1	10

Table A-3. Data reference for considered geophysical survey sources.

Equipment	System	Frequency	Source level	Peak source level	Beam width	Pulse duration	Repetition rate
Shallow subbottom profiler	EdgeTech Chirp 216	Vineyard Wind indicates they will use a comparable frequency range, which is narrower than the proxy source frequency range	Considered EdgeTech Chirp 512i as proxy for source levels as Chrip512i has similar operation settings as Chirp216 tow vehicle (App. A.4.2). See Table 18 in Crocker and Fratantonio (2016) source for levels at 100% power and 1–10 kHz.	Considered EdgeTech Chirp 512i as a proxy for source levels as Chrip512i has similar operation settings as Chirp216 tow vehicle (App. A.4.2). See Table 18 in Crocker and Fratantonio (2016) source for levels at 100% power and 1–10 kHz.	Used EdgeTech Chirp 512i as proxy source. See Table 20 in Crocker and Fratantonio (2016) for beamwidth corresponding to proxy source bandwidth and power for source level.	Used EdgeTech Chirp 512i as proxy source. See Table 18 in Crocker and Fratantonio (2016).	Vineyard Wind indicates they will use a comparable repetition rate.
	Innomar SES 2000 Medium	Manufacturer specification sheet or manual (App. A.4.3)	Specification sheet (App. A.4.3) indicates peak source level of 247 dB re 1 μPa m (Jens Wunderlich, Innomar, personal communication, 2019-07-18). Average difference between peak and SPL source level for sub-bottom profilers measured by Crocker and Fratantonio (2016) was 6 dB. We estimate SPL source level is 241 dB re 1 μPa m.	Manufacturer specification sheet or manual (App. A.4.3). Jens Wunderlich (Innomar, personal communication, 2019-07-18) indicates this is peak source level.	Manufacturer specification sheet or manual (App. A.4.3)	Manufacturer specification sheet or manual (App. A.4.3).	Manufacturer specification sheet or manual (App. A.4.3).
Deep seismic profiler	Applied Acoustics AA251 Boomer	Estimated from Figs 14 and 16 in Crocker and Fratantonio (2016)	Crocker and Fratantonio (2016)	Crocker and Fratantonio (2016)	Crocker and Fratantonio (2016)	Crocker and Fratantonio (2016), after correcting for full pulse duration	Vineyard Wind indicates they will use a comparable repetition rate

Equipment	System	Frequency	Source level	Peak source level	Beam width	Pulse duration	Repetition rate
	GeoMarine Geo Spark 2000 (400 tip)	Estimated from Table 10 and manufacturer specification in Crocker and Fratantonio (2016). Values are in general agreement with manufacturer specification sheet or manual (App. A.4.4).	Source levels were unavailable. A levels were derived from Crocker and Fratantonio (2016). Based on operational experience utilizing this equipment in the MA WEA, Vineyard Wind anticipates operating the Sparker source up to approximately 800J. Derived source level was obtained by interpolation between Applied Acoustics Dura-Spark 400 tip sparker levels operating at 2 kJ and 500 J, see Table 10 in Crocker and Fratantonio (2016)[a].	Peak source levels were unavailable. Source levels were derived from Crocker and Fratantonio (2016). Based on operational experience utilizing this equipment in the MA WEA, Vineyard Wind anticipates operating the Sparker source up to approximately 800J. Derived source level was obtained by interpolation between Applied Acoustics Dura-Spark 400 tip sparker levels operating at 2 kJ and 500 J, see Table 10 in Crocker and Fratantonio (2016)	Assume omnidirectional source to be conservative.	Crocker and Fratantonio (2016), most conservative pulse duration from Table 10.	Vineyard Wind indicates they will use a comparable repetition rate
Underwater positioning (USBL)	SonarDyne Scout Pro	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Assume omnidirectional source to be conservative.	Unknown	Unknown
	ixBlue Gaps	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Assume omnidirectional source to be conservative.	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.

[a] SL(2000 J) = 214 dB. SL(500 J) = 203 dB. The interpolated source level at 800 J is 206 dB. SL(800 J) = (214-203)/(2000-500)*(800-500)+203.

A.2.2. Derived Out-of-beam Levels

Table A-4 lists the corrections applied to obtain out-of-beam source levels.

Table A-4. Correction factors for out-of-beam source levels.

Description		**In-beam**		**Correction (dB)**	**Out-of-beam**	
Equipment	System	Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)		Source level (dB re 1 µPa m)	Peak source level (dB re 1 µPa m)
Shallow subbottom profilers	EdgeTech Chirp 216	178	182	-8.1	169.9	173.9
Shallow subbottom profilers	Innomar SES 2000 Medium	241	247	-36.3	204.7	210.7
Deep seismic profilers	Applied Acoustics AA251 Boomer	205	212	0.0	205	212
Deep seismic profilers	GeoMarine Geo Spark 2000 (400 tip)	206	214	0.0	206	214
Underwater positioning (USBL)	SonarDyne Scout Pro	188	191	0.0	188	191
Underwater positioning (USBL)	ixBlue Gaps	191	194	0.0	191	194

A.3. Distances

Table A-5 lists the geophysical survey sources and the horizontal impact distances to the Level A criteria that were obtained by applying the methods from Appendix A.1 with the source parameters in Appendix A.2. Sources with a repetition rate greater than 10 Hz were assessed based on the non-impulsive SEL thresholds due to the relatively high repetition rate.

Table A-5. Horizontal distance to Level A impact threshold.

Equipment	System	Level A horizontal impact distance (m)					Impulsive source
		LF	MF	HF	PW	OW	(Y/N)
Shallow subbottom profilers	EdgeTech Chirp 216	<1	<1	<1	<1	<1	Y
Shallow subbottom profilers	Innomar SES 2000 Medium	<1	<1	60	<1	<1	N
Deep seismic profilers	Applied Acoustics AA251 Boomer	<1	<1	60	<1	<1	Y
Deep seismic profilers	GeoMarine Geo Spark 2000 (400 tip)	<1	<1	6	<1	<1	Y
Underwater positioning (USBL)	SonarDyne Scout Pro	*	*	*	*	*	*
Underwater positioning (USBL)	ixBlue Gaps	<1	<1	55	<1	<1	Y

*Unable to compute distance due to unavailable source parameters (see Appendix A.2).

The methods used here are approximate, and a rigorous propagation loss model coupled with a full beam pattern and spectral source model would result in more accurate impact distances. The Bay State Wind IHA Application (Feehan 2018) included modeling of the Innomar sub-bottom profiler with BELLHOP, a ray-tracing sound propagation model, and found the Level A distance was <75 m.

A.4. Equipment Specification Reference Sheets

A.4.1. Applied Acoustics AA2xx Seismic Source Operation Manual

The source specifications were primarily obtained from Crocker and Fratantonio (2016) measurements. Manufacturer specifications are included below for reference.

11. Technical Specifications

Mechanical:

Boomer plate size	: 38 x 38 cm depth 9 cm (including connectors)
Weight in air	: 19 kg
Weight in water	: 11.4 kg
Depth rating	: 10 metres
Hole fixing centres	: 31.5 cm
Connector types	:Joy plug male and female (AA200 & AA250) :RMK male and female (AA201, AA202, AA251 & AA252)

Dynamic:

Recommended duty cycle	: 50 Joule @ 6 PPS : 100 – 200 Joule @ 3 PPS
Maximum	: 300 Joule @ 2 PPS : 200 Joule @ 3 PPS : 100 Joule @ at 5 PPS : 50 Joule @ 8 PPS
Static operation duty cycle	: 200 Joule @ 1 PPS : 150 Joule @ 2PPS : 100 Joule @ 3 PPS : 50 Joule @ 5 PPS

PPS = Pulse per Second

The settings apply to seawater temperatures up to a maximum of 18 deg C.

Seawater temperatures above 18 deg C, de-rate the power input by 25%.

Seawater temperatures above 24 deg C to a Maximum of 30 deg C, de-rate the power input by 50%.

Maximum input voltage	: 4000 volts
Male connector input	: Positive
Female connector (ground)	: Negative

Warning for static (non towed operation), reduce maximum energy input by a factor of 50% after 30 minutes of continuous operation.

Source Level at 200J is 215 dB at 1m acoustic pressure (re 1 µPa) (approx 0.5bar metre), although it will vary with cable type/length.

Typical pulse length	: 150 to 250 µS
Reverberation time	: < 1/10 X initial pulse

A.4.2. EdgeTech Chirp 216

2.1.3 Power Amplifier

The specifications for the Power Amplifier are shown in Table 2-3.

Table 2-3: Power Amplifier Specifications

Number of channels:	2
Gain:	33 dB/channel
Output power:	2000 W peak
Input voltage:	120–220 VAC, 50/60 Hz, manually selectable

2.2 SB-424, SB-216S and SB-512i Tow Vehicles

The general specifications for the SB-424, SB-216S and SB-512i Tow Vehicles are shown in Table 2-4.

Table 2-4: Tow Vehicle Specifications

	SB-424	SB-216S	SB-512i
Frequency range:	4–24 kHz	2–16 kHz	0.5–12 kHz
Pulse type:	FM	FM	FM & WB (wide band)
Pulse bandwidth/pulse length:	4-24 kHz/10 ms 4–20 kHz/10 ms 4–16 kHz/10 ms	2-15 kHz/20 ms 2–12 kHz/20 ms 2–10 kHz/20 ms	0.5–8.0 kHz/5 ms FM 0.5–2.7 kHz/40 ms WB 0.5–6.0 kHz/20 ms WB 0.5–4.5 kHz/50 ms FM 0.5–6.0 kHz/9 ms FM 0.5–6.0 kHz/18 ms FM 0.5–7.2 kHz/30 ms FM 0.7–12.0 kHz/20 ms FM 2.0–12.0 kHz/20 ms FM
Calibration:	Gaussian shaped pulse spectrum	Gaussian shaped pulse spectrum	Gaussian and rectangular shaped pulse spectrum
Vertical resolution: [a]	4 cm (4–24 kHz) 6 cm (4–20 kHz) 8 cm (4–16 kHz)	6 cm (2–15 kHz) 8 cm (2–12 kHz) 10 cm (2–10 kHz)	19 cm (1–5.0 kHz) 12 cm (1.5–7.5 kHz) 8 cm (2–12 kHz)
Penetration in coarse and calcareous sand: [b]	2 m (typ)	6 m (typ)	30 m (typ)

EdgeTech

Table 2-4: Tow Vehicle Specifications (Continued)



	SB-424	SB-216S	SB-512i
Penetration in soft clay: [b]	40 m	80 m	250 m
Beam width: [c]	16°, 4–24 kHz 19°, 4–20 kHz 23°, 4–16 kHz	17°, 2–15 kHz 20°, 2–12 kHz 24°, 2–10 kHz	41°, 0.5–5 kHz 32°, 1–6 kHz 24°, 1.5–7.5 kHz 16°, 2–12 kHz
Optimum tow vehicle pitch/roll:	<7°, 4–24 kHz <8°, 4–20 kHz <10°, 4–16 kHz	<7°, 2–15 kHz <8°, 2–12 kHz <10°, 2–10 kHz	<16°, 0.5–5 kHz <13°, 1–6 kHz <10°, 2–8 kHz <8°, 2–10 kHz <7°, 2–12 kHz
Optimum tow height:	3–5 m above sea floor	3–5 m above sea floor	3–5 m above sea floor
Transmitters:	1	1	2
Receive arrays:	2	2	4
Output power:	2000 W	2000 W	2000 W
Tow vehicle size:	77 cm (30 in.) L 50 cm (20 in.) W 34 cm (13 in.) H	105 cm (41 in.) L 67 cm (26 in.) W 46 cm (18 in.) H	158 cm (62 in.) L 134 cm (53 in.) W 46 cm (18 in.) H
Shipping container size:	91 cm (36 in.) L 66 cm (26 in.) W 64 cm (25 in.) H	117 cm (46 in.) L 79 cm (31 in.) W 61 cm (24 in.) H	173 cm (68 in.) L 137 cm (54 in.) W 71 cm (28 in.) H
Weight in air:	35 kg (78 lb)	72 kg (160 lb)	186 kg (410 lb)
Shipping weight:	110 kg (243 lb)	162 kg (357 lb)	356 kg (783 lb)
Tow cable requirements:	3 shielded twisted wire pairs	3 shielded twisted wire pairs	3 shielded twisted wire pairs
Depth rating:	300 m (984 ft) max	300 m (984 ft) max	300 m (984 ft) max

a. Vertical resolution is the smallest distinguishable distance between the peaks of two reflections that can be displayed on the screen as separate reflectors. Sound energy is reflected back to the sonar system when the transmitted pulse encounters a change in density. The resolution of a sonar system is measured by its ability to distinguish between two adjacent targets. The vertical resolution is dependent on the transmitted chirp pulse bandwidth. It is theoretically calculated by the product of the transmitted pulse length (inverse of the bandwidth) and half the speed of sound in water (approximately 750 m/s). For example, a full bandwidth pulse from an SB-424 Tow Vehicle has a vertical resolution of 3.75 cm (1/20,000 x 750).

A.4.3. Innomar Sub-bottom Profiler

SES-2000 medium-100

Parametric Sub-bottom Profiler

▶ Performance
- water depth range: 2 – 2,000 m
- penetration: up to 70 m, depending on sediments
- layer resolution: up to 5 cm
- motion compensation: heave, roll
- beam width @ 3 dB: ±1 ° / footprint < 3.5 % of water depth for all frequencies

▶ Transmitter
- primary frequencies: approx. 100 kHz (band 85 – 115 kHz)
- secondary low frequencies: 4, 5, 6, 8, 10, 12, 15 kHz (band 2 – 22 kHz)
- primary source level: > 247 dB//μPa re 1 m
- pulse width: 0.07 – 2 ms
- pulse rate: up to 40/s
- multi-ping mode
- pulse type: CW, Ricker, LFM (chirp)

▶ Acquisition
- primary frequency (echo sounder, bottom track)
- secondary low frequency (sub-bottom data, multi-frequency mode)
- sample rate 96 kHz @ 24 bit

▶ System Components
- transceiver unit 19 inch / 12 U (WHD: 0.52 m x 0.58 m x 0.40 m; 56 kg)
- transducer incl. 30 m cable (WHD: 0.50 m x 0.12 m x 0.50 m; 60 kg)
- system control: internal PC
- KVM remote control

▶ Software
- SESWIN data acquisition software
- SES Convert SEG-Y/XTF data export
- SES NetView remote display
- ISE post-processing software

▶ Power Supply Requirements
- 100 – 240 V AC / 50 – 60 Hz
- power consumption: < 700 W

Innomar

www.innomar.com

A.4.4. GeoMarine Geo Spark 2000 (400 tip)

Geo

Geo-Source 200 - 400

Marine Multi-Tip Sparker System

Operational Features

- **Powerful hi-resolution seismic source**
- **Primary pulse < 1ms, no ringing**
- **Proven operation in 1000 m water depth**
- **Penetration to 400 ms below seabed, depending on geology and survey conditions**
- **Vertical resolution < 30 cm**

Ideal seismic profiling system for small and large vessels

- **Site & route surveys**
- **Offshore engineering**
- **Mineral exploration**
- **Oceanographic research**

INNOVATIVE Preserving Electrode Mode

The innovative Geo-Source 200 has been designed for operation with the Geo-Spark 1000 pulsed power supply (PPS) using the patented **Preserving Electrode Mode.** This mode uses a NEGATIVE electric discharge pulse instead of a positive pulse.

(Please note that this negative pulse is NOT the same as the simple reversal of the positive polarity of a 'standard' power supply.)

Maintenance free electrodes 5 year guarantee

The Preserving Electrode Mode **reduces the tip wear to practically zero**. You can shoot day after day, week after week, month after month with practically **NO tip maintenance.**

Always a stable acoustic pulse

Zero tip wear is essential for the **acoustic repeatability** of the pulse, which depends largely on a constant, unaltered electrode surface and tip insulation.

Efficient & Cost Effective

With the Geo-Spark HV power supplies you will save a lot of time and money, since the electrodes do NOT burn off like in all other systems.

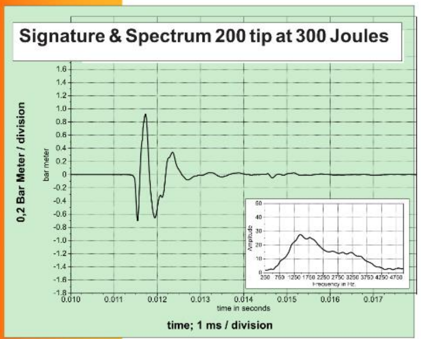
You don't need to trim tips during the survey. There is no need to have any stock of consumables.

Examples of Records

To see examples of our sparker records, please visit the 'Downloads' page on our website: ***www.geo-spark.com***

Geo-Source 200-400

Technical Specifications



Maintenance free electrodes, no trimming, stable signature

Electrodes Geometry

The electrode modules are evenly spaced in a planar array of 0.75 m x 1.00 m. This geometry not only enhances the downward projection of the acoustic energy, it also reduces the primary pulse length, since all tips are perfectly in phase.

Control of Source Parameters 200 - 400 tips

The advanced Geo-Source 200-400 design gives you total control of the source depth and the energy (Joules) per tip

Source depth

Two floats provide a stable towing configuration and insure the proper depth of the electrode tips. This is critical to achieve constructive interference between the primary pulse and its own sea-surface reflection (surface ghost)

Number of tips in use and Energy per tip

Four individually powered electrode modules of 50 or 100 tips each allow you to distribute the energy from the Geo-Spark power supply over 50, 100......, up to 400 tips. (Each tip has an exposed surface area of 1.4 mm^2.)

200 tips, the classic 200 tip configuration is normally used with the Geo-Spark 1000 PPS and consists of four 50-tip electrode modules. This configuration gives an excellent hi-res pulse over the 100 to 500 J power range.

400 tips, for higher energies above 1000 J, and in particular with the Geo-Spark 2000X, we recommend a 400 tip configuration with 4 x 100-tip electrode modules

Coaxial High Voltage (HV) Power/Tow Cable

The Geo-Source 200 is towed by a very high quality, Kevlar-reinforced, coaxial power/tow cable with stainless steel kellum grip. This dedicated high voltage (HV) cable contains **4 x 10 mm^2** inner cores (negative) plus a **40 mm^2** braiding (ground-referenced). It is designed to have a very low self-inductance to preserve the high dI/dt pulse output of the Geo-Spark 1000 PPS.

The coaxial structure of the HV cable reduces the electromagnetic interference to the absolute minimum.

The wet end of the cable is terminated with four special HV connectors to the electrode modules and a ground connector to the frame. Connecting or disconnecting the cable to the Geo-Source 200 takes only 10 minutes; so you can handle the sparker sled and the HV cable as independent units.

The dry end of the cable is terminated at the Geo-Source 200 patch panel, which allows you to select the number of electrode arrays in use

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Appendix B. Vineyard Wind HRG Distance from Source Level B Technical Memo

B.1. Methods

This section describes the methods used to estimate the horizontal distance to the root-mean-square sound pressure level (SPL) 160 dB re 1 µPa isopleth for the purposes of estimating Level B harassment. We use the methods specified in the Interim Recommendation for Sound Source Level and Propagation Analysis for High Resolution Geophysical (HRG) Sources (NOAA 19 Sep 2019), with modifications to use a more accurate seawater absorption formula and a method to account for energy emitted outside of the primary beam of the source. The method is described below.

The sonar equation is first used to calculate the in-beam distance at which 160 dB re 1 µPa is reached:

$$SPL(r) = SL - PL(r) \,, \tag{B-1}$$

where *SPL* is the sound pressure level (dB re 1 µPa), *r* is the in-beam range (m), *SL* is the in-beam source level (dB re 1 µPa m), and PL is the propagation loss as a function of distance. Propagation loss is calculated using:

$$\mathrm{PL}(r) = 20\log_{10}(r) + \alpha(f) \cdot r/1000, \tag{B-2}$$

where α is the absorption coefficient (dB/km) and *f* is frequency (kHz). The absorption coefficient is approximated by discarding the boric acid term from Ainslie (2010, p 29 equation 2.2):

$$\alpha(f) \approx 0.000339 f^2 + 48.5 f^2/(75.6^2 + f^2)\,. \tag{B-3}$$

When a range of frequencies is produced by a source, we use the lowest frequency for determining the absorption coefficient.

For pulses of duration less than 100 ms, the source level is calculated over the pulse duration and for an averaging time of 100 ms, the latter chosen to represent a typical integration time for marine mammal hearing ([COL] Consortium for Ocean Leadership 2018).

For a downwards-pointing source with a beamwidth less than 180°, the horizontal impact distance (*R*) is calculated from the in-beam range using:

$$R = r \cdot \sin\left(\frac{\delta\theta}{2}\right) , \tag{B-4}$$

where $\delta\theta$ is the −3 dB beamwidth.

To account for energy emitted outside of the primary beam of the source, we estimate a single representative out-of-beam source level and propagate the sound horizontally. For narrow-beam sources (up to 36° beamwidth) the representative source level is estimated by first calculating upper and lower bounds and then taking the average of these. We assume the beam pattern $b(u)$ is that of an unshaded circular transducer:

$$b(u) = (2\ J_1(u)/u)^2 \,, \tag{B-5}$$

where $J_1(u)$ is a first order Bessel function of the first kind, whose argument is a function of off-axis angle θ and beamwidth (full width at half maximum) $\delta\theta$

$$u = u_0 \frac{\sin\theta}{\sin\frac{\delta\theta}{2}} \,, \tag{B-6}$$

where $u_0 = 1.614$.

For the upper limit we choose the highest sidelobe level of the beam pattern, given by (2010 p 265 Table 6.2):

$$B_{\max} = -17.6\ \mathrm{dB}\,. \tag{B-7}$$

For the lower limit we consider the asymptotic behavior of the beam pattern in the horizontal direction

$$J_1(u) \sim \sqrt{\frac{2}{\pi u}} \cos\left(u - \frac{3\pi}{4}\right), \tag{B-8}$$

where

$$u = \frac{u_0}{\sin\frac{\delta\theta}{2}}\,. \tag{B-9}$$

In this way we obtain the lower limit as

$$B_{\min} = 10\log_{10}\left(\frac{8}{\pi\, u_0^3}\sin^3\frac{\delta\theta}{2}\right)\mathrm{dB}\,. \tag{B-10}$$

The out-of-beam source level is found by adding the arithmetic mean of $B_{\min}$ and $B_{\max}$ to the in-beam source level.

For broad beam sources (beamwidths larger than 90°), we assumed the source was omnidirectional. For intermediate beam sources (beamwidths between 36° and 90°), we interpolated the correction between the two methods. The resulting correction as a function of beamwidth is shown in Figure A-1.

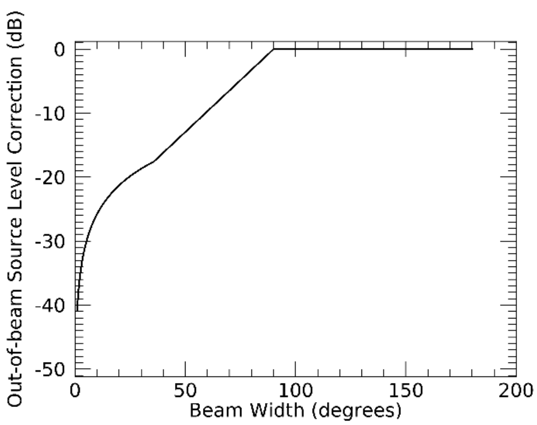

Figure B-1. Correction for calculating out-of-beam source level (i.e., in the horizontal direction) from in-beam source level, as a function of source beamwidth.

Separate sound levels were calculated using the in-beam source level at the angle corresponding to the −3 dB half-width and the out-of-beam source level in the horizontal direction. The higher of the two sound levels was then selected for assessing impact distance.

Both the pulse duration and 100 ms averaged source levels were used to compute two different horizontal impact distances for each source. These two distances were provided to show the effect of using a 100 ms averaging time as recommended by COL (2018).

B.2. Overview of Source Properties

The following subsections describe the source characteristics of HRG equipment that operates at and below 200 kHz (BOEM 2014a). The horizontal impact distance to the Level B harassment threshold (160 dB re 1 µPa) was computed for each source by applying the methods from Appendix B.1. We used the following conservative assumptions when calculating impact distances:

- For sources that operate with different beamwidths, we used the maximum beamwidth.
- We use the lowest frequency of the source when calculating the absorption coefficient.

Table B-1 lists the geophysical survey sources that produce underwater sound at frequencies at or less than 200 kHz and their acoustic characteristics. Table B-2 provides the accompanying data source reference.

Table B-1. Considered geophysical survey sources.

Equipment	System	Frequency (kHz)	Source level (dB re 1 µPa m)	Beam width (°)	Pulse duration (ms)	Repetition rate (Hz)	Adjusted source level for 100 ms averaging time (dB re 1 µPa m)
Shallow subbottom profilers	EdgeTech Chirp 216	2–10	178	65	2	3.75	161.0
	Innomar SES 2000 Medium	85–115	241	2	2	40	230.0
Deep seismic profilers	Applied Acoustics AA251 Boomer	0.2–15	205	180	0.9	2	184.5
	GeoMarine Geo Spark 2000 (400 tip)	0.25–5	206	180	2.8	1	190.5
Underwater positioning (USBL)	SonarDyne Scout Pro	35 – 50	188	180	Unknown	Unknown	188.0
	ixBlue Gaps	20 – 32	191	180	1	10	171.0

Table B-2. Data reference for considered geophysical survey sources.

Equipment	System	Frequency	Source level	Beam width	Pulse duration	Repetition rate
Shallow subbottom profilers	EdgeTech Chirp 216	Vineyard Wind indicates they will use a comparable frequency range, which is narrower than full source frequency range.	Considered EdgeTech Chirp 512i as proxy for source levels as Chrip512i has similar operation settings as Chirp216 tow vehicle (App. B.4.2). See Table 18 in Crocker and Fratantonio (2016) source for levels at 100% power and 1–10 kHz.	Considered EdgeTech Chirp 512i as proxy source. See Table 20 in Crocker and Fratantonio (2016) for beamwidth corresponding to proxy source bandwidth and power for source level.	Used EdgeTech Chirp 512i as proxy source. See Table 20 in Crocker and Fratantonio (2016).	Vineyard Wind indicates they will use this repetition rate.
	Innomar SES 2000 Medium	Manufacturer specification sheet or manual (App. B.4.3)	Specification sheet (App. B.4.3) indicates peak source level of 247 dB re 1 μPa m (Jens Wunderlich, Innomar, personal communication, 2019-07-18). Average difference between peak and SPL source level for sub-bottom profilers measured by Crocker and Fratantonio (2016) was 6 dB. We estimate SPL source level is 241 dB re 1 μPa m.	Manufacturer specification sheet or manual (App. B.4.3)	Manufacturer specification sheet or manual (App. B.4.3).	Manufacturer specification sheet or manual (App. B.4.3).
Deep seismic profilers	Applied Acoustics AA251 Boomer	Estimated from Figs 14 and 16 in Crocker and Fratantonio (2016)	Crocker and Fratantonio (2016)	Crocker and Fratantonio (2016)	Crocker and Fratantonio (2016), after correcting for full pulse duration	Vineyard Wind indicates they will use this repetition rate
	GeoMarine Geo Spark 2000 (400 tip)	Estimated from Table 10 and manufacturer specification in Crocker and Fratantonio (2016). Values are in general agreement with manufacturer specification sheet or manual (App. A.4.4)	Source levels were unavailable. Levels were derived from Crocker and Fratantonio (2016). Based on operational experience utilizing this equipment in the MA WEA, Vineyard Wind anticipates operating the sparker source up to approximately 800J. Derived source level was obtained by interpolation between Applied Acoustics Dura-Spark 400 tip sparker levels operating at 2 kJ and 500 J, see Table 10 in Crocker and Fratantonio (2016).[a]	Assume omnidirectional source to be conservative.	Crocker and Fratantonio (2016), most conservative pulse duration from Table 10.	Vineyard Wind indicates they will use a comparable repetition rate
	SonarDyne Scout Pro	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	unknown	unknown

Equipment	System	Frequency	Source level	Beam width	Pulse duration	Repetition rate
Underwater positioning (USBL)	ixBlue Gaps	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.	Source specifications provided by Vineyard Wind.

[a] SL(2000 J) = 214 dB. SL(500 J) = 203 dB. The interpolated source level at 800 J is 206 dB. SL(800 J) = (214-203)/(2000-500)*(800-500)+203.

B.3. Distances to Threshold

Table B-3 presents the geophysical survey sources and the horizontal impact distances to Level B thresholds that were obtained by applying the methods from Appendix B.1 with the source parameters in Appendix B.2. The Level B horizontal impact distances were calculated from the (pulse-duration averaged) source levels shown in the table below and do not reflect calculations for a 100 ms integration time.

Table B-3. Estimated horizontal distances to Level B threshold criteria (160 dB SPL)

Equipment	System	Frequency (kHz)	Source level (dB re 1 µPa m)	Beam width (°)	Level B horizontal impact distance (m)
Shallow subbottom profilers	EdgeTech Chirp 216	2–10	178	65	4
	Innomar SES 2000 Medium	85–115	241	2	116
Deep seismic profilers	Applied Acoustics AA251 Boomer	0.2–15	205	180	178
	GeoMarine Geo Spark 2000 (400 tip)	0.25–5	206	180	195
Underwater positioning (USBL)	SonarDyne Scout Pro	35 – 50	188	180	24
	ixBlue Gaps	20 – 32	191	180	35

B.4. Equipment Specification Reference Sheets

B.4.1. Applied Acoustics AA2xx Seismic Source Operation Manual

The source specifications were primarily obtained from Crocker and Fratantonio (2016) measurements. Manufacturer specifications are included below for reference.

AA2xx Series Seismic Source Operation Manual
BPL-0200-8000/1

APPLIED ACOUSTICS
Underwater Technology

11. Technical Specifications

Mechanical:

Boomer plate size : 38 x 38 cm depth 9 cm (including connectors)

Weight in air : 19 kg
Weight in water : 11.4 kg

Depth rating : 10 metres

Hole fixing centres : 31.5 cm

Connector types :Joy plug male and female (AA200 & AA250)
:RMK male and female (AA201, AA202, AA251 & AA252)

Dynamic:

Recommended duty cycle : 50 Joule @ 6 PPS
: 100 – 200 Joule @ 3 PPS
Maximum : 300 Joule @ 2 PPS
: 200 Joule @ 3 PPS
: 100 Joule @ at 5 PPS
: 50 Joule @ 8 PPS

Static operation duty cycle : 200 Joule @ 1 PPS
: 150 Joule @ 2PPS
: 100 Joule @ 3 PPS
: 50 Joule @ 5 PPS

PPS = Pulse per Second

The settings apply to seawater temperatures up to a maximum of 18 deg C.

Seawater temperatures above 18 deg C, de-rate the power input by 25%.

Seawater temperatures above 24 deg C to a Maximum of 30 deg C, de-rate the power input by 50%.

Maximum input voltage : 4000 volts
Male connector input : Positive
Female connector (ground) : Negative

Warning for static (non towed operation), reduce maximum energy input by a factor of 50% after 30 minutes of continuous operation.

Source Level at 200J is 215 dB at 1m acoustic pressure (re 1 μPa)
(approx 0.5bar metre), although it will vary with cable type/length.

Typical pulse length : 150 to 250 μS
Reverberation time : < 1/10 X initial pulse

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B.4.2. EdgeTech Chirp 216

2.1.3 Power Amplifier

The specifications for the Power Amplifier are shown in Table 2-3.

Table 2-3: Power Amplifier Specifications

Number of channels:	2
Gain:	33 dB/channel
Output power:	2000 W peak
Input voltage:	120–220 VAC, 50/60 Hz, manually selectable

2.2 SB-424, SB-216S and SB-512i Tow Vehicles

The general specifications for the SB-424, SB-216S and SB-512i Tow Vehicles are shown in Table 2-4.

Table 2-4: Tow Vehicle Specifications

	SB-424	SB-216S	SB-512i
Frequency range:	4–24 kHz	2–16 kHz	0.5–12 kHz
Pulse type:	FM	FM	FM & WB (wide band)
Pulse bandwidth/pulse length:	4-24 kHz/10 ms 4–20 kHz/10 ms 4–16 kHz/10 ms	2-15 kHz/20 ms 2–12 kHz/20 ms 2–10 kHz/20 ms	0.5–8.0 kHz/5 ms FM 0.5–2.7 kHz/40 ms WB 0.5–6.0 kHz/20 ms WB 0.5–4.5 kHz/50 ms FM 0.5–6.0 kHz/9 ms FM 0.5–6.0 kHz/18 ms FM 0.5–7.2 kHz/30 ms FM 0.7–12.0 kHz/20 ms FM 2.0–12.0 kHz/20 ms FM
Calibration:	Gaussian shaped pulse spectrum	Gaussian shaped pulse spectrum	Gaussian and rectangular shaped pulse spectrum
Vertical resolution: [a]	4 cm (4–24 kHz) 6 cm (4–20 kHz) 8 cm (4–16 kHz)	6 cm (2–15 kHz) 8 cm (2–12 kHz) 10 cm (2–10 kHz)	19 cm (1–5.0 kHz) 12 cm (1.5–7.5 kHz) 8 cm (2–12 kHz)
Penetration in coarse and calcareous sand: [b]	2 m (typ)	6 m (typ)	30 m (typ)

EdgeTech

B.4.3. Innomar Sub-bottom Profiler

SES-2000 medium-100

Parametric Sub-bottom Profiler

▶ Performance
- water depth range: 2 – 2,000 m
- penetration: up to 70 m, depending on sediments
- layer resolution: up to 5 cm
- motion compensation: heave, roll
- beam width @ 3 dB: ±1 ° / footprint < 3.5 % of water depth for all frequencies

▶ Transmitter
- primary frequencies: approx. 100 kHz (band 85 – 115 kHz)
- secondary low frequencies: 4, 5, 6, 8, 10, 12, 15 kHz (band 2 – 22 kHz)
- primary source level: > 247 dB//µPa re 1 m
- pulse width: 0.07 – 2 ms
- pulse rate: up to 40/s
- multi-ping mode
- pulse type: CW, Ricker, LFM (chirp)

▶ Acquisition
- primary frequency (echo sounder, bottom track)
- secondary low frequency (sub-bottom data, multi-frequency mode)
- sample rate 96 kHz @ 24 bit

▶ System Components
- transceiver unit 19 inch / 12 U (WHD: 0.52 m x 0.58 m x 0.40 m; 56 kg)
- transducer incl. 30 m cable (WHD: 0.50 m x 0.12 m x 0.50 m; 60 kg)
- system control: internal PC
- KVM remote control

▶ Software
- SESWIN data acquisition software
- SES Convert SEG-Y/XTF data export
- SES NetView remote display
- ISE post-processing software

▶ Power Supply Requirements
- 100 – 240 V AC / 50 – 60 Hz
- power consumption: < 700 W

Innomar

www.innomar.com

B.4.4. GeoMarine Geo Spark 2000 (400 tip)

geo

Geo-Source 200 - 400

Marine Multi-Tip Sparker System

Operational Features

- Powerful hi-resolution seismic source
- Primary pulse < 1ms, no ringing
- Proven operation in 1000 m water depth
- Penetration to 400 ms below seabed, depending on geology and survey conditions
- Vertical resolution < 30 cm

Ideal seismic profiling system for small and large vessels

- Site & route surveys
- Offshore engineering
- Mineral exploration
- Oceanographic research

INNOVATIVE Preserving Electrode Mode

The innovative Geo-Source 200 has been designed for operation with the Geo-Spark 1000 pulsed power supply (PPS) using the patented **Preserving Electrode Mode.** This mode uses a NEGATIVE electric discharge pulse instead of a positive pulse.

(Please note that this negative pulse is NOT the same as the simple reversal of the positive polarity of a 'standard' power supply.)

Maintenance free electrodes 5 year guarantee

The Preserving Electrode Mode **reduces the tip wear to practically zero**. You can shoot day after day, week after week, month after month with practically **NO tip maintenance.**

Always a stable acoustic pulse

Zero tip wear is essential for the **acoustic repeatability** of the pulse, which depends largely on a constant, unaltered electrode surface and tip insulation.

Efficient & Cost Effective

With the Geo-Spark HV power supplies you will save a lot of time and money, since the electrodes do NOT burn off like in all other systems.

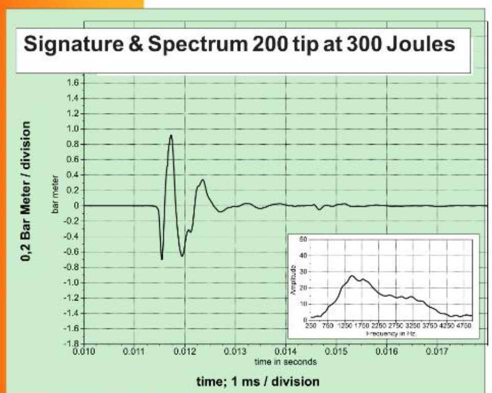
You don't need to trim tips during the survey. There is no need to have any stock of consumables.

Examples of Records

To see examples of our sparker records, please visit the 'Downloads' page on our website: ***www.geo-spark.com***

Geo-Source 200-400

Technical Specifications



Maintenance free electrodes, no trimming, stable signature

Electrodes Geometry

The electrode modules are evenly spaced in a planar array of 0.75 m x 1.00 m. This geometry not only enhances the downward projection of the acoustic energy, it also reduces the primary pulse length, since all tips are perfectly in phase.

Control of Source Parameters 200 - 400 tips

The advanced Geo-Source 200-400 design gives you total control of the source depth and the energy (Joules) per tip

Source depth

Two floats provide a stable towing configuration and insure the proper depth of the electrode tips. This is critical to achieve constructive interference between the primary pulse and its own sea-surface reflection (surface ghost)

Number of tips in use and Energy per tip

Four individually powered electrode modules of 50 or 100 tips each allow you to distribute the energy from the Geo-Spark power supply over 50, 100......, up to 400 tips. (Each tip has an exposed surface area of 1.4 mm^2.)

200 tips, the classic 200 tip configuration is normally used with the Geo-Spark 1000 PPS and consists of four 50-tip electrode modules. This configuration gives an excellent hi-res pulse over the 100 to 500 J power range.

400 tips, for higher energies above 1000 J, and in particular with the Geo-Spark 2000X, we recommend a 400 tip configuration with 4 x 100-tip electrode modules

Coaxial High Voltage (HV) Power/Tow Cable

The Geo-Source 200 is towed by a very high quality, Kevlar-reinforced, coaxial power/tow cable with stainless steel kellum grip. This dedicated high voltage (HV) cable contains **4 x 10 mm^2** inner cores (negative) plus a **40 mm^2** braiding (ground-referenced). It is designed to have a very low self-inductance to preserve the high dI/dt pulse output of the Geo-Spark 1000 PPS.

The coaxial structure of the HV cable reduces the electromagnetic interference to the absolute minimum.

The wet end of the cable is terminated with four special HV connectors to the electrode modules and a ground connector to the frame. Connecting or disconnecting the cable to the Geo-Source 200 takes only 10 minutes; so you can handle the sparker sled and the HV cable as independent units.

The dry end of the cable is terminated at the Geo-Source 200 patch panel, which allows you to select the number of electrode arrays in use

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