Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V *Marcus G. Langseth* of the Blake Plateau, Northwest Atlantic Ocean

submitted by

Lamont-Doherty Earth Observatory
61 Route 9W, P.O. Box 1000
Palisades, NY, 10964-8000

to

National Marine Fisheries Service
Office of Protected Resources
1315 East–West Hwy, Silver Spring, MD 20910-3282

Application Prepared by

LGL Limited, environmental research associates
22 Fisher St., POB 280
King City, Ont. L7B 1A6

18 November 2022

LGL Report FA0241-02

TABLE OF CONTENTS

Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V *Marcus G. Langseth* of the Blake Plateau, Northwest Atlantic Ocean

SUMMARY

Researchers from the University of Texas Institute of Geophysics (UTIG) and Lamont-Doherty Earth Observatory (L-DEO), with funding from the U.S. National Science Foundation (NSF), propose to conduct marine geophysical research of the Blake Plateau, off the southeastern U.S. in the Northwest Atlantic Ocean in 2023. The research would include high-energy seismic surveys conducted from the research vessel (R/V) *Marcus G. Langseth* (*Langseth*). The majority of the proposed two-dimensional (2-D) seismic surveys would occur within the Exclusive Economic Zones (EEZ) of the U.S., but a portion would also occur within the EEZ of the Bahamas and in International Waters. The surveys would use a 36-airgun towed array with a total discharge volume of approximately (~) 6600 in^3 in water depths ranging from >100 m to 5200 m.

Numerous species of marine mammals inhabit the proposed marine project area in the Northwest Atlantic Ocean. Under the U.S. Endangered Species Act (ESA), several of these species are listed as *endangered*, including the North Atlantic right, sei, fin, blue, and sperm whales, which are managed by NMFS. Thus, this request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5). The West Indian manatee is listed as *threatened* and managed by the U.S. Fish and Wildlife Service (USFWS). Although they occur along the coast of the southeastern U.S., manatees are not expected to be encountered or impacted during the proposed surveys as all activities would occur in water deeper than 100 m.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, "Submission of Requests", are set forth below. They include descriptions of the specific operations to be conducted, the marine mammals occurring in the survey area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor any behavioral effects of the operations on those marine mammals.

I. OPERATIONS TO BE CONDUCTED

> A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

Overview of the Activity

The research activities, including the seismic surveys with the 36-airgun array, would examine the structure and evolution of the rifted margins of the southeastern U.S., including the rift dynamics during the formation of the Carolina Trough and Blake Plateau. The proposed research would occur within the survey area (depicted in Fig. 1), ~27.5–33.5°N, 74–80°W, within the Exclusive Economic Zone (EEZ) of the U.S. and Bahamas, and in International Waters, in water depths ranging from >100–5200 m. Representative seismic survey tracklines are shown in Figure 1. The closest approach of the proposed survey area to the 100-m isobath would be 10.1 km. The distances to all state waters [5.6 km (3 n.mi.)] would be >80 km, and to the coast would be ~90 km to Georgia, ~98 km to Florida, and ~107 km to South Carolina.

The main goal of the high-energy seismic program proposed by the Principal Investigator (PI) Dr. H. Van Avendonk, and co-PIs Drs. N. Bangs (UTIG) and A. Bécel (L-DEO), is to investigate the structure and evolution of the rifted margins of the southeastern U.S., including the rift dynamics during the formation of the Carolina Trough and Blake Plateau. By imaging the sediments and crystalline crust of the margins, the science team would better understand the interaction between tectonic and magmatic processes that led to continental breakup and the onset of seafloor spreading in the central Atlantic Ocean 200 million years ago. The PIs are particularly interested in the stratigraphy of sediments that formed during and after rifting, the degree of crustal stretching at the continental margins, crustal faults that formed during extension of the margin, and the geometry of lava flows that were placed on the crust before the start of seafloor spreading. To achieve project goals of the seismic surveys, the PIs propose to utilize the seismic surveying capabilities of R/V *Langseth*, as well as Ocean Bottom Seismometers (OBS).

The seismic surveys would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array with a discharge volume of ~6600 in^3 at a depth of 10–12 m. The receiving system would consist of a 15-km long solid-state hydrophone streamer (solid flexible polymer – not gel or oil filed) and ~40 OBSs. The airguns would fire at a shot interval of 50 m (~24 s) during multi-channel seismic (MCS) reflection surveys with the hydrophone streamer and at a 200-m (~78 s) interval during OBS seismic refraction surveys. As the airgun arrays are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system, and the OBSs would receive and store the returning acoustic signals internally for later analysis.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Langseth* continuously during the seismic surveys, including during transit. All planned geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.
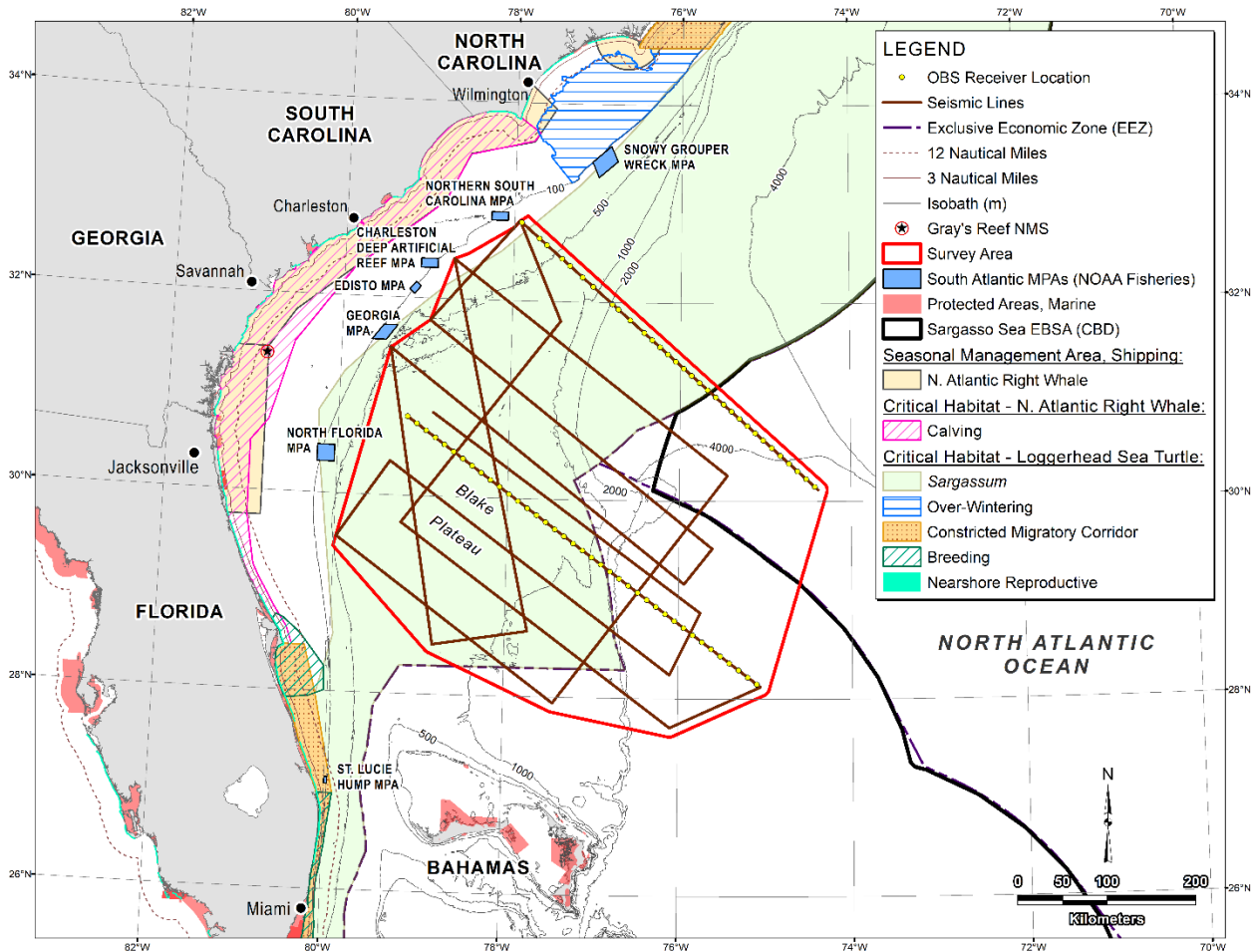
FIGURE 1. Location of the proposed Blake Plateau seismic surveys, marine conservation areas, and marine critical habitat in the Northwest Atlantic Ocean. Representative survey tracklines are included in the figure; however, the tracklines could occur anywhere within the survey area. MPA = marine protected area; NMS = National Marine Sanctuary. EBSA = Ecologically or Biologically Significant Marine Areas. CBD = Convention on Biological Diversity. N = North.

Source Vessel Specifications

R/V *Marcus G. Langseth* is described in § 2.2.2.1 of the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Records of Decision (NSF 2012; USGS 2013) referred to herein as the PEIS. The vessel speed during seismic operations with the 36-airgun array would be ~4–5 kt (~7.4–9.3 km/h). When R/V *Langseth* tows the airguns and hydrophone streamer, the turning rate of the vessel would be limited to five degrees per minute.

Airgun Description

During the MCS seismic reflection and OBS seismic refraction surveys, R/V *Langseth* would tow four strings with 36 airguns (plus 4 spares); the strings would be spaced 16 m apart. The airgun array consists of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The four airgun strings would be distributed across an area of ~24x16 m behind the *Langseth* and would be towed ~140 m behind the vessel. During the surveys, all four strings, totaling 36 active airguns with a total discharge volume of 6600 in^3, would be used. The array would be towed at a depth of 10 m, and the shot interval would be 50 m (~24 s) during MCS seismic reflection surveys and 200 m (~78 s) during OBS seismic refraction surveys. The airgun array and its source level and frequency components are described in § 2.2.3.1 of the PEIS and summarized below, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. During firing, a brief pulse of sound with a duration of ~0.1 s would be emitted. The airguns would be silent during the intervening periods. During operations, airguns would be operated 24/7 for multiple days to meet science objectives unless maintenance or mitigation measures warranted.

36-Airgun Array Specifications

Energy Source	Thirty-six 1900 psi Bolt airguns of 40–360 in^3, in four strings each containing nine operating airguns
Source output (downward)	0-pk is 84 bar-m (259 dB re 1 μPa·m); pk-pk is 177 bar·m (265 dB)
Air discharge volume	~6600 in^3
Dominant frequency components	2–188 Hz
Firing Pressure	1900 psi

The source levels for the airgun array can be derived from the modeled farfield source signature, which is estimated using the PGS Nucleus software. The nominal downward-directed source level indicated above does not represent the actual sound level that can be measured at any location in the water. Rather, it represents the level that would be found 1 m from a hypothetical point source emitting the same total amount of sound as is emitted by the airgun array. The actual received level at any location in the water near the airguns would not exceed the source level of the strongest individual source. Actual levels experienced by any organism more than 1 m from the airguns would be significantly lower.

A further consideration is that the rms[1] (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak (p or 0–p) or peak to peak (p–p) values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in biological literature. A measured received sound pressure level (SPL) of 160 dB re 1 μPa$_{rms}$ in the farfield would typically correspond to ~170 dB re 1 μPa$_p$ or 176–178 dB re 1 μPa$_{p-p}$, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

_____
[1] The rms (root mean square) pressure is an average over the pulse duration.

Mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the exclusion zones (EZ) for Level A takes and for the Level B (160 dB re 1μPa$_{rms}$) threshold. The background information and methodology for this are provided in Appendix A. L-DEO model results are used to determine the 160-dB$_{rms}$ radius for the airgun source down to a maximum depth of 2000 m (see Appendix A), as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. Table 1 shows the distances at which the 160-dB re 1μPa$_{rms}$ sound levels are expected to be received for the 36-airgun array. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

TABLE 1. Predicted distances to behavioral disturbance sound levels ≥160-dB re 1 μPa$_{rms}$ that could be received during the proposed surveys on the Blake Plateau off the southeastern U.S. The 160-dB criterion applies to all hearing groups of marine mammals (Level B harassment).

Source and Volume	Tow Depth (m)[1]	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level
4 strings, 36 airguns 6600 in³	12	>1000 m 100–1000 m	6,733[2] 10,100[3]

[1] Maximum tow depth was used for conservative distances. [2] Distance is based on L-DEO model results. [3] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are available for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW) (NMFS 2016a, 2018). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances for marine mammals. Here, SEL$_{cum}$ is used for LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups. The PTS thresholds for the MCS surveys are shown in Table 2; the PTS thresholds for the refraction surveys with OBSs are shown in Table 3.

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for shut downs and to monitor an additional 500-m buffer zone beyond the EZ for marine mammals and a 150-m EZ for sea turtles. We have proposed monitoring and mitigation measures that have been required by NMFS for other similar recent high-energy seismic surveys. Enforcement of mitigation zones via shut downs would be implemented as described in § XI or as otherwise required by regulators.

TABLE 2. Level A (PTS) threshold distances for different marine mammal hearing groups for the 36-airgun array based on a speed of 4.1 kts and a shot interval of 50 m for the MCS surveys. Consistent with NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PTS SEL$_{cum}$	**320.2**	0	1.0	10.4	0
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**

TABLE 3. Level A (PTS) threshold distances for different marine mammal hearing groups for the 36-airgun array based on a speed of 5 kts and a shot interval of 200 m for the refraction surveys with OBSs. Consistent with NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PTS SEL$_{cum}$	**80.0**	0	0.3	2.6	0
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**

Seismometer Description

Approximately 40 short-period OBSs would be provided by the Ocean Bottom Seismometer Instrument Center (OBSIC) at Woods Hole Oceanographic Institution (WHOI) – they would remain on the seafloor for ~8 days. The OBSIC OBSs have a height of ~1 m, a diameter of ~0.5 m, and a weight ~22 kg; the steel anchor is 30.5 cm x 38 cm x 2.5 cm high and weighs ~24 kg. All OBSs would be recovered by the end of the survey. To retrieve the OBSs, the instrument is released to float to the surface via an acoustic release system from the anchor, which is not retrieved. The acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz.

Description of Operations

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys conducted by L-DEO and would use conventional seismic methodology. The seismic surveys would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array with a discharge volume of ~6600 in^3 at a depth of 10–12 m. The receiving system would consist of a 15-km long solid-state hydrophone streamer (solid flexible polymer – not gel or oil filed) and ~40 OBSs. The airguns would fire at a shot interval of 50 m (~24 s) during multi-channel seismic (MCS) reflection surveys with the hydrophone streamer and at a 200-m (~78 s) interval during OBS seismic refraction surveys. As

the airgun arrays are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system, and the OBSs would receive and store the returning acoustic signals internally for later analysis.

Approximately 6682 km of seismic acquisition are proposed: 5730 km of 2-D MCS seismic reflection data and 952 km of OBS refraction data. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the take calculations, 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed. Overall, just over half (55%) of all survey effort would occur in intermediate water (100–1000 m deep), and 45% would occur in deep water (>1000 m deep); no seismic acquisition would take place in shallow water (<100 m). When only MCS reflection surveys are considered, most of the effort (58%) would occur in intermediate-depth water, and 42% of effort would occur in deep water. When only refraction surveys with OBSs are considered, most of that effort (60%) would occur in deep water, and 40% would occur in intermediate-depth water. Refraction surveys with OBSs would be acquired along two lines – one 456 km long line across the southern Carolina Trough (32 OBS drops) and a 496 km long line across Blake Plateau (39 drops). Following refraction shooting of one line, OBSs on that line would be recovered, serviced, and redeployed on a subsequent refraction line.

In addition to the operations of the airgun array, the ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of the PEIS and Section 2.1.2.7 of the associated Draft EA.

II. DATES, DURATION, AND REGION OF ACTIVITY

The date(s) and duration of such activity and the specific geographical region where it will occur.

The proposed research would occur within ~27.5–33.5°N, 74–80°W; representative seismic survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual tracklines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the research activities, including the seismic surveys, could occur anywhere within the survey area and coordinates noted above in water >100 m. The research would take place within the Exclusive Economic Zone (EEZ) of the U.S. and Bahamas, and in International Waters, in water depths ranging from >100–5200 m. The closest approach of the proposed survey area to the 100-m isobath would be 10.1 km. The distances to all state waters [5.6 km (3 n.mi.)] would be >80 km, and to the coast would be ~90 km to Georgia, ~98 km to Florida, and ~107 km to South Carolina.

The proposed high-energy survey with the 36-airgun array would be expected to take place during summer or fall 2023 for a period of ~61 days, spread between two operational legs, with ~40 days of seismic operations. One leg would include ~32 days of MCS seismic operations and ~4 days of transit time, whereas the other leg would consist of ~8 days of seismic operations with OBSs, ~13 days of OBS deployment, and 4 days of transit. R/V *Langseth* would likely leave out of and return to port in Jacksonville, Florida (~100 km from the survey area) during summer/fall 2023.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

The species and numbers of marine mammals likely to be found within the activity area

Thirty-one cetacean species (7 mysticetes and 24 odontocetes) could occur near the proposed survey area (Table 4). Six of the 31 species are listed under the U.S. Endangered Species Act (ESA) as ***endangered***: the North Atlantic right, humpback, blue, fin, sei, and sperm whales. Four species that are known to occur in the wider North Atlantic are unlikely to occur near the proposed survey area because their ranges generally do not extend as far south; these include the northern bottlenose whale (*Hyperoodon ampullatus*), Sowerby's beaked whale (*Mesoplodon bidens*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), and white-beaked dolphin (*Lagenorhynchus albirostris*). These cetacean species are not considered further.

Harbor seals (*Phoca vitulina*) and hooded seals (*Cystophora cristata*) are considered extralimital off the southeastern U.S. (DoN 2008c). In addition, harbor seals are unlikely to occur in the deeper waters of the proposed survey area. Harp seals (*Pagophilus groenlandicus*) and gray seals (*Halichoerus grypus*) are not expected to occur in the proposed survey area. There are no records of pinnipeds within the proposed survey area (DoN 2008b); thus, pinnipeds are not discussed further. The Florida subpopulation of the West Indian manatee (*Trichechus manatus latirostris*) is known to occur in shallow water along the east coast of the U.S. None of the survey effort would occur in shallow water (<100 m), and no manatees along the coast would be exposed to sound levels >160 dB. The survey area would be at least 90 km from coast.

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

IV. STATUS, DISTRIBUTION AND SEASONAL DISTRIBUTION OF AFFECTED SPECIES OR STOCKS OF MARINE MAMMALS

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities

Sections III and IV are integrated here to minimize repetition. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of cetaceans are given in § 3.6.1 and § 3.7.1 of the PEIS. The general distributions of mysticetes and odontocetes in the Northwest Atlantic Ocean are discussed in the Northwestern Atlantic Detailed Analysis Area (DAA) in § 3.6.2.1 and § 3.7.2.1 of the PEIS, respectively. Additionally, information on marine mammals in this region is included in § 4.2.2.1 of the Bureau of Ocean Energy Management (BOEM) Final PEIS for Atlantic OCS Proposed Geological and Geophysical Activities, Mid-Atlantic and South Atlantic Planning Areas (BOEM 2014), and in § 3.7 of the U.S. Navy's Atlantic Fleet Training and Testing (AFTT) Final EIS (DoN 2018). The rest of this section focuses on species distribution in and near the proposed survey area in offshore waters of South Carolina, Georgia, and Florida.

Mysticetes

North Atlantic Right Whale (*Eubalaena glacialis*)

The North Atlantic right whale occurs primarily in the continental shelf waters of the eastern U.S. and Canada, from Florida to Nova Scotia (Winn et al. 1986; Jefferson et al. 2015; Hayes et al. 2022). There is a general seasonal north-south migration between feeding and calving areas (Gaskin 1982). The migration route between the Cape Cod spring/summer feeding grounds and the Georgia/Florida winter calving grounds is known as the mid-Atlantic corridor, and whales move through these waters regularly in

TABLE 4. The habitat, occurrence, population sizes, and conservation status of marine mammals that could occur in or near the proposed Blake Plateau survey area in the Northwest Atlantic Ocean.

Species	Habitat	Occurrence in Survey Area[1]	Abundance in Western North Atlantic[2]	US ESA[3]	IUCN[5]	CITES[6]
Mysticetes						
North Atlantic right whale	Coastal	Rare	368	E	CR	I
Fin whale	Coastal, pelagic	Uncommon	6,802	E	VU	I
Minke whale	Coastal waters	Uncommon	21,968[10]	NL	LC	I
Bryde's whale	Pelagic and coastal	Rare	unk / 51[20]	NL	LC	I
Sei whale	Pelagic	Uncommon	6,292[9]	E	EN	I
Blue whale	Pelagic	Uncommon	402[8]	E	EN	I
Humpback whale *West Indies DPS*	Mainly nearshore and banks	Uncommon	1,396[11] 11,570[12]	NL	LC[7]	I
Odontocetes						
Sperm whale	Usually pelagic and deep seas	Common	4,349[13]	E	VU	I
Pygmy sperm whale	Deeper waters off the shelf	Uncommon	7,750[14]	NL	LC	II
Dwarf sperm whale	Deeper waters off the shelf	Uncommon	7,750[14]	NL	LC	II
Cuvier's beaked whale	Pelagic	Uncommon	5,744	NL	LC	II
Gervais' beaked whale	Pelagic	Rare	10,107[15]	NL	LC	II
Blainville's beaked whale	Pelagic	Rare	10,107[15]	NL	LC	II
True's beaked whale	Pelagic	Rare	10,107[15]	NL	LC	II
Rough-toothed dolphin	Mostly pelagic	Rare	136[16]	NL	LC	II
Bottlenose dolphin	Continental shelf, coastal, offshore	Common	62,851[17]	NL	LC	II
Pantropical spotted dolphin	Mainly pelagic	Uncommon	6,593	NL	LC	II
Atlantic spotted dolphin	Mainly coastal waters	Common	39,921	NL	LC	II
Spinner dolphin	Coastal, pelagic	Rare	4,102	NL	LC	II
Clymene dolphin	Pelagic	Rare	4,237	NL	LC	II
Striped dolphin	Off the continental shelf	Uncommon	67,036	NL	LC	II
Fraser's dolphin	Water >1000 m	Rare	unk / 492[18]	NL	LC	II
Risso's dolphin	Waters 400-1000 m	Common	35,215	NL	LC	II
Common dolphin	Shelf, pelagic	Common	172,974	NL	LC	II
Melon-headed whale	Oceanic	Rare	unk / 1,175[18]	NL	LC	II
Pygmy killer whale	Oceanic	Rare	unk	NL	LC	II
False killer whale	Pelagic	Rare	1,791	NL	NT	II
Killer whale	Widely distributed	Uncommon	unk / 6,600[19]	NL	DD	II
Short-finned pilot whale	Mostly pelagic	Common	28,924	NL	LC	II
Long-finned pilot whale	Mostly pelagic	Rare	39,215	NL	LC	II
Harbor porpoise	Mostly coastal	Rare	95,543	NL	LC	II

unk = unknown in stock assessment (Hayes et al. 2022).
[1] Occurrence in area at the time of the survey; based on professional opinion and available data including sightings and densities.
[2] Abundance for North Atlantic from U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment (Hayes et al. 2022) unless otherwise indicated.
[3] U.S. Endangered Species Act: E = endangered, NL = not listed.
[5] International Union for the Conservation of Nature Red List of Threatened Species version 2022-1: VU = vulnerable; NT = near threatened; LC = least concern; DD = data deficient.

[6] Convention on International Trade in Endangered Species of Wild Fauna and Flora: Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

[7] Global status.

[8] Minimum population size for Western North Atlantic.

[9] Nova Scotia.

[10] Canadian East Coast.

[11] Gulf of Maine.

[12] Entire North Atlantic (Stevick et al. 2003).

[13] North Atlantic.

[14] Estimate includes dwarf and pygmy sperm whales.

[15] Estimate includes all Mesoplodont whales in the North Atlantic, including Sowerby's beaked whale.

[16] Hayes et al. (2019) noted that this abundance estimate for the Western North Atlantic is highly uncertain as it is based on a single sighting; the abundance estimate for the Gulf of Mexico stock is 624. Roberts et al. (2016a) reported an abundance estimate of 4,989 for the Gulf of Mexico.

[17] Offshore stock.

[18] Roberts et al. (2016a).

[19] Estimate for North Atlantic (Iceland and Faroe Islands; Reyes 1991).

[20] Abundance for Gulf of Mexico from U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment (Hayes et al. 2022).

all seasons (Reeves and Mitchell 1986; Winn et al. 1986; Kenney et al. 2001; Reeves 2001; Knowlton et al. 2002; Whitt et al. 2013).

North Atlantic right whales are found at feeding grounds off the northeastern U.S. during early spring and summer. The highest abundance in Cape Cod Bay is in February and April (Winn et al. 1986; Hamilton and Mayo 1990) and from April to June in the Great South Channel east of Cape Cod (Winn et al. 1986; Kenney et al. 1995). Throughout the remainder of summer and into fall (June–November), they are most commonly seen farther north on feeding grounds in Canadian waters, with a peak abundance during August, September, and early October (Gaskin 1987). Jeffrey's Ledge, off the coast of northern Massachusetts, New Hampshire, and Maine, could also be an important fall feeding area and summer nursery area for right whales (Weinrich et al. 2000). Morano et al. (2012) and Mussoline et al. (2012) indicated that right whales are present in the southern Gulf of Maine year-round and that they occur there over longer periods than previously thought. Some right whales, including mothers and calves, remain on the feeding grounds through the fall and winter. However, most right whales leave the feeding grounds for unknown wintering habitats and return when the cow-calf pairs return.

The majority of the right whale population is unaccounted for on the southeastern U.S. winter calving ground, and not all reproductively-active females return to the area each year (Kraus et al. 1986; Winn et al. 1986; Kenney et al. 2001). Other wintering areas have been suggested, based on sparse data or historical whaling logbooks; these include the Gulf of St. Lawrence, Newfoundland and Labrador, coastal waters of New York and between New Jersey and North Carolina, Bermuda, and Mexico (Payne and McVay 1971; Aguilar 1986; Mead 1986; Lien et al. 1989; Knowlton et al. 1992; Cole et al. 2009; Patrician et al. 2009). Surveys off North Carolina during the winter of 2001 and 2002 reported eight calves, suggesting that there could be a calving area as far north as Cape Fear, NC (Hayes et al. 2022).

During 2016, NMFS designated 102,084 km^2 of combined critical habitat for North Atlantic right whales in the Gulf of Maine and Georges Bank region (Unit 1) and off the Southeast U.S. coast (Unit 2) (NNMFS 2016b). The 2016 final ruling incorporated a southward extension of Unit 2 such that it now includes nearshore and offshore waters from Cape Fear to south of Cape Canaveral, Florida. Unit 2 has been recognized as critical for calving right whales, and mother-calf pairs are consistently observed there, particularly during January and February. The Unit 2 critical habitat may require special management considerations/protections for offshore energy development, large-scale offshore aquaculture operations, and global climate change. Unit 2 of the calving critical habitat occurs more than 50 km west of the proposed survey area in water <100 m deep.

Since January 2017, in increase in the number of stranded North Atlantic right whales has been reported, with 92 strandings of dead and injured whales to date. Most of these incidents have involved entanglement and vessel strikes (NOAA 2022a). To reduce the occurrence of fatal or serious collisions with vessels, NOAA Fisheries encourages all mariners/boaters to reduce vessel speed to ≤10 knots within areas that North Atlantic right whales are likely present and to preemptively check the following NOAA resources for the latest sighting information and active right whale safety zones, including Seasonal and Dynamic Management Areas: NOAA Right Whale Sightings Advisory System, Whale Alert App, Right Whale Slow Zones, and 'recent whale sightings near your location' (NOAA 2022b). The Mid-Atlantic U.S. (South) and the Southeast U.S. SMAs for shipping occur in water depths <100 m at least 50 km west of the proposed survey area (NOAA 2022c). The Mid-Atlantic SMA is active from 1 November to 30 April, and the Southeast SMA is active from 15 November to 15 April (NOAA 2022c), so outside of the time R/V *Langseth* would be in the area. Within active SMAs, it is mandatory that all vessels ≥65 feet must travel at ≤10 knots (NOAA 2022d). This speed restriction is also being proposed for vessels ≥35 feet and <65 feet and within dynamic speed zones or DSZs that are triggered by whale presence (NMFS 2022). R/V *Langseth* maximum cruising speed would be ~10 knots, and during seismic operations it would be no more than 5 knots.

Knowlton et al. (2002) provided an extensive and detailed analysis of survey data, satellite tag data, whale strandings, and opportunistic sightings along State waters of the mid-Atlantic migratory corridor[2], from the border of Georgia/South Carolina to south of New England, spanning the period from 1974–2002. The majority of sightings (94%) along the migration corridor were within 56 km of shore, and more than half (64%) were within 18.5 km of shore. Water depth preference was for shallow waters; 80% of all sightings were in depths <27 m, and 93% were in depths <45 m (Knowlton et al. 2002). Most sightings farther than 56 km from shore occurred at the northern end of the corridor, off New York and south of New England. North of Cape Hatteras, most sightings were reported for March–April; south of Cape Hatteras, most sightings occurred during February–April. Similarly, sighting data analyzed by Winn et al. (1986) dating back to 1965 showed that the occurrence of North Atlantic right whales in the Cape Hatteras region peaked in March; in the mid-Atlantic area, it peaked in April.

Acoustic detections have been made off the southeastern U.S. in all seasons with peak occurrence during winter (November–February); fewer detections were made the rest of the year (Hodge et al. 2015; Davis et al. 2017; Palka et al. 2021). On WhaleMap, there are ~2000 records for the waters off the southeastern U.S. between 2010 and 2022; all sightings were made between November and March, but no detections were made in the proposed survey area (Johnson et al. 2021). Similarly, Hayes et al. (2022) showed numerous sightings on the shelf off Georgia and Florida for 2015–2019, but no sightings within the proposed survey area. DoN (2008c) showed peak occurrence on the shelf off the southeastern U.S. during winter, including some along the western edge of the proposed survey area; fewer sightings were reported during fall, and nearly no sightings during spring and summer (DoN 2008c). There are no OBIS records of right whales for the proposed survey area on the Blake Plateau (OBIS 2022).

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all oceans of the World (Clapham 2018). Based on genetic data, there could be three subspecies occurring in the North Pacific, North Atlantic, and Southern

_____

[2] Multi-year datasets for the analysis were provided by the New England Aquarium (NEAQ), North Atlantic Right Whale Consortium (NARWC), Oregon State University, Coastwise Consulting Inc, Georgia Department of Natural Resources, University of North Carolina Wilmington (UNCW), Continental Shelf Associates, Cetacean and Turtle Assessment Program (CETAP), NOAA, and University of Rhode Island.

Hemisphere (Jackson et al. 2014). It is highly migratory, undertaking one of the world's longest mammalian migrations by traveling between mid- to high-latitude waters where it feeds during spring to fall and low-latitude wintering grounds over shallow banks, where it mates and calves (Winn and Reichley 1985; Bettridge et al. 2015). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Calambokidis et al. 2001; Garrigue et al. 2002, 2015; Zerbini et al. 2011).

In the western North Atlantic, the humpback whale occurs from Greenland to Venezuela (Würsig et al. 2000). Based on modeling for the western North Atlantic, higher densities of humpbacks are expected to occur north of 35°N during the summer; very low densities are expected south of 35°N (Mannocci et al. 2017; Palka et al. 2021). For most North Atlantic humpbacks, the summer feeding grounds range from the northeast coast of the U.S. to the Barents Sea (Katona and Beard 1990; Smith et al. 1999). In the winter, the majority of humpback whales migrate to wintering areas in the West Indies (Smith et al. 1999); this is known as the West Indies Distinct Population Segment (DPS) (Bettridge et al. 2015). Some individuals from the North Atlantic migrate to Cape Verde to breed (e.g., Wenzel et al. 2009); however, a small proportion of the Atlantic humpback whale population remains in high latitudes in the eastern North Atlantic during winter (e.g., Christensen et al. 1992). Feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016c). According to Hayes et al. (2020), NMFS is reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (e.g., NMFS 2016c).

In the North Atlantic, a Gulf of Maine stock of the humpback whale is recognized off the northeastern U.S. coast as a distinct feeding stock (Palsbøll et al. 2001; Vigness-Raposa et al. 2010). Whales from this stock feed during spring, summer, and fall in areas ranging from Cape Cod to Newfoundland. In summer, the greatest concentrations of humpback whales occur in the southern Gulf of Maine and east of Cape Cod (Clapham et al. 1993; Hayes et al. 2020). Off the southeastern U.S., most sightings have been reported for winter and mostly nearshore (DoN 2008c; Conley et al. 2017); there were fewer sightings in fall and spring, and no sightings during summer (DoN 2008c). Similarly, summer surveys by the Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) showed no sightings off the southeastern U.S. (Hayes et al. 2020). One satellite-tagged humpback whale was reported near the northern portion of the survey area during January 2021 (DoN 2022). Davis et al. (2020) detected humpback whales acoustically off the southeastern U.S. during winter (November–February) and spring (March–April), with few detections during summer (May–July), and no detections during fall (August–October). Kowarski et al. (2022) reported acoustic detections on the Blake Plateau during summer. There are no records in the OBIS database for the proposed survey area (OBIS 2022).

An increased mortality of humpback whales has been reported since January 2016 along the Atlantic coast from Maine through Florida, with 161 strandings to date. For some whales examined, there was evidence of human interaction such as ship strikes; however, more research is needed (NOAA 2022e).

Common Minke Whale (*Balaenoptera acutorostrata scammoni*)

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also be seen in pelagic waters during its northward migration in spring/summer and southward migration in autumn (Stewart and Leatherwood 1985). There are four recognized minke whale populations in the North Atlantic largely based on feeding grounds: Canadian east coast, west Greenland, central North Atlantic, and northeast Atlantic (Donovan 1991). Although some minke whale populations have been well studied on summer feeding grounds, information on wintering areas and migration routes is lacking (Risch et al. 2014).

Based on modeling for the western North Atlantic, higher densities are expected to occur north of 35°N; very low densities are expected south of 35°N (Mannocci et al. 2017; Palka et al. 2021). Minke whales are common off the U.S. east coast over continental shelf waters during spring to fall (CETAP 1982; DoN 2008a,b; Hayes et al. 2022). Seasonal movements in the Northwest Atlantic are apparent, with animals moving south and into offshore waters from late fall through early spring (DoN 2008a,b; Hayes et al. 2022). Risch et al. (2014) deployed acoustic detectors throughout the North Atlantic to detect minke whale occurrence. They found that minke whales migrate north of 30°N from March–April and migrate south from mid-October to early November. During spring migration, animals migrate along the continental shelf, whereas they migrate farther offshore during fall. In the southeastern U.S., minke whales were commonly detected during winter; at recorders situated at the shelf edge, detections were from November through April, with no detections during the summer (Risch et al. 2014; Kowarski et al. 2022). However, detections were made during every season in deep, offshore waters (Kowarski et al. 2022). Based on a reduced number of acoustic detections during summer off the southeastern U.S., Risch et al. (2014) suggested that most minke whales likely occur in Canadian waters during the summer. Off the coasts of Georgia and Florida, there are numerous sightings on the shelf during winter (December–April), but there were no records for summer, and very few during spring and fall (DoN 2008c). Summer surveys by NEFSC and SEFSC found no sightings off the southeastern U.S. (Hayes et al. 2022). There are no records in the OBIS database for the proposed survey area (OBIS 2022).

Since January 2017, there has been increased mortality of minke whales along the Atlantic coast from Maine through South Carolina, with 123 strandings to date. There is evidence of human interaction or diseases, but the evidence is not consistent between all individuals that has been examined; NOAA notes that more research is needed (NOAA 2022f).

Bryde's Whale (*Balaenoptera edeni/brydei*)

Bryde's whale occurs in all tropical and warm temperate waters in the Pacific, Atlantic, and Indian oceans, between 40°N and 40°S (Kato and Perrin 2018). It is one of the least known large baleen whales, and it remains uncertain how many species are represented in this complex (Kato and Perrin 2018). *B. brydei* is commonly used to refer to the larger form or "true" Bryde's whale and *B. edeni* to the smaller form; however, some authors apply the name *B. edeni* to both forms (Kato and Perrin 2018). Bryde's whale remains in warm (>16°C) water year-round, although seasonal movements have been recorded towards the Equator in winter and offshore in summer (Kato and Perrin 2018). However, Debrot (1998) noted that this species is sedentary in the tropics. Bryde's whales are known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2015). It does not undertake long north/south migrations, although local seasonal movements toward the Equator in winter and to higher latitudes in summer take place in some areas (Evans 1987; Jefferson et al. 2015). No sightings have been made in the proposed survey area, although strandings have been reported along the coasts of South Carolina, Georgia, and Florida during all season (DoN 2008c). There are no records in the OBIS database for the proposed survey area (OBIS 2022).

Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2018) but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018). On summer feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987). Habitat suitability models indicate that sei whale distribution is related to cool water with high chlorophyll levels (Palka et al. 2017; Chavez-Rosales eta al. 2019). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and

Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985). A small number of individuals have been sighted in the eastern North Atlantic between October and December, indicating that some animals may remain at higher latitudes during winter (Evans 1992). Sei whales have been seen from South Carolina south into the Gulf of Mexico and the Caribbean during winter (Rice 1998); however, the location of sei whale wintering grounds in the North Atlantic is unknown (Víkingsson et al. 2010). Based on modeling for the western North Atlantic, higher densities are expected to occur north of 35°N during the summer; very low densities are expected south of 35°N (Mannocci et al. 2017; Palka et al. 2021).

Three stocks are currently recognized in the North Atlantic: the Nova Scotia, Iceland-Denmark Strait, and Eastern North Atlantic stocks; a third stock off Labrador was proposed by Donovan (1991), but was never designated (Huijser et al. 2018). Although Huijser et al. (2018) did not a high degree of genetic divergence between the current North Atlantic stocks, they noted that multiple stocks could occur. The Nova Scotia stock has a distribution that includes continental shelf waters from the northeastern U.S. to areas south of Newfoundland (Hayes et al. 2022). The southern portion of the Nova Scotia stock's range includes the Gulf of Maine and Georges Bank during spring and summer (Hayes et al. 2022). Mitchell and Chapman (1977) suggested that this stock moves from spring feeding grounds on or near Georges Bank to the Scotian Shelf in June and July, eastward to Newfoundland and the Grand Banks in late summer, back to the Scotian Shelf in fall, and offshore and south in winter. During summer, most sei whale sightings occur in feeding grounds of the eastern Scotian Shelf or Grand Banks; however, they may occur in the proposed survey area from fall through spring, although no sightings were reported off the southeastern U.S. by DoN (2008c), and a single stranding was reported for fall (DoN 2008b).

Sei whales have been detected acoustically from southern New England to the Scotian Shelf primarily during spring and summer (Davis et al. 2020). Off North Carolina and in the deep waters of the Blake Plateau, detections have mainly been made during winter, with no detections during summer (Davis et al. 2020; Palka et al. 2021; Kowarski et al. 2022). There have been no sightings off the southeastern U.S. during summer surveys conducted by NEFSC and SEFSC (Hayes et al. 2022). There are no records in the OBIS database for the proposed survey area (OBIS 2022).

Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the World's oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2015). Fin whales most commonly occur offshore but can also be found in coastal areas (Jefferson et al. 2015). Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar and García-Vernet 2018). Some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015). The northern and southern fin whale populations likely do not interact owing to their alternate seasonal migration; the resulting genetic isolation has led to the recognition of two subspecies, *B. physalus quoyi* and *B. p. physalus* in the Southern and Northern hemispheres, respectively (Anguilar and García-Vernet 2018). The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex (Jefferson et al. 2015).

In the North Atlantic, fin whales are found in summer from Baffin Bay, Spitsbergen, and the Barents Sea, south to North Carolina and the coast of Portugal (Rice 1998). In winter, they have been sighted from Newfoundland to the Gulf of Mexico and the Caribbean, and from the Faroes and Norway south to the

Canary Islands (Rice 1998). Based on geographic differences in fin whale calls, Delarue et al. (2014) suggested that there are four distinct stocks in the Northwest Atlantic, including a central North Atlantic stock that extends south along the Mid-Atlantic Ridge. The four feeding stocks in the Northwest Atlantic currently recognized by the North Atlantic Marine Mammal Commission (NAMMCO 2022) are located off West Iceland (in the Central Atlantic), Eastern Greenland, Western Greenland, and Eastern Canada; there are an additional three stocks in the eastern Atlantic.

In the western North Atlantic, higher densities are typically found north of 35°N especially during spring and summer, with lower densities south of 35°N (Edwards et al. 2015; Mannocci et al. 2017; Hayes et al. 2022). Fin whales occur off the eastern U.S. year-round, but generally north of Cape Hatteras (Davis et al. 2020; Hayes et al. 2022). During winter, fin whales are sighted more frequently on the shelf than any other large whale (DoN 2008a,b). Based on acoustic detections using the U.S. Navy's Sound Surveillance System (SOSUS), fin whales are believed to move south during the fall and north during the spring (Clark 1995). However, not all individuals likely follow an annual migration (Hayes et al. 2022). During spring and summer, the majority of fin whales occur on feeding grounds off New England and Gulf of St. Lawrence (Hayes et al. 2022).

Very few fin whales were sighted by Conley et al. (2017) off the southeastern U.S.; all sightings were made during winter. There are two sighting records for the JAX/CHASN OPAREA which was reported during winter and several strandings have been reported during the spring and fall; no sightings were made during summer (DoN 2008c). No sightings were made during NEFSC and SEFSC summer surveys off the southeastern U.S. (Hayes et al. 2022). Fin whales have only been detected acoustically on the shelf of the southeastern U.S. during fall and winter (Davis et al. 2020; Palka et al. 2021; Kowarski et al. 2022), and in the offshore waters of the Blake Plateau from fall through spring (Palka et al. 2021; Kowarski et al. 2022); there were no detections south of Cape Hatteras during summer (Davis et al. 2020; Palka et al. 2021; Kowarski et al. 2022). There are no records in the OBIS database for the proposed survey area (OBIS 2022).

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). Blue whales are most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). Generally, blue whales are seasonal migrants between high latitudes in summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). Their summer range in the North Atlantic extends from Davis Strait, Denmark Strait, and the waters north of Svalbard and the Barents Sea, south to the Gulf of St. Lawrence and the Bay of Biscay (Rice 1998). Although the winter range is mostly unknown, some occur near Cape Verde at that time of year (Rice 1998). The acoustic detections during the SOSUS program tracked blue whales throughout most of the North Atlantic, including deep waters east of the U.S. Atlantic EEZ and subtropical waters north of the West Indies (Clark 1995).

In the western North Atlantic, higher densities are typically found north of 40°N especially during summer, with lower densities south of 40°N (DoN 2008a,b). Several sightings were reported during NEFSC and SEFSC summer surveys off the northeastern U.S. coast and in particular Canada (Hayes et al. 2020). Wenzel et al. (1988) suggested that it is unlikely that blue whales occur regularly in the shelf waters off the U.S. east coast. Similarly, Hayes et al. (2020) suggested that the blue whale is, at best, an occasional visitor in the U.S. Atlantic EEZ. However, blue whales have been detected acoustically in the

deep waters of Blake Plateau from summer through winter (Palka et al. 2021; Kowarski et al. 2022). Detections have also been made off North Carolina throughout the year, with the greatest number of detections during fall and winter (Davis et al. 2020; Palka et al. 2021). There are no records in the OBIS database for the proposed survey area (OBIS 2022).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is widely distributed, occurring from the edge of the polar pack ice to the Equator in both hemispheres, with the sexes occupying different distributions (Whitehead 2018). In general, it is distributed over large temperate and tropical areas that have high secondary productivity and steep underwater topography, such as volcanic islands (Jaquet and Whitehead 1996). Its distribution and relative abundance can vary in response to prey availability, most notably squid (Jaquet and Gendron 2002). Females generally inhabit waters >1000 m deep at latitudes <40º where sea surface temperatures are <15ºC; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds (Whitehead 2018).

In the Northwest Atlantic, the shelf edge, oceanic waters, seamounts, and canyon shelf edges are predicted habitats of sperm whales (Waring et al. 2001). Off the eastern U.S. coast, they are also known to concentrate in regions with well-developed temperature gradients, such as along the edges of the Gulf Stream and warm core rings, which may aggregate their primary prey, squid (Jaquet 1996). Based on modeling, sperm whales are expected to occur throughout the deeper offshore waters of the western North Atlantic (Mannocci et al. 2017; Palka et al. 2021).

Sperm whales appear to have a well-defined seasonal cycle in the Northwest Atlantic (CETAP 1982; Stanistreet et al. 2018). In winter, most historical records are in waters east and northeast of Cape Hatteras, with few animals north of 40ºN; in spring, they shift the center of their distribution northward to areas east of Delaware and Virginia, but they are widespread throughout the central area of the Mid-Atlantic Bight and southern tip of Georges Bank (DoN 2005; Hayes et al. 2020). During summer, they expand their spring distribution to include areas east and north of Georges Bank, the Northeast Channel, and the continental shelf south of New England (Hayes et al. 2020). By fall, sperm whales are most common south of New England on the continental shelf but also along the shelf edge in the Mid-Atlantic Bight (DoN 2005; Hayes et al. 2020).

Several sightings have been made in and near Blake Plateau, including the proposed survey area, during NEFSC and SEFSC summer surveys (Hayes et al. 2020; NEFSC and SEFSC 2021); however, the majority of sightings were further north (Hayes et al. 2020). DoN (2008c) reported sperm whale sightings in the proposed survey area from winter through summer. Conley et al. (2017) reported no sperm whales near or in the survey. However, acoustic detections have been made year-round at hydrophones deployed along the western edge of the Blake Plateau as well as in deeper water offshore (Stanistreet et al. 2018; Krowaski et al. 2022). There are 42 records in the OBIS database for the proposed survey area, which were reported throughout the year (OBIS 2022).

Pygmy and Dwarf Sperm Whales (*Kogia breviceps and K. sima*)

Pygmy and dwarf sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2018). It has been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993). *Kogia* spp. are difficult to sight at sea, because of

their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). When they are observed, both *Kogia* species are found primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015). However, McAlpine (2018) noted that dwarf sperm whales may be more pelagic than pygmy sperm whales. Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas.

In the western North Atlantic, pygmy sperm whales are known to occur from Nova Scotia to Cuba, and dwarf sperm whales are distributed from Virginia to the Caribbean (Würsig et al. 2000; Würsig 2017). Based on modeling for the western North Atlantic, higher densities of *Kogia* sp. are expected to occur south of 40°N compared to northern regions (Maannocci et al. 2017; Palka et al. 2021). Hayes et al. (2020) reported numerous sightings of *Kogia* sp. off the U.S. east coast during NEFSC and SEFSC surveys, including within the proposed survey area. A dwarf sperm whale was also seen just north of the survey area during summer 2021 (NEFSC and SEFSC 2021). DoN (2008c) reported several *Kogia* sp. sightings within the proposed survey area during winter and summer, but strandings were reported throughout the year. Between 2013 and 2017, there were 46 dwarf sperm whale strandings recorded from Massachusetts to Florida, 20 of which were for Florida, 5 for Georgia, and 4 for South Carolina; there were 120 strandings of pygmy sperm whales, 46 of which were reported for Florida, 14 for Georgia, and 18 for South Carolina (Hayes et al. 2020). Acoustic detections of *Kogia* sp. were made within and near the survey area during 2016 (Palka et al. 2021), and possible from 2017–2020 (Kowarski et al. 2022). There are three records of Kogia sp. in the OBIS database within the proposed survey area (OBIS 2022).

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is probably the most widespread and common of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989; Baird 2018a). Cuvier's beaked whale is found in deep water in the open ocean and over and near the continental slope (Gannier and Epinat 2008; Baird 2018a). It is rarely found close to mainland shores, except in submarine canyons or in areas where the continental shelf is narrow and coastal waters are deep (Carwardine 1995). Its inconspicuous blows, deep-diving behavior, short surfacing intervals, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006; Shearer et al. 2019).

In the western North Atlantic, these whales typically occur from Massachusetts to Florida, the West Indies, and the Gulf of Mexico (Würsig et al. 2000), although sightings have also been made to the north (Hayes et al. 2020). Most sightings in the Northwest Atlantic occur in late spring or summer, particularly along the continental shelf edge in the mid-Atlantic region (CETAP 1982; Waring et al. 2001), with likely lower densities south of Virginia, based on modeling (Palka et al. 2021).

Shearer et al. (2019) and Foley et al. (2021) tagged Cuvier's beaked whales off Cape Hatteras. The whales kept to the outer continental shelf and slope waters off Cape Hatteras, and some whales were recorded diving in the deeper sections of proposed survey area. The whales performed frequent dives and median surface intervals where only 2.2 min. The time spent at the surface was not prolonged even when performing deep extended dives, often to depths >1500 m. Between 2014 and 2015, Cuvier's beaked whales were detected acoustically around Onslow Bay, but no detections were made off Jacksonville (Stanistreet et al. 2017). They have also been detected acoustically and visually near the survey area during winter, spring, and summer (Palka et al. 2021; Kowarski et al. 2022). Sightings have been reported for the proposed survey area for winter, spring, and summer, with no sightings during fall; strandings were reported along the coast during all seasons (DoN 2008c). Satellite-tagged whales were reported within the northern

part of the survey area during studies in 2021 (DoN 2022). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

Gervais' Beaked Whale (*Mesoplodon europaeus*)

Although Gervais' beaked whale is generally considered to be a North Atlantic species, it likely occurs in deep waters of the temperate and tropical Atlantic Ocean in both the northern and southern hemispheres (Jefferson et al. 2015). Its distribution is primarily known from stranding records. Strandings may be associated with calving, which takes place in shallow water (Würsig et al. 2000). Gervais' beaked whale usually inhabits deep waters (Davis et al. 1998). It is more frequent in the western than the eastern Atlantic (Mead 1989). Off the U.S. east coast, it occurs from Cape Cod Bay, Massachusetts (Moore et al. 2004) to Florida, with a few records in the Gulf of Mexico (Mead 1989). Sightings of beaked whales have been reported for the proposed survey area for winter, spring, and summer, with no sightings for the fall; strandings were reported along the coast of the southeastern U.S. during all seasons (DoN 2008c). One sighting was reported off North Carolina during spring (DoN 2008a,b). Gervais' beaked whales were detected acoustically between 2011 and 2013 around Onslow Bay during all monitored months; they were also occasionally detected around Jacksonville in 2015 (Stanistreet et al. 2017). Acoustic detections within the survey area were reported by Palka et al. (2021), and potential detections were reported by Kowarski et al. (2022). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans; it has the widest distribution throughout the world of any *Mesoplodon* species (Pitman 2018). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). It is rarely sighted, and most of the knowledge on the distribution of this species is derived from stranding data. There is no evidence that Blainville's beaked whales undergo seasonal migrations, although movements into higher latitudes are likely related to warm currents, such as the Gulf Stream in the North Atlantic. Like other beaked whales, Blainville's beaked whale is generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). However, it may also occur in coastal areas, particularly where deep-water gullies come close to shore. In the western North Atlantic, it is found from Nova Scotia to Florida, the Bahamas, and the Gulf of Mexico (Würsig et al. 2000). One sighting was made just north of the proposed survey area during summer 2021 (NEFSC and SEFSC 2021). Blainville's beaked whales were detected acoustically within the proposed survey area during 2016 (Palka et al. 2021). There are numerous stranding records along the east coast of the U.S. (Macleod et al. 2006; DoN 2008a,b). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

True's Beaked Whale (*Mesoplodon mirus*)

True's beaked whale is mainly oceanic and occurs in warm temperate waters of the North Atlantic and southern Indian oceans (Pitman 2018). In the western North Atlantic, strandings have been recorded from Nova Scotia (~46°N) to Florida (~27°N; MacLeod et al. 2005). Sightings of unidentified beaked whales have been reported for the proposed survey area for winter, spring and summer, with no sightings for the fall; strandings along the coast close to the survey area from all seasons (DoN 2008c). Two sightings of True's beaked whales have been reported off North Carolina during spring (DoN 208a,b), and there are three stranding records for North Carolina (DoN 2008a,b). Potential acoustic detections for the survey area were reported by Kowarski et al. (2022). Macleod et al. (2006) reported numerous other stranding records for the east coast of the U.S. There are no records for the proposed survey area in the OBIS database (OBIS 2022).

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Miyazaki and Perrin 1994). It generally occurs in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2015). In the western Atlantic, this species occurs between the southeastern U.S. and southern Brazil (Jefferson et al. 2015). During NEFSC and SEFSC summer surveys, four sightings were made off North Carolina (Hayes et al. 2019). DoN (2008c) reported four sightings off the southeastern U.S. and several strandings; it is considered rare in the region, although it could potentially occur there any time of the year. There is one record for June for the proposed survey area in the OBIS database (OBIS 2022).

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin occurs in tropical, subtropical, and temperate waters throughout the world (Wells and Scott 2018). Although it is more commonly found in coastal and shelf waters, it can also occur in deep offshore waters (Jefferson et al. 2015). In the Northwest Atlantic, these dolphins occur from Nova Scotia to Florida, the Gulf of Mexico, and the Caribbean and southward to Brazil (Würsig et al. 2000). There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal waters and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Walker et al. 1999). The nearshore dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m (Davis et al. 1998, 2002). Klatsky (2004) noted that offshore dolphins show a preference for water <2186 m deep. As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Coastal common bottlenose dolphins exhibit a range of movement patterns including seasonal migration, year-round residency, and a combination of long-range movements and repeated local residency (Wells and Scott 2018).

There are regional and seasonal differences in the distribution of the offshore and coastal forms of bottlenose dolphins off the U.S. east coast. Evidence of year-round or seasonal residents and migratory groups exist for the coastal form of bottlenose dolphins, with the northern migratory coastal stock occurring from north of Cape Hatteras to New Jersey, but only during summer and in waters <25 m deep (Hayes et al. 2020). The offshore form appears to be most abundant along the shelf break and is differentiated from the coastal form by occurring in waters >34 m deep and >34 km from shore (Torres et al. 2003). Bottlenose dolphin records in the Northwest Atlantic suggest that they can occur year-round from the continental shelf to deeper waters over the abyssal plain, from the Scotian Shelf to North Carolina (DoN 2005, 2008a,b). However, based on modeling, densities are expected to be relatively low throughout the deep offshore waters of the western North Atlantic (Mannocci et al. 2017; Palka et al. 2021). Numerous sightings have been made off the southeastern U.S. during all seasons, but sightings were especially common during winter (DoN 2008c; Conley et al. 2017). Sightings have also been made within the proposed survey area, along the western edge of the Blake Plateau, throughout the year, with most sightings reported there during spring and summer (DoN 2008c; Conley et al. 2017; Hayes et al. 2020). There are 146 records within the proposed survey area in the OBIS database throughout the year, most of which were made during summer (OBIS 2022).

Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). It is one of the most abundant cetaceans and is found in coastal, shelf, slope, and deep waters (Perrin 2018a). In the Northwest Atlantic, it occurs from North Carolina to the West Indies and south to the Equator (Würsig et al. 2000). However, modeling shows that sighting rates are expected to be very low in most of the region, except in deep water off the central coast

of Florida (DoN 2008c). Nonetheless, several sightings have been reported within and near the survey area, including during the summer (DoN 2008c; Hayes et al. 2020). There are 15 records in the OBIS database for the survey area, all of which were made during summer (OBIS 2022).

Atlantic Spotted Dolphin (*Stenella frontalis*)

The Atlantic spotted dolphin is one of the most abundant cetaceans and is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). In the North Atlantic, it occurs from Brazil to New England and to the coast of Africa (Jefferson et al. 2015). There are two forms of Atlantic spotted dolphin—a large, heavily spotted coastal form that is usually found in shelf waters, and a smaller and less-spotted offshore form that occurs in pelagic offshore waters and around oceanic islands (Jefferson et al. 2015). In the western Atlantic, the distribution extends from southern New England, south to the Gulf of Mexico, and the Caribbean to Venezuela (Leatherwood et al. 1976; Perrin et al. 1994a; Rice 1998). Based on modeling, Atlantic spotted dolphins occur at low densities in deep waters off the southeastern U.S. (DoN 2008c; Mannocci et al. 2017), but sightings are numerous on the shelf and along the shelf edge, with some sightings reported within the proposed survey area during summer (Hayes et al. 2020). There are 46 records within the proposed survey area in the OBIS database throughout the year, but most were made during summer (OBIS 2022).

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, including oceanic tropical and sub-tropical waters between 40ºN and 40ºS (Jefferson et al. 2015). It is generally considered a pelagic species (Perrin 2018b) but can also be found in coastal waters and around oceanic islands (Rice 1998). The distribution of spinner dolphins in the Atlantic is poorly known, but in the western North Atlantic, it occurs from South Carolina to Florida, the Caribbean, Gulf of Mexico, and southward to Venezuela (Würsig et al. 2000). Sightings off the northeast U.S. coast have occurred exclusively in offshore waters >2000 m (Hayes et al. 2020). A few sightings have also been made in deep waters of the Blake Plateau survey area during summer, spring, and winter (DoN 2008c). There are no OBIS records for the proposed survey area (OBIS 2022).

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994b; Jefferson et al. 2015). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; however, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). In the Northwest Atlantic, the striped dolphin occurs from Nova Scotia to the Gulf of Mexico and south to Brazil (Würsig et al. 2000). Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected in offshore waters north of ~35°N, with the lowest densities south of ~32°N. Similarly, DoN (2008b) showed the highest densities north of ~35°N during April–July. Off the northeastern U.S. coast, striped dolphins occur along the shelf edge and over the continental slope from Cape Hatteras to the southern edge of Georges Bank (Hayes et al. 2020). In all seasons, striped dolphin sightings have been centered along the 1000-m depth contour (CETAP 1982); sightings have been associated with the north edge of the Gulf Stream and warm core rings (see Hayes et al. 2020). One sighting has been reported within the proposed survey area for winter; otherwise, there are very few records off the southeastern U.S. (DoN 2008c). There are no OBIS records for the proposed survey area (OBIS 2022).

Clymene Dolphin (*Stenella clymene*)

The Clymene dolphin only occurs in tropical and subtropical waters of the Atlantic Ocean (Jefferson et al. 2015). It inhabits areas where water depths are 700–4500 m or deeper (Fertl et al. 2003).

However, there are a few records in water as shallow as 44 m (Fertl et al. 2003). In the western Atlantic, it occurs from New Jersey to Florida, the Caribbean Sea, the Gulf of Mexico, and south to Venezuela and Brazil (Würsig et al. 2000; Fertl et al. 2003). Sightings off the U.S. east coast are rare, with only 10 reported since 1995 (Hayes et al. 2020). There is one bycatch record for the proposed survey area during winter, and a sighting on the shelf waters off Georgia during summer (DoN 2008c). There are no OBIS records for the proposed survey area (OBIS 2022).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is distributed worldwide in mid-temperate and tropical oceans (Kruse et al. 1999). although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it occurs from coastal to deep water (~200–1000 m depth), it shows a strong preference for mid-temperate waters of upper continental slopes and steep shelf-edge areas (Hartman 2018). In the western Atlantic, this species is distributed from Newfoundland to Brazil (Kruse et al. 1999).

Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected to occur north of 35°N. Risso's dolphins occurs along the edge of the Mid-Atlantic shelf of the U.S. year-round (Payne et al. 1984). Off the northeast coast, Risso's dolphins are distributed along the continental shelf edge from Cape Hatteras to Georges Bank during spring, summer, and autumn (CETAP 1982; Payne et al. 1984), but they range to the Mid-Atlantic Bight and into oceanic waters during winter (Payne et al. 1984). Risso's dolphin sightings off the U.S. east coast suggests that they could occur year-round from the Scotian Shelf to the coast of the southeastern U.S. in waters extending from the continental shelf to the continental rise (Hayes et al. 2022). Several sightings have been reported within the proposed survey area during all seasons (DoN 2008c; Jefferson et al. 2014; Conley et al. 2017; NEFSC and SEFSC 2021; Hayes et al. 2022). In the OBIS database, there are two records for May and eight records for July in the proposed survey area (OBIS 2022).

Common Dolphin (*Delphinus delphis delphis*)

The common dolphin is distributed in tropical to cool temperate waters of the Atlantic and the Pacific oceans from 60ºN to ~50ºS (Jefferson et al. 2015). It is common in coastal waters 200–300 m deep (Evans 1994), but it can also occur thousands of kilometers offshore; the pelagic range in the North Atlantic extends south to ~35ºN (Jefferson et al. 2015). It appears to have a preference for areas with upwelling and steep sea-floor relief (Doksæter et al. 2008; Jefferson et al. 2015).

Off the U.S. east coast, the common dolphin occurs from Cape Hatteras to Georges Bank during mid-January–May, moves onto Georges Bank and the Scotian Shelf during mid-summer and fall, and has been observed in large aggregations on Georges Bank in fall (CETAP 1982; Selzer and Payne 1988; Payne et al. 1994; Hayes et al. 2022). Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities occur in offshore areas north of ~35°N; very low densities are expected south of 35°N. It is less commonly sighted south of Cape Hatteras, although there have been several sightings as far south as 32°N (Jefferson et al. 2009). Sightings have been made within the proposed survey area during all seasons, with most sightings in winter (DoN 2008c; Conley et al. 2017). Hayes et al. (2022) did not report any sightings south of North Carolina during NEFSC and SEFSC summer surveys. In the OBIS database, there is one record of a common dolphin in the proposed survey area for November (OBIS 2021).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical oceanic species distributed between 30°N and 30°S that generally inhabits deep oceanic water (Dolar 2018). The distribution of this species in the Atlantic is poorly

understood, but it is known to occur from the Gulf of Mexico to Uruguay in the western Atlantic (Rice 1998). Sightings of this species in the northwestern Atlantic are rare; there has been a single sighting during NMFS surveys which was recorded off North Carolina (Hayes et al. 2020). There are no OBIS records for the proposed survey area (OBIS 2022).

Short-finned Pilot Whale (*Globicephala macrorhynchus*) and Long-finned Pilot Whale (*G. melas*)

There are two species of pilot whales. The long-finned pilot whale (*G. melas*) is distributed antitropically, whereas the short-finned pilot whale (*G. macrorhynchus*) is found in tropical, subtropical, and warm temperate waters (Olson 2018). The ranges of the two species overlap in the shelf/shelf-edge and slope waters of the northeastern U.S. between New Jersey and Cape Hatteras, with long-finned pilot whales mainly occurring to the north (Bernard and Reilly 1999). In the Northwest Atlantic, pilot whales often occupy areas of high relief or submerged banks and associated with the Gulf Stream edge or thermal fronts along the continental shelf edge (Waring et al. 1992). Pilot whales are generally nomadic and occur on the shelf break, over the slope, and in areas with prominent topographic features (Olson 2018).

In the western North Atlantic, short-finned pilot whales occur from Virginia to northern South America, including the Caribbean and Gulf of Mexico (Würsig et al. 2000). Long-finned pilot whales are typically distributed from North Carolina northwards to Iceland (Hayes et al. 2022). Thus, most pilot whale sightings south of Cape Hatteras are likely to be short-finned pilot whale (see Garrison and Rosel 2017 *in* Hayes et al. 2022). Based on density modeling by Mannocci et al. (2017), densities of pilot whales are expected to be low in the proposed survey area. Sightings of pilot whales have been made in the proposed survey area throughout the year, with the fewest sightings reported for fall (DoN 2008c; Hayes et al. 2022). There are nine records of pilot whales for the proposed survey area in the OBIS database, most of which were reported during summer (OBIS 2022).

Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales tend to be more common in nearshore areas and at higher latitudes (Jefferson et al. 2015). The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975). In the Northwest Atlantic, killer whales occur from the polar pack ice to Florida and the Gulf of Mexico (Würsig et al. 2000). Based on historical sightings and whaling records, killer whales apparently were most often found along the shelf break and offshore in the Northwest Atlantic (Katona et al. 1988). They are considered uncommon or rare in waters of the U.S. Atlantic EEZ (Katona et al. 1988). One sighting has been made in the proposed survey area during spring, and one sighting has been reported on the shelf off Florida during winter; several strandings were also reported along the coast during winter (DoN 2008c). During surveys by NEFSC and SEFSC (2021), a group of killer whlaes was seen just north of the proposed survey area during summer 2021. There are no records for the proposed survey area in the OBIS database (OBIS 2022).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but rare to uncommon throughout its range (Baird 2018b). It generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow water (Jefferson et al. 2015; Baird 2018b). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018b). In the Northwest Atlantic, it occurs from Maryland to the Gulf of Mexico and the Caribbean (Würsig et al. 2000).

Very few false killer whales have been sighted off the southeastern U.S., but several have been made within the proposed survey area during winter and spring (DoN 2008c; Hayes et al. 2022). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale has a worldwide distribution in tropical waters (Baird 2018c). It is found in nearshore areas where the water is deep and in offshore waters (Jefferson et al. 2015). It is known to inhabit the warm waters of the Indian, Pacific, and Atlantic oceans (Jefferson et al. 2015). In the Northwest Atlantic, it occurs from the Carolinas to Texas and the West Indies, and the Gulf of Mexico (Würsig et al. 2000). There is no abundance estimate for the pygmy killer whale off the U.S. east coast because it is rarely sighted during surveys (Hayes et al. 2022). Nonetheless, a few sightings have been reported for the proposed survey area during winter and spring, as well as strandings (DoN 2008c; Hayes et al. 2022). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is an oceanic species found worldwide in tropical and subtropical waters from ~40°N to 35°S (Jefferson et al. 2015). Occasional occurrences in temperate waters are extralimital, likely associated with warm currents (Perryman et al. 1994). It occurs most often in deep offshore waters and occasionally in nearshore areas where deep oceanic waters occur near the coast (Perryman and Danil 2018). In the western Atlantic, its typical range extends from the Gulf of Mexico to southern Brazil (Rice 1998); sightings are rare north of the Gulf of Mexico (Hayes et al. 2020). There are stranding records from Florida to South Carolina, as well as Virginia and New Jersey (Hayes et al. 2020). Off the east coast of the U.S., two sightings have been made off Cape Hatteras in waters >2500 m deep (Hayes et al. 2020). One stranding has been reported along the southeastern coast of the U.S. during winter, but no sightings (DoN 2008c). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits cool temperate to subarctic waters of the Northern Hemisphere (Jefferson et al. 2015). Most animals are found over the continental shelf, but some are also encountered over deep water (Westgate et al. 1998). There are likely four populations in the western North Atlantic: Gulf of Maine/Bay of Fundy, Gulf of St. Lawrence, Newfoundland, and Greenland (Gaskin 1984, 1992). Individuals found off the eastern U.S. coast likely would be almost exclusively from the Gulf of Maine/Bay of Fundy stock. Mannocci et al. (2017) reported relatively high densities in offshore waters north of ~35°N; very low densities are expected to occur south of ~35°N.

Harbor porpoises concentrate in the northern Gulf of Maine and southern Bay of Fundy during July–September, with a few sightings ranging as far south as Virginia and North Carolina (Hayes et al. 2020). During October–December and April–June, harbor porpoises mainly occur from New Jersey to Maine, although there are lower densities at the northern and southern extremes (DoN 2005; Hayes et al. 2020). During January–March, harbor porpoises concentrate farther south, from New Jersey to North Carolina, with lower densities occurring from New York to New Brunswick (DoN 2005, 2008b; Hayes et al. 2002). One sighting has been reported for nearshore waters of North Carolina and one for South Carolina, in addition to strandings along the coast of Florida during winter (DoN 2008c). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

> The type of incidental taking authorization that is being requested (i.e., takes by harassment only, takes by harassment, injury and/or death), and the method of incidental taking.

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic surveys in the Northwest Atlantic Ocean in summer/fall 2023. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the surveys, by echosounders, and by general vessel operations. "Takes" by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of "Level B Harassment" for those species managed by NMFS. Although NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes, no take by serious injury or lethal takes would be expected, given the nature of the planned operations, the mitigation measures that are planned (see § XI, MITIGATION MEASURES), in addition to the general avoidance by marine mammals of loud sound.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

> By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [section V], and the number of times such takings by each type of taking are likely to occur.

The material for § VI and § VII has been combined and presented in reverse order to minimize duplication between sections.

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

> The anticipated impact of the activity upon the species or stock of marine mammal.

The material for § VI and § VII has been combined and presented in reverse order to minimize duplication between sections.

First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the Northwest Atlantic Ocean. As called for in § VI, this section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned surveys, as well Level A "takes".

Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent (Hastie et al. 2019; Martin et al. 2020), and may become less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016; Houser 2021). Although the possibility cannot be entirely excluded, it would be unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals were encountered during an active survey, some behavioral disturbance could result, but this would be localized and short-term.

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers (e.g., Nieukirk et al. 2012). Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen and toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite variable.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Situations with prolonged strong reverberation are infrequent. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Gedamke 2011; Guerra et al. 2011, 2016; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the

Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012), Blackwell et al. (2013), and Dunlop (2018) also noted the potential for masking effects from seismic surveys on large whales.

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015; Thode et al. 2020; Fernandez-Betelu et al. 2021). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

Disturbance Reactions

Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Based on NMFS (2001, p. 9293), National Research Council (NRC 2005), and Southall et al. (2007), we believe that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean, 'in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations'.

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012, 2018). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Kastelein et al. (2019a) surmized that if disturbance by noise would displace harbor porpoises from a feeding area or otherwise impair foraging ability for a short period of time (e.g., 1 day), they would be able to compensate by increasing their food consumption following the disturbance. Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level; this has proven to be complicated by numerous factors including variability in responses between individuals (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017; Dunlop et al. 2021; Gallagher et al. 2021; McHuron et al. 2021; Mortensen et al. 2021).

Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a

particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals could be disturbed to some biologically important degree by a seismic program are based primarily on behavioral observations of a few species; detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species, there are no data on responses to marine seismic surveys; many data gaps remain where exposure criteria are concerned (Southall 2021).

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995). Kavanagh et al. (2019) analyzed more than 8000 hr of cetacean survey data in the northeastern Atlantic Ocean to determine the effects of the seismic surveys on cetaceans. They found that sighting rates of baleen whales were significantly lower during seismic surveys compared with control surveys.

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. Off Western Australia, avoidance reactions began at 5–8 km from the array, and those reactions kept most pods ~3–4 km from the operating seismic boat; there was localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs (McCauley et al. 1998, 2000). However, some individual humpback whales, especially males, approached within distances of 100–400 m.

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b, 2020). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in^3) within 3 km and received levels of at least 140 dB re 1 μPa$^2 \cdot$s (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks deviated from their southbound migration when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1 μPa$^2 \cdot$s (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000). Dunlop et al. (2020) found that humpback whales reduce their social interactions at greater distances and lower received levels than regulated by current mitigation practices.

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015). On their summer feeding grounds in southeast Alaska, there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis (Malme et al. 1985). It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years indicated that there was no observable direct correlation between strandings and seismic surveys (IWC 2007).

Matthews and Parks (2021) summarized the known responses of *right whales* to sounds; however, there are no data on reactions of right whales to seismic surveys. However, Rolland et al. (2012) suggested that ship noise causes increased stress in right whales; they showed that baseline levels of stress-related faecal hormone metabolites decreased in North Atlantic right whales with a 6-dB decrease in underwater noise from vessels. Wright et al. (2011), Atkinson et al. (2015), Houser et al. (2016), and Lyamin et al. (2016) also reported that sound could be a potential source of stress for marine mammals.

Bowhead whales show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source (Miller et al. 1999; Richardson et al. 1999). Subtle but statistically significant changes in surfacing–respiration–dive cycles were shown by traveling and socializing bowheads exposed to airgun sounds in the Beaufort Sea, including shorter surfacings, shorter dives, and decreased number of blows per surfacing (Robertson et al. 2013). More recent research on bowhead whales corroborates earlier evidence that, during the summer feeding season, bowheads are less responsive to seismic sources (e.g., Miller et al. 2005; Robertson et al. 2013).

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 μPa; at SPLs <108 dB re 1 μPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received $CSEL_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu Pa^2 \cdot s$, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 $\mu Pa^2 \cdot s$, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 $\mu Pa^2 \cdot s$. Thode et al. (2020) reported similar changes in bowhead whale vocalizations when data were analyzed for the period 2008–2014. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

A multivariate analysis of factors affecting the distribution of calling bowhead whales during their fall migration in 2009 noted that the southern edge of the distribution of calling whales was significantly closer to shore with increasing levels of airgun sound from a seismic survey a few hundred kilometers to the east of the study area (i.e., behind the westward-migrating whales; McDonald et al. 2010, 2011). It was not known whether this statistical effect represented a stronger tendency for quieting of the whales farther offshore in deeper water upon exposure to airgun sound, or an actual inshore displacement of whales.

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, despite rigorous monitoring and mitigation measures during multiple seismic surveys in 2015 (Aerts et al. 2022; Rutenko et al. 2022), data collected during a program with multiple seismic surveys in 2015 showed short-term and long-term displacement of animals from the feeding area, at least short-term behavioral changes, and responses to lower sound levels than expected (Gailey et al. 2017, 2022a,b; Sychenko et al. 2017). However, stochastic dynamic programming (SDP) model predictions showed similar reproductive success and habitat use by gray whales with or without exposure to airgun sounds during the 2015 program (Schwarz et al. 2022).

Gray whales in B.C., Canada, exposed to seismic survey sound levels up to ~170 dB re 1 μPa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994–2010 showed that the detection rate for minke whales was significantly higher when airguns were not operating; however, during surveys with small arrays, the detection rates for minke whales were similar during seismic and non-seismic periods (Stone 2015). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach or CPA of ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km; Stone 2015). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity (Stone 2015). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

During seismic surveys in the northwest Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods. Baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during

single airgun operations, ramp up, and all other airgun operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, fin whales were seen at significantly farther distances during ramp up than during periods without airgun operations; there was also a trend for fin whales to be sighted farther from the vessel during other airgun operations, but the difference was not significant (Moulton and Holst 2010). Minke whales were seen significantly farther from the vessel during periods with than without seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when airguns were not operating (Moulton and Holst 2010). However, Matos (2015) reported no change in sighting rates of minke whales in Vestfjorden, Norway, during ongoing seismic surveys outside of the fjord. Vilela et al. (2016) cautioned that environmental conditions should be taken into account when comparing sighting rates during seismic surveys, as spatial modeling showed that differences in sighting rates of rorquals (fin and minke whales) during seismic periods and non-seismic periods during a survey in the Gulf of Cadiz could be explained by environmental variables.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. The western Pacific gray whale population continued to feed off Sakhalin Island every summer, despite seismic surveys in the region. In addition, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years. Pirotta et al. (2018) used a dynamic state model of behavior and physiology to assess the consequences of disturbance (e.g., seismic surveys) on whales (in this case, blue whales). They found that the impact of localized, acute disturbance (e.g., seismic surveys) depended on the whale's behavioral response, with whales that remained in the affected area having a greater risk of reduced reproductive success than whales that avoided the disturbance. Chronic, but weaker disturbance (e.g., vessel traffic) appeared to have less effect on reproductive success.

Toothed Whales.—Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Observations from seismic vessels using large arrays off the U.K. from 1994–2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and short-beaked common dolphins were similar during seismic (small or large array) vs. non-seismic operations (Stone 2015). CPA distances for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins were significantly farther (>0.5 km) from large airgun arrays during periods of airgun activity compared with periods of inactivity, with significantly more animals traveling away from the vessel during airgun operation (Stone 2015). Observers' records suggested that fewer cetaceans were feeding and fewer delphinids were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating (Stone 2015).

During seismic surveys in the northwest Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was significantly farther (by ~200 m) during seismic operations compared with periods when the seismic source was not active; however, there was no significant difference between sighting rates (Moulton and Holst 2010). The same results were evident when only long-finned pilot whales were considered.

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland, (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment. However, Heide-Jørgensen et al. (2021) did report avoidance reaction at distances >11 km from an active seismic vessel, as well as an increase in travel speed and changes in direction at distances up to 24 km from a seismic source. No long-term effects were reported. Tervo et al. (2021) reported that narwhal buzzing rates decreased in response to concurrent ship noise and airgun pulses (being 50% at 12 km from ship), and that the whales discontinued to forage at 7–8 km from the vessel, and that exposure effects could still be detected >40 km from the vessel.

The beluga, however, is a species that (at least at times) shows long-distance (10s of km) avoidance of seismic vessels (e.g., Miller et al. 2005). Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys, but the animals tolerated high received levels of sound before exhibiting aversive behaviors (e.g., Finneran et al. 2000, 2002, 2005). Schlundt et al. (2016) also reported that bottlenose dolphins exposed to multiple airgun pulses exhibited some anticipatory behavior.

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010). Winsor et al. (2017) outfitted sperm whales in the Gulf of Mexico with satellite tags to examine their spatial distribution in relation to seismic surveys. They found no evidence of avoidance or changes in orientation by sperm whales to active seismic vessels. Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Foraging behavior can also be altered upon exposure to airgun sound (e.g., Miller et al. 2009), which according to Farmer et al. (2017), could have significant consequences on individual fitness. Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity and periods with airgun operations (Sidorovskaia et al. 2014).

There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998) and/or change their behavior in response to sounds from vessels (e.g., Pirotta et al. 2012). Thus, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel. Observations from seismic vessels off the U.K. from 1994–2010 indicated that detection rates of beaked whales were significantly higher ($p<0.05$) when airguns were not operating vs. when a large array was in operation, although sample sizes were small (Stone 2015). Some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (e.g., Simard et al. 2005).

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. The apparent tendency for greater responsiveness in the harbor

porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB µPa$^2 \cdot$ s). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 µPa$_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in^3 airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB µPa$^2 \cdot$ s. One porpoise moved away from the sound source but returned to natural movement patters within 8 h, and two porpoises had shorter and shallower dives but returned to natural behaviors within 24 h.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is developing new guidance for predicting behavioral effects (Scholik-Schlomer 2015). As behavioral responses are not consistently associated with received levels, some authors have made recommendations on different approaches to assess behavioral reactions (e.g., Gomez et al. 2016; Harris et al. 2017; Tyack and Thomas 2019).

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for gray seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of gray or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in^3 airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed by Southall et al. 2007; Finneran 2015). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Ketten 2012; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b, 2020a,b,c,d,e,f, 2021a,b, 2022; Supin et al. 2016).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 µPa2 · s (Finneran et al. 2015; Schlundt et al. 2016). However, auditory evoked potential measurements were more variable; one dolphin showed a small (9 dB) threshold shift at 8 kHz (Finneran et al. 2015; Schlundt et al. 2016).

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 µPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a SEL_{cum} of 188 and 191 $µPa^2 \cdot s$, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

Popov et al. (2016) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015, 2016; Nachtigall et al. 2018; Finneran 2020; Kastelein et al. 2020g).

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga, and that for pinnipeds has mostly been obtained from California sea lions and elephant seals (see § 3.6.4.3, § 3.7.4.3, § 3.8.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans or pinnipeds (*cf.* Southall et al. 2007). Some cetaceans or pinnipeds could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin or California sea lion and elephant seal, respectively.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Based on studies that exposed harbor porpoises to one-sixth-octave noise bands ranging from 1 to 88.4 kHz, Kastelein et al. (2019c,d, 2020d,e,f) noted that susceptibility to TTS increases with an increase in sound less than 6.5 kHz but declines with an increase in frequency above 6.5 kHz. At a noise band centered at 0.5 kHz (near the lower range of hearing), the SEL required to elicit a 6 dB TTS is higher than that required at frequencies of 1 to 88.4 kHz (Kastelein et al. 2021a). Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 µPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB. For the harbor porpoise, Tougaard et al. (2015) suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). Simulation modeling to assess the risk of sound exposure to marine mammals (gray seal and harbor porpoise) showed that SEL is most strongly influenced by the weighting function (Donovan et al. 2017).

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001; Kastelein et al. 2013a). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. A maximum TTS >45 dB was elicited from a harbor seal exposed to 32 kHz at 191 dB SEL (Kastelein et al. 2020c). For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Harbor seals appear to be equally susceptible to incurring TTS when exposed to sounds from 2.5 to 40 kHz (Kastelein et al. 2020a,b), but at frequencies of 2 kHz or lower, a higher SEL was required to elicit the same TTS (Kastelein et al. 2020c). Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Similarly, no TTS was measured when a bearded seal was exposed to a single airgun pulse with an unweighted SEL of 185 dB and an SPL of 207 dB; however, TTS was elicited at 400 Hz when exposed to four to ten consecutive pulses with a cumulative unweighted SEL of 191–195 dB, and a weighted SEL of 167–171 dB (Sills et al. 2020). Kastelein et al. (2021b) found that susceptibility of TTS of California sea

lions exposed to one-sixth-octave noise bands centered at 2, 4, and 8 kHz is similar to that of harbor seals, but at 16 kHz, California sea lion haring is less susceptible to TTS than harbor seals (Kastelein et al. 2022).

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor seals or harbor porpoises when using single airguns in shallow water. SPLs for impulsive sounds are generally lower just below the water surface, and seals swimming near the surface are likely to be exposed to lower sound levels than when swimming at depth (Kastelein et al. 2018). However, the underwater sound hearing sensitivity for seals is the same near the surface and at depth (Kastelein et al. 2018). It is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. However, Gedamke et al. (2011), based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, suggested that some baleen whales whose CPA to a seismic vessel is 1 km or more could experience TTS.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372ff; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

Noise exposure criteria for marine mammals that were released by NMFS (2016a, 2018) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). Tougaard et al. (2022) indicate that there is empirical evidence to support the thresholds for very-high frequency cetaceans and pinnipeds in water, but caution that above 10 kHz for porpoise and outside of 3–16 kHz for seals, there are differences between the TTS thresholds and empirical data.

Nowacek et al. (2013a) concluded that current scientific data indicate that seismic airguns have a low probability of directly harming marine life, except at close range. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. Also, many marine mammals show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves would reduce or (most likely) avoid any possibility of hearing impairment. Aarts et al. (2016) noted that an understanding of animal movement is necessary in order to estimate the impact of anthropogenic sound on cetaceans.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship

between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. Williams et al. (2022) reported an increase in energetic cost of diving by narwhals that were exposed to airgun noise, as they showed marked cardiovascular and respiratory reactions.

It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale strandings along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2106). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 72 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2022g). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (https://www.energy.senate.gov/public/index.cfm/2016/5/hearing-is-examine-the-bureau-of-ocean-energy-management-s-2017-2022-ocs-oil-and-gas-leasing-program), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico. Similarly, the large whale UME Core Team found that seismic testing did not contribute to the 2015 UME involving humpbacks and fin whales from Alaska to B.C. (Savage 2017).

Non-auditory effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Possible Effects of Other Acoustic Sources

The Kongsberg EM 122 MBES and Knudsen Chirp 3260 SBP would be operated from the source vessel during the proposed surveys. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs and SBPs on marine mammals appears in § 3.6.4.3, § 3.7.4.3, and § 3.8.4.3 and Appendix E of the PEIS.

Some attention has been given to the potential effects of an MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales off Madagascar (Southall et al. 2013). During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally,

the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event was the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

Reference has also been made that two beaked whales stranded in the Gulf of California in 2002 were observed during a seismic survey in the region by the R/V *Ewing* (Malakoff 2002, Cox et al. 2006 *in* PEIS:3-136), which used a similar MBES system. As noted in the PEIS, however, "The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence" (Hogarth 2002, Yoder 2002 *in* PEIS:3-190).

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on R/V *Langseth*. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, "all ranges are multiplied by a factor of 4" (Lurton 2016:209). However, Ruppel et al. (2022) found that MBESs, SBPs, sidescan sonars, ADCPs, and pingers are unlikely to result in take of marine mammals as these sources typically operate at frequencies inaudible to marine mammals, have low source and received levels, narrow beams, downward directed transmission, and/or have low exposure (e.g., short pulse lengths, intermittency of pulses).

During a recent study, group vocal periods (GVP) were used as proxies to assess foraging behavior and use of habitat by Cuvier's beaked whales during multibeam mapping with a 12 kHz MBES in southern California (Varghese et al. 2021). The studies found that there was no significant difference between GVP during multibeam mapping and non-exposure periods, suggesting that the level of foraging and habitat use likely did not change during multibeam mapping. During an analogous study assessing naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011; Varghese et al. 2020).

In the fall of 2006, an Ocean Acoustic Waveguide Remote Sensing (OAWRS) experiment was carried out in the Gulf of Maine (Gong et al. 2014); the OAWRS emitted three frequency-modulated (FM) pulses centered at frequencies of 415, 734, and 949 Hz (Risch et al. 2012). Risch et al. (2012) found a reduction in humpback whale song in the Stellwagen Bank National Marine Sanctuary during OAWRS activities that were carried out ~200 km away; received levels in the sanctuary were 88–110 dB re 1 µPa. In contrast, Gong et al. (2014) reported no effect of the OAWRS signals on humpback whale vocalizations in the Gulf of Maine. Range to the source, ambient noise, and/or behavioral state may have differentially influenced the behavioral responses of humpbacks in the two areas (Risch et al. 2014).

Frankel and Stein (2020) reported that gray whales responded to a 21–25 kHz active sonar by deflecting 1–2 km away from the sound. Sperm whales exposed to sounds from a low-frequency 1–2 kHz sonar transitioned to non-foraging and non-resting states, but did not respond to 4.7–5.1 kHz or 6–7 kHz sonar signals (Isojunno et al. 2016). Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a

resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

Despite the aforementioned information that has recently become available, and in agreement with § 3.6.7, 3.7.7, and 3.8.7 of the PEIS, the operation of MBESs and SBPs would not likely to impact marine mammals, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal given the movement and speed of the vessel.

Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear.

Vessel noise from R/V *Langseth* could affect marine animals in the proposed survey area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2017) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20–300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014; Kyhn et al. 2019; Landrø and Langhammer 2020); low levels of high-frequency sound from vessels have been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have also been shown to affect foraging by porpoise (Teilmann et al. 2015; Wisniewska et al. 2018). Wisniewska et al. (2018) suggest that a decrease in foraging success could have long-term fitness consequences.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2017; Cholewiak et al. 2018). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017; Branstetter and Sills 2022). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016; Oakley et al. 2017). Based on modeling, Halliday et al. (2017) suggested that shipping noise can be audible more than 100 km away and could affect the behavior of a marine mammal at a distance of 52 km in the case of tankers.

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey areas during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and rorquals (fin, blue, and minke whales). Reactions of humpback whales to boats are variable, ranging from approach to avoidance (Payne 1978; Salden 1993). Baker et al. (1982, 1983) and Baker and Herman (1989) found humpbacks often move away when vessels are within several kilometers. Humpbacks seem less likely to react overtly when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984, 1986). Increased levels of ship noise have been shown to affect foraging by humpback whales (Blair et al. 2016) and killer whales (Williams et al. 2021). Fin whale sightings in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015). Minke whales and gray seals have shown slight displacement in response to construction-related vessel traffic (Anderwald et al. 2013).

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or have had little or no recent exposure to ships (Richardson et al. 1995). Dolphins of many species tolerate and sometimes approach vessels (e.g., Anderwald et al. 2013). Some dolphin species approach moving vessels to ride the bow or stern waves (Williams et al. 1992). Physical presence of vessels, not just ship noise, has been shown to disturb the foraging activity of bottlenose dolphins (Pirotta et al. 2015) and blue whales (Lesage et al. 2017b). Sightings of striped dolphin, Risso's dolphin, sperm whale, and Cuvier's beaked whale in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015).

There are few data on the behavioral reactions of beaked whales to vessel noise, though they seem to avoid approaching vessels (e.g., Würsig et al. 1998) or dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Based on a single observation, Aguilar Soto et al. (2006) suggest foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels.

The PEIS concluded that project vessel sounds would not be at levels expected to cause anything more than possible localized and temporary behavioral changes in marine mammals, and would not be expected to result in significant negative effects on individuals or at the population level. In addition, in all oceans of the world, large vessel traffic is currently so prevalent that it is commonly considered a usual source of ambient sound.

Another concern with vessel traffic is the potential for striking marine mammals (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.4.4.4, § 3.6.4.4, and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals exists but would be extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. There has been no history of marine mammal vessel strikes with R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

Numbers of Marine Mammals that could be "Taken by Harassment"

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. No injurious takes (Level A) would be expected. Consistent with past

similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the proposed activities and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels for the high-energy surveys, and we present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys (additional details are provided in Appendix B). The estimates are based on consideration of the number of marine mammals that could be harassed by sound (Level B takes) produced by the seismic surveys off the southeastern U.S., in the Northwest Atlantic Ocean.

It is assumed that, during simultaneous operations of the airgun array and the other sources, any marine mammals close enough to be affected by the MBES, SBP, and ADCP would already be affected by the airguns. However, whether or not the airguns are operating simultaneously with the other sources, marine mammals are expected to exhibit no more than short-term and inconsequential responses to the MBES and SBP given their characteristics (e.g., narrow downward-directed beam) and other considerations described in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that could be affected by sound sources other than airguns.

Basis for Estimating "Takes"

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the area in the absence of seismic surveys. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

The numbers of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) on one or more occasions have been estimated using a method recommended by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting seismic tracklines that could be surveyed on one day (~182 km) during MCS surveys and on one day of surveys with OBSs (222 km) that are roughly similar to that of the MCS and OBS surveys regarding the proportion of water depths to be surveyed. The area expected to be ensonified on a single day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by "drawing" the applicable Level B and PTS threshold buffers) around each line. The ensonified areas, increased by 25%, were then multiplied by the number of survey days (32 days for MCS; 8 for OBS). This is equivalent to adding an additional 25% to the proposed line km (Appendix B). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V *Langseth* approaches.

We used habitat-based stratified marine mammal densities for the North Atlantic for the U.S. Navy Atlantic Fleet Testing and Training (AFTT) Area from Roberts et al. (2016); the highest mean monthly density was chosen for each species from the months of May to October. The habitat-based density models consisted of 10 km x 10 km grid cells. Average densities in the grid cells for the AFTT Area overlapping the proposed survey area (plus a 40 km buffer) were averaged for each of two water depth categories (intermediate and deep).

Table 5 shows estimated densities for cetacean species that could occur in the proposed survey area. There is uncertainty about the representativeness of the data and the assumptions used to estimate exposures below. Thus, for some species, the densities derived from the abundance models described above may not precisely represent the densities that would be encountered during the proposed seismic surveys.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Table 6 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix B for more details), along with the *Requested Take Authorization*. It should be noted that the exposure estimates assume that the proposed surveys would be completed; in fact, the calculated takes for cetaceans **have been increased by 25%** (see below). Thus, the estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in the NSF/USGS PEIS. The 160-dB_{rms} criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary.

Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2013). The context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (e.g., Ellison et al. 2012; NMFS 2013; Hastie et al. 2021; Hückstädt et al. 2020; Southall et al. 2021; Booth et al. 2022; Miller et al. 2022). Southall et al. (2021) provide a detailed framework for assessing marine mammal behavioral responses to anthropogenic noise and note that use of a single threshold can lead to large errors in prediction impacts due to variability in responses between and within species.

Conclusions

The proposed seismic surveys would involve towing an airgun array, which introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". In §3.6.7 and 3.7.7, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticetes and odontocetes, and that Level A effects were unlikely.

Consistent with past similar proposed actions, NSF has followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for the Proposed Action involving the high-energy surveys; however, following a different methodology than used in the PEIS. For recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects;

TABLE 5. Densities of marine mammals for the proposed survey area off the southeastern U.S., Northwest Atlantic Ocean.

	Density (#/km^2) in Survey Area[1]		Month of Highest Density During May-Oct for Intermediate/Deep water
	Intermediate Water	*Deep Water*	
LF Cetaceans			
North Atlantic right whale	0.0000006	0.0000002	May/October
Bryde's whale	N.A.	N.A.	N.A.
Humpback whale	0.0000009	0.0000002	May/May
Minke whale	0.0000965	0.0001776	May/May
Fin whale	0.0000266	0.0000271	May/May
Sei whale	0.0001681	0.0001753	October/October
Blue whale	0.0000115	0.0000124	Same each month
MF Cetaceans			
Sperm whale	0.0013001	0.0090562	May/May
Cuvier's beaked whale	0.0000953	0.0056729	Same each month
Mesoplodont whales	0.0001318	0.0022294	Same each month
Risso's dolphin	0.0109262	0.0010384	August/August
Rough-toothed dolphin	0.0016741	0.0018725	Same each month
Bottlenose dolphin	0.0328258	0.0128819	May/May
Pantropical spotted dolphin	0.0023233	0.0026089	Same each month
Atlantic spotted dolphin	0.0072551	0.0154221	July/Same each month
Spinner dolphin	0.0008544	0.0008658	Same each month
Striped dolphin	9.580E-10	4.200E-08	Same each month
Clymene dolphin	3.270E-08	1.430E-09	Same each month
Fraser's dolphin	0.0013009	0.0013183	Same each month
Common dolphin	0.0008332	0.0014130	May/May
Globicephala spp.	0.0089973	0.0069079	Same each month
Killer whale	0.0000315	0.0000319	Same each month
False killer whale	0.0000233	0.0000236	Same each month
Pgymy killer whale	0.0001168	0.0001183	Same each month
Melon-headed whale	0.0012219	0.0012382	Same each month
HF Cetaceans			
Kogia spp.	0.0008602	0.0088538	Same each month
Harbor porpoise	0.0000002	0.0000001	May/May

N.A. means not available/not applicable.
[1] Densities for marine mammals are based on Roberts et al. (2016).

TABLE 6. Estimates of the possible numbers of individual marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed Blake Plateau seismic surveys, Northwest Atlantic Ocean.

Species	Level B Takes[1]	Level A Takes[2]	% of North Atlantic Populaton (Based on Total Takes)[3]	Requested Level A+B Take Authorization[4]
LF Cetaceans				
Night Atlantic right whale	0	0	0	0
Bryde's whale	0	0	N.A.	*2*
Humpback whale	0	0	0.21	**3**
Minke whale	21	1	0.10	22
Fin whale	5	0	0.07	5
Sei whale	29	1	0.47	30
Blue whale	2	0	0.51	2
MF Cetaceans				
Sperm whale	707	5	16.38	712
Cuvier's beaked whale	363	3	6.38	366
Beaked whales[5]	153	1	1.53	154
Blaineville's beaked whale	51	0	N.A.	51
Gervais' beaked whale	51	1	N.A.	52
True's beaked whale	51	0	N.A.	51
Risso's dolphin	1,279	1	3.63	1,280
Rough-toothed dolphin	302	1	N.A.	303
Bottenose dolphin	4,450	7	7.09	4,457
Pantropical spotted dolphin	421	1	6.40	422
Atlantic spotted dolphin	1,765	8	4.44	1,773
Spinner dolphin	149	0	3.64	149
Striped dolphin	0	0	0.09	**60**
Clymene dolphin	0	0	1.04	***44***
Fraser's dolphin	226	1	N.A.	227
Common dolphin	180	1	0.10	181
Pilot whales[6]	1,429	4	4.96	1,433
Short-finned pilot whales	1,143	4	N.A.	1,147
Long-finned pilot whales	286	0	N.A.	286
Killer whale	6	0	N.A.	**7**
False killer whale	4	0	0.67	**12**
Pgymy killer whale	20	0	N.A.	20
Melon-headed whale	212	1	N.A.	213
HF Cetaceans				
Kogia spp.[7]	555	96	8.40	651
Dwarf sperm whale	277	48	N.A.	325
Pygmy sperm whale	278	48	N.A.	326
Harbor porpoise	0	0	0	**2**

N.A. means not applicable or not available. [1]Level B takes, based on the 160-dB criterion for marine mammals, excluding exposures to sound levels equivalent to PTS thresholds. [2]Level A takes if there were no mitigation measures. [3]Requested take authorization expressed as % of population for the North Atlantic (see Table 2), except for rough-toothed dolphin, for which abundance in North Atlantic and Gulf of Mexico were added together. [4]Requested take authorization is Level A plus Level B calculated takes unless indicated in bold. Bold takes have been increased to mean group size from Palka (2020); when group size was not available from Palka (2020), takes in bold and italics were increased to mean group size from Maze-Foley and Mullin (2006). [5]Assigned 1/3 of the Level B takes to the three species of beaked whales. [6]Takes for *Globicephala* sp. were equally assigned between the two species. [7]Takes for *Kogia* spp. were equally assigned to *K. sima* and *K. breviceps*.

however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (e.g., NMFS 2019a,b). The brief duration of exposure of any given animal, the large proportion of survey effort in deeper water, and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level B harassment are low percentages of the regional population sizes. However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activities.

In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by R/V *Langseth* off the coast of North Carolina in September–October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015). During an USGS-funded, ~2700 km, 2-D seismic survey conducted by R/V *Langseth* along the U.S. east coast in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The Level B estimates are thought to be conservative; thus, not all animals detected within this threshold distance would be expected to have been exposed to actual sound levels >160 dB.

III. ANTICIPATED IMPACT ON SUBSISTENCE

> The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

There is no subsistence hunting near the proposed survey area, so the proposed activity would not have any impact on the availability of the species or stocks for subsistence users.

IX. ANTICIPATED IMPACT ON HABITAT

> The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

The proposed seismic surveys would not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. Effects of seismic sound on marine invertebrates, marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations.

X. ANTICIPATED IMPACT OF LOSS OR MODIFICATION OF HABITAT ON MARINE MAMMALS

The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

The proposed activities are not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, because operations would be limited in duration. However, a small minority of the marine mammals that are present near the proposed activity may be temporarily displaced by as much as a few kilometers by the planned activities.

XI. MITIGATION MEASURES

The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

Numerous marine mammals species are known to occur in the proposed survey area. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species and following requirements issued in the IHA and associated Incidental Take Statement (ITS).

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity. The procedures described here are based on protocols used during previous L-DEO seismic research cruises as approved by NMFS, and on best practices recommended in Richardson et al (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017).

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity. The procedures described here are based on protocols used during previous L-DEO seismic research cruises as approved by NMFS, and on best practices recommended in Richardson et al (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017).

Planning Phase

As discussed in § 2.4.1.1 of the PEIS, mitigation of potential impacts from the proposed activities begins during the planning phase of the proposed activity. Several factors were considered during the planning phase of the proposed activity, including

1. *Energy Source*—Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source than the 36-airgun source. The 36-airgun energy source was determined to be the lowest practical source to meet the scientific objectives, including penetrating crustal depths.

2. *Survey Location and Timing*— The PIs, along with L-DEO and NSF, considered potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals), weather conditions, equipment, and optimal timing for other proposed seismic surveys using R/V *Langseth*. Most species of

marine mammals are expected to occur in the proposed survey area throughout the year (DoN 2008c); baleen whales appear to be most common off the southeastern U.S. during winter. The occurrence of North Atlantic right whales appears to peak during November–February off the southeastern U.S., but they are unlikely to occur in the deep waters of the offshore survey area. Hurricane season typically occurs during June–November. Summer/fall was determined to be the most practical timing for the proposed surveys based on the occurrence of marine mammals, weather conditions, other operational requirements, and availability of researchers.

3. *Mitigation Zones*—During the planning phase, mitigation zones for the proposed marine seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the exclusion zones (EZ) for Level A takes and for the Level B (160 dB re $1\mu Pa_{rms}$) threshold. The background information and methodology for this are provided in Appendix A. L-DEO model results are used to determine the 160-dB_{rms} radius for the airgun source down to a maximum depth of 2000 m (see Appendix A), as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5.

Mitigation During Operations

Numerous marine mammal species are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities are expected to be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with the PEIS and past IHA and incidental take statement (ITS) requirements, include: (1) monitoring by PSOs for marine mammals, and ESA-listed sea turtles and seabirds (diving/foraging) near the vessel, and observing for potential impacts of acoustic sources on fish; (2) passive acoustic monitoring (PAM); (3) PSO data and documentation; and (4) mitigation during operations (speed or course alteration; shut-down and ramp-up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats). It would be unlikely that concentrations of large whales would be encountered within the 160-dB isopleth, but if they were, they would be avoided. Mitigation measures that would be adopted during the proposed surveys include (1) shut downs and (2) ramp ups. These measures are proposed by L-DEO based on past experience and for consistency with the PEIS.

Shut Down Procedures

The operating airgun(s) would be shut down if a marine mammal was seen within or approaching the EZ. Shut downs would not be required for small dolphins that are most likely to approach the vessel. The airgun array would be shut down if ESA-listed sea turtles or seabirds (diving/foraging) were observed within a 150-m designated EZ.

Following a shut down, airgun activity would not resume until the marine mammal, ESA-listed seabird, or sea turtle has cleared the EZ. The animal would be considered to have cleared the EZ if

- it was visually observed to have left the EZ, or
- it was not seen within the zone for 15 min in the case of small odontocetes, ESA-listed seabirds, and sea turtles, or
- it was not seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

The airgun array would be ramped up gradually after a shut down for marine mammals but would not be required for ESA-listed sea turtles or seabirds. Ramp up procedures are described below.

Ramp Up Procedures

A ramp up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that this period would be 30 min, as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal has not cleared the EZ as described earlier. As previously noted, for shut downs implemented for sea turtles and ESA-listed seabirds, no ramp up would be required, as long as the animal is no longer observed within the EZ.

Ramp up would begin with the smallest airgun in the array. Ramp up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals or ESA-listed sea turtles/seabirds (diving/foraging) are sighted, a shut down would be implemented, respectively, as though the full array were operational. Ramp up would only commence at night or during poor visibility if the EZ has been monitored acoustically with PAM for 30 min prior to the start of operations without any marine mammal detections during that period.

The proposed operational mitigation measures are standard for seismic cruises, per the PEIS. Five independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours. During the high-energy surveys, one observer would conduct PAM during day- and night-time seismic operations. Monitoring and mitigation measures are further described in the IHA application. A monitoring report would be provided to NMFS, both the Permits and Conservation Division and the ESA Interagency Cooperation Division.

With the proposed monitoring and mitigation provisions, potential effects on most, if not all, individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individual marine mammals and on the associated species and stocks. Ultimately, survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and ITS requirements.

XII. PLAN OF COOPERATION

Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:

(i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;

(ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;

(iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and

(iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

Not applicable. The proposed activities would take place in the Northwest Atlantic Ocean, and no activities would take place in traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

> The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding.

L-DEO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring and to satisfy the expected monitoring requirements of the IHA. L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan would be subject to review by NMFS and that refinements may be required. The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. L-DEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

Observations by PSOs would take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations would be shut down when marine mammals are observed within, or about to enter, designated EZs [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs would also watch for marine mammals near the seismic vessel for at least 30 min prior to the planned start of airgun operations. Observations would also be made during daytime periods when R/V *Langseth* is underway without seismic operations, such as during transits. PSOs would also watch for any potential impacts of the acoustic sources on fish.

During seismic operations, five PSOs would be based aboard R/V *Langseth*. All PSOs would be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs would monitor for marine mammals around the seismic vessel; these observers may be referred to as the visual PSOs or "PSVOs". Use of two simultaneous observers would increase the effectiveness of detecting animals around the source vessel. PSVO(s) would be on duty in shifts of duration no longer than 4 h, or per the IHA. Other crew would also be instructed to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic surveys, the crew would be given additional instruction regarding how to do so.

R/V *Langseth* is a suitable platform for marine mammal observations. When stationed on the observation platform, the eye level would be ~21.5 m above sea level, and the observer would have a good view around the entire vessel. During daytime, the PSVO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) would be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required.

Passive Acoustic Monitoring

Passive acoustic monitoring (PAM) would take place to complement the visual monitoring program during the surveys. Visual monitoring typically is not effective during periods of poor visibility or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical monitoring can be used in addition to visual observations to improve detection, identification, and localization of cetaceans. The acoustic monitoring would serve to alert PSVOs (if on duty) when vocalizing cetaceans are detected. It is only useful when marine mammals call, but it can be effective either by day or by night, and does not depend on good visibility. It would be monitored in real time so that the visual observers can be advised when cetaceans are detected.

The PAM system consists of hardware (i.e., hydrophones) and software. The "wet end" of the system consists of a towed hydrophone array that is connected to the vessel by a tow cable. The tow cable is 250 m long, and the hydrophones are fitted in the last 10 m of cable. A depth gauge is attached to the free end of the cable, and the cable is typically towed at depths <20 m. The array would be deployed from a winch located on the back deck; however, at times, deployment and connection to the vessel may deviate depending upon conditions such as severe weather or airgun configuration. A deck cable would connect the tow cable to the electronics unit in the main computer lab where the acoustic station, signal conditioning, and processing system would be located. The acoustic signals received by the hydrophones are amplified, digitized, and then processed by the Pamguard software. The system can detect marine mammal vocalizations at frequencies up to 250 kHz.

The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey areas during airgun operations, and during most periods when R/V *Langseth* is underway while the airguns are not operating. PAM may not be possible if damage occurs to the array or back-up systems during operations; in that event, the PAM system would be repaired and re-deployed as quickly as possible. One PSO would monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSO monitoring the acoustical data referred to as the PSAO, would be on shift for no longer than 4 h at a time, or per the IHA. All observers would be expected to rotate through the PAM position, although the most experienced with acoustics would be on PAM duty more frequently.

When a vocalization is detected while visual observations are in progress, the PSAO would contact the PSVO immediately, to alert him/her to the presence of cetaceans (if they have not already been seen), and to allow a shut down to be initiated, if required. The information regarding the call would be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection could also be recorded for further analysis.

PSO Data and Documentation

PSOs would record data to estimate the numbers of marine mammals exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. They would also record any observations of fish potentially affected by the sound sources. Data would be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA). They would also provide information needed to order a shut down of the airguns when a marine mammal is within or near the EZ.

When a sighting is made, the following information about the sighting would be recorded:

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.

2. Time, location, heading, speed, activity of the vessel, sea state, visibility, and sun glare.

The data listed under (2) would also be recorded at the start and end of each observation watch, and during a watch whenever there is a change in one or more of the variables.

All observations and shut downs would be recorded in a standardized format. Data would be entered into an electronic database. The accuracy of the data entry would be verified by computerized data validity checks as the data are entered and by subsequent manual checking of the database. These procedures would allow initial summaries of data to be prepared during and shortly after the field program, and would facilitate transfer of the data to statistical, graphical, and other programs for further processing and archiving.

Results from the vessel-based observations would provide

1. the basis for real-time mitigation (airgun shut down);

2. information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS;

3. data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted;

4. information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity;

5. data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity; and

6. any observations of fish potentially affected by the sound sources.

A report would be submitted to NMFS and NSF within 90 days after the end of the cruise. The report would describe the operations that were conducted and sightings of marine mammals near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring and would summarize the dates and locations of seismic operations and all marine mammal observations. The report would also include estimates of the number and nature of exposures that could result in "takes" of marine mammals by harassment or in other ways.

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

L-DEO and NSF would coordinate with applicable U.S. agencies (e.g., NMFS), and would comply with all requirements.

XV. LITERATURE CITED

Aarts, G., A.M. von Benda-Beckmann, K. Lucke, H.Ö. Sertlek, R. Van Bemmelen, S.C. Geelhoed, S. Brasseur, M. Scheidat, F.P.A. Lam, H. Slabbekoorn, and R. Kirkwood. 2016. Harbour porpoise movement strategy affects cumulative number of animals acoustically exposed to underwater explosions. **Mar. Ecol. Prog. Ser.** 557:261-275.

Acosta, A., N. Nino-Rodriquez, M.C. Yepes, and O. Boisseau. 2017. Mitigation provisions to be implemented for marine seismic surveying in Latin America: a review based on fish and cetaceans. **Aquat. Biol.** 26:199-216.

Aerts, L., M.R. Jenkerson, V.E. Nechayuk, G. Gailey, R. Racca, A.L. Blanchard, L.K. Schwarz, and H.R. Melton. 2022. Seismic surveys near gray whale feeding areas off Sakhalin Island, Russia: assessing impact and mitigation effectiveness. **Env. Monit. Assess.** 194 (Suppl. 1):746. https://doi.org/10.1007/s10661-022-10016-9.

Aguilar, A. 1986. A review of old Basque whaling and its effect on the right whales of the North Atlantic. **Rep. Int. Whal. Comm. Spec. Iss**. 10:191-199.

Aguilar, A. and R. García-Vernet. 2018. Fin whale *Balaenoptera physalus*. p. 368-371 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd ed. Academic Press/Elsevier, San Diego, CA. 1157 p.

Aguilar-Soto, N., M. Johnson, P.T. Madsen, P.L. Tyack, A. Bocconcelli, and J.F. Borsani. 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)? **Mar. Mamm. Sci.** 22(3):690-699.

Anderwald, P., A. Brandecker, M. Coleman, C. Collins, H. Denniston, M.D. Haberlin, M. O'Donovan, R. Pinfield, F. Visser, and L. Walshe. 2013. Displacement responses of a mysticete, an odontocete, and a phocid seal to construction-related vessel traffic. **Endang. Species Res.** 21(3):231-240.

Atkinson, S., D. Crocker, D. Houser, and K. Mashburn. 2015. Stress physiology in marine mammals: How well do they fit the terrestrial model? **J. Comp. Physiol.** B 185(5):463-486.

Azzara, A.J., W.M. von Zharen, and J.J. Newcomb. 2013. Mixed-methods analytic approach for determining potential impacts of vessel noise on sperm whale click behavior. **J. Acoust. Soc. Am.** 134(6):4566-4574.

Bain, D.E. and R. Williams. 2006. Long-range effects of airgun noise on marine mammals: responses as a function of received sound level and distance. Int. Whal. Comm. Working Pap. SC/58/E35. 13 p.

Baird, R.W. 2018a. Cuvier's beaked whale *Ziphius cavirostris*. p. 234-237 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Baird, R.W. 2018b. False killer whale *Pseudorca crassidens*. p. 347-349 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Baird, R.W. 2018c. Pygmy killer whale *Feresa attenuata*. p. 788-790 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Baker, C.S. and L.M. Herman. 1989. Behavioral responses of summering humpback whales to vessel traffic: experimental and opportunistic observations. NPS-NR-TRS-89-01. Rep. from Kewalo Basin Mar. Mamm. Lab., Univ. Hawaii, Honolulu, HI, for U.S. Natl. Park Serv., Anchorage, AK. 50 p. NTIS PB90-198409.

Baker, C.S., L.M. Herman, B.G. Bays, and G.B. Bauer. 1983. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska: 1982 season. Rep. from Kewalo Basin Mar. Mamm. Lab., Honolulu, HI, for U.S. Nat. Mar. Mamm. Lab., Seattle, WA. 30 p. + fig., tables.

Baker, C.S., L.M. Herman, B.G. Bays, and W.F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Rep. from Kewalo Basin Mar. Mamm. Lab., Honolulu, HI, for U.S. Natl. Mar. Fish. Serv., Seattle, WA. 78 p.

Barlow, J. and R. Gisiner. 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. **J. Cetac. Res. Manage**. 7(3):239-249.

Barry, S.B., A.C. Cucknell and N. Clark. 2012. A direct comparison of bottlenose dolphin and common dolphin behaviour during seismic surveys when airguns are and are not being utilised. p. 273-276 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Bernard, H.J. and S.B. Reilly. 1999. Pilot whales *Globicephala* Lesson, 1828. p. 245-279 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Bernstein, L. 2013. The Washington Post: Health, Science, and Environment. Panel links underwater mapping sonar to whale stranding for first time. Published 6 October 2013. Accessed in April 2014 at http://www.washingtonpost.com/national/health-science/panel-links-underwater-mapping-sonar-to-whale-stranding-for-first-time/2013/10/06/52510204-2e8e-11e3-bbed-a8a60c601153_story.html.

Bettridge, S., C.S. Baker, J. Barlow, P.J. Clapham, M. Ford, D. Gouveia, D.K. Mattila, R.M. Pace, III, P.E. Rosel, G.K. Silber, and P.R. Wade. 2015. Status review of the humpback whale (*Megaptera novaeangliae*) under the Endangered Species Act. NOAA Tech. Memo. NMFS-SWFSC-540. Nat. Mar. Fish. Service, Southwest Fish. Sci. Center, La Jolla, CA. 240 p.

Bittencourt, L., I.M.S. Lima, L.G. Andrade, R.R. Carvalho, T.L. Bisi, J. Lailson-Brito, Jr., and A.F. Azevedo. 2016. Underwater noise in an impacted environment can affect Guiana dolphin communication. **Mar. Poll. Bull.** 114(2):1130-1134.

Blackwell, S.B., C.S. Nations, T.L. McDonald, A.M. Thode, D. Mathias, K.H. Kim, C.R. Greene, Jr., and A.M. Macrander. 2015. Effects of airgun sounds on bowhead whale calling rates: evidence for two behavioral thresholds. **PLoS ONE** 10(6): e0125720.

Blackwell, S.B., C.S. Nations, T.L. McDonald, C.R. Greene, Jr., A.M. Thode, M. Guerra, and A.M. Macrander. 2013. Effects of airgun sounds on bowhead whale calling rates in the Alaskan Beaufort Sea. **Mar. Mamm. Sci.** DOI: 10.1111/mms.12001.

Blair, H.B., N.D. Merchant, A.S. Friedlaender, D.N. Wiley, and S.E. Parks. 2016. Evidence for ship noise impacts on humpback whale foraging behaviour. **Biol. Lett.** 12:20160005.

Booth, C.G., R.R. Sinclair, and J. Harwood. 2020. Methods for monitoring for the population consequences of disturbance in marine mammals: a review. **Front. Mar. Sci.** 7:115.

Booth, C.G., N. Brannan, R. Dunlop, A. Friedlander, S. Isojunno, P. Miller, N. Quick, B. Southall, and E. Pirotta. 2022. A sampling, exposure and receptor framework for identifying factors that modulate behavioural responses to disturbance in cetaceans. **J. Animal Behav.** doi: 10.1111/1365-2656.13787

Branstetter, B.K., J.S. Trickey, H. Aihara, J.J. Finneran, and T.R. Liberman. 2013. Time and frequency metrics related to auditory masking of a 10 kHz tone in bottlenose dolphins (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 134(6):4556-4565.

Branstetter, B.K., K.L. Bakhtiari, J.S. Trickey, and J.J. Finneran. 2016. Hearing mechanisms and noise metrics related to auditory masking in bottlenose dolphins (*Tursiops truncatus*). p. 109-116 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Branstetter, B.K. and J.M. Sills. 2022. Mechanisms of auditory masking in marine mammals. **Animal Cogn.** https://doi.org/10.1007/s10071-022-01671-z

Breitzke, M. and T. Bohlen. 2010. Modelling sound propagation in the Southern Ocean to estimate the acoustic impact of seismic research surveys on marine mammals. **Geophys. J. Int.** 181(2):818-846.

Bröker, K., G. Gailey, J. Muir, and R. Racca. 2015. Monitoring and impact mitigation during a 4D seismic survey near a population of gray whales off Sakhalin Island, Russia. **Endang. Species Res.** 28:187-208.

Bröker, K., J. Durinck, C. Vanman, and B. Martin. 2013. Monitoring of marine mammals and the sound scape during a seismic survey in two license blocks in the Baffin Bay, West Greenland, in 2012. p. 32 *In:* Abstr. 20th Bienn. Conf. Biol. Mar. Mamm., 9–13 December 2013, Dunedin, New Zealand. 233 p

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J. Urbán R., J.K. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabrielle, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P.L. de Guevara, M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow, and T.J. Quinn II. 2001. Movements and population structure of humpback whales in the North Pacific. **Mar. Mamm. Sci.** 17(4):769-794.

Campana, I., R. Crosti, D. Angeletti, L. Carosso, L. Davis, N. Di-Méglio, A. Moulins, M. Rosso, P. Tepsich, and A. Arcangeli. 2015. Cetacean response to summer maritime traffic in the western Mediterranean Sea. **Mar. Environ. Res.** 109:1-8.

Carwardine, M. 1995. Whales, dolphins, and porpoises. Dorling Kindersley Publishing, Inc., New York, NY. 256 p.

Castellote, M. and C. Llorens. 2016. Review of the effects of offshore seismic surveys in cetaceans: Are mass strandings a possibility? p. 133-143 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Castellote, M., C.W. Clark, and M.O. Lammers. 2012. Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. **Biol. Conserv**. 147(1):115-122.

Cerchio, S., S. Strindberg, T. Collins, C. Bennett, and H. Rosenbaum. 2014. Seismic surveys negatively affect humpback whale singing activity off northern Angola. **PLoS ONE** 9(3): e86464.

CETAP (Cetacean and Turtle Assessment Program). 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the USA outer continental shelf. Cetacean and Turtle Assessment Program, University of Rhode Island. Final Report #AA51-CT8-48 to the Bureau of Land Management, Washington, DC. 538 p.

Chavez-Rosales, S., D.L. Palka, L.P. Garrison and E.A. Josephson. 2019. Environmental predictors of habitat suitability and occurrence of cetaceans in the western North Atlantic Ocean. **Sci. Rep.** 9. https://doi.org/10.1038/s41598-019-42288-6.

Cholewiak, D., A. Izzi, D. Palka, P. Corkeron, and S. Van Parijs. 2017. Beaked whales demonstrate a marked acoustic response to the use of shipboard echosounders. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, NS, Canada.

Christensen, I., T. Haug, and N. Øien. 1992. Seasonal distribution, exploitation and present abundance of stocks of large baleen whales (Mysticeti) and sperm whales (*Physeter macrocephalus*) in Norwegian and adjacent waters. ICES **. J. Mar. Sci.** 49:341-355.

Clapham, P.J. 2018. Humpback whale Megaptera novaeangliae. p. 489-492 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Clapham, P.J., L.S. Baraff, C.A. Carlson, M.A. Christian, D.K. Mattila, C.A. Mayo, M.A. Murphy, and S. Pittman. 1993. Seasonal occurrence and annual return of humpback whales, *Megaptera novaeangliae*, in the southern Gulf of Maine. **Can. J. Zool.** 71:440-443.

Clark, C.W. 1995. Application of U.S. Navy underwater hydrophone arrays for scientific research on whales. **Rep. Int. Whal. Comm.** 45:210-212.

Clark, C.W. and G.C. Gagnon. 2006. Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. Working Pap. SC/58/E9. **Int. Whal. Comm.**, Cambridge, U.K. 9 p.

Clark, C.W., W.T. Ellison, B.L. Southall, L. Hatch, S.M. Van Parijs, A. Frankel, and D. Ponirakis. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. **Mar. Ecol. Prog. Ser.** 395:201-222.

Cole T., A. Glass, P.K. Hamilton, P. Duley, M. Niemeyer, C. Christman, R.M. Pace III, and T. Fraiser. 2009. Potential mating ground for North Atlantic right whales off the Northeast USA. Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec City, 12–16 Oct. 2009. 58 p.

Conley, M.F., M.G. Anderson, N. Steinberg, and A. Barnett (eds.) 2017. The South Atlantic Bight Marine Assessment: Species, Habitats and Ecosystems. The Nature Conservancy, Eastern Conservation Science.

Costa, D.P. and T.M. Williams. 1999. Marine mammal energetics. p. 176-217 *In:* J.E. Reynolds III and S.A. Rommel (eds.) Biology of marine mammals. Smithsonian Institution Press, Washington. 578 p.

Costa, D.P., L. Schwarz, P. Robinson, R. Schick, P.A. Morris, R. Condit, D.E. Crocker, and A.M. Kilpatrick. 2016a. A bioenergetics approach to understanding the population consequences of disturbance: elephant seals as a model system. p. 161-169 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Costa, D.P., L.A. Huckstadt, L.K. Schwarz, A.S. Friedlaender, B.R. Mate, A.N. Zerbini, A. Kennedy, and N.J. Gales. 2016b. Assessing the exposure of animals to acoustic disturbance: towards an understanding of the population consequences of disturbance. Proceedings of Meetings on Acoustics 4ENAL 27(1):010027.

Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P.D. Jepson, D. Ketten, C.D. MacLeod, P. Miller, S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. **J. Cetac. Res. Manage**. 7(3):177–187.

Crone, T.J., M. Tolstoy, and H. Carton. 2014. Estimating shallow water sound power levels and mitigation radii for the R/V Marcus G. Langseth using an 8 km long MCS streamer. Geochem., Geophys., Geosyst. 15(10):3793-3807.

Crone, T.J., M. Tolstoy, and H. Carton. 2017. Utilizing the R/V Marcus G. Langseth's streamer to measure the acoustic radiation of its seismic source in the shallow waters of New Jersey's continental shelf. PloS ONE 12(8):e0183096. http://doi.org/10.1371/journal.pone.0183096.

Culloch, R.M., P. Anderwald, A. Brandecker, D. Haberlin, B. McGovern, R. Pinfield, F. Visser, M. Jessopp, and M. Cronin. 2016. Effect of construction-related activities and vessel traffic on marine mammals. **Mar. Ecol. Prog. Ser.** 549:231-242.

Currie, J.J., S.H. Stack, and G.D. Kaufman. 2017. Modelling whale-vessel encounters: the role of speed in mitigating collisions with humpback whales (*Megaptera novaeangliae*). **J. Cetacean Res. Manage.** 17(1):57-63.

Dahlheim, M. and M. Castellote. 2016. Changes in the acoustic behavior of gray whales *Eschrichtius robustus* in response to noise. **Endang. Species Res.** 31:227-242.

Davis, G.E., M.F. Baumgartner, J.M. Bonnell, J. Bell, C. Berchok, J. Bort Thornton, S. Brault, G. Buchanan, R.A. Charif, D. Cholewiak, C.W. Clark, P. Corkeron, J. Delarue, K. Dudzinski, L. Hatch, J. Hildebrand, L. Hodge, H. Klinck, S. Kraus, B. Martin, D.K. Mellinger, H. Moors-Murphy, S. Nieukirk, D.P. Nowacek, S. Parks, A.J. Read, A.N. Rice, D. Risch, A. Širović, M. Soldevilla, K. Stafford, J.E. Stanistreet, E. Summers, S. Todd, A. Warde, and S.M Van Parijs. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. **Sci. Rep.** 7:13460. https://doi.org/10.1038/s41598-017-13359-3.

Davis, G.E., M.F. Baumgartner, P.J. Corkeron, J. Bell, C. Berchok, J.M. Bonnell, J. Bort Thornton, S. Brault, G.A. Buchanan, D.M. Cholewiak, and C.W. Clark. 2020. Exploring movement patterns and changing distributions of baleen whales in the western North Atlantic using a decade of passive acoustic data. **Glob. Change Biol.** 26(9): 4812-4840.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. **Mar. Mamm. Sci.** 14(3):490-507.

Davis, R.W., J.G. Ortega-Ortiz, C.A. Ribic, W.E. Evans, D.C. Biggs, P.H. Ressler, R.B. Cady, R.R Lebend, K.D. Mullin, and B. Würsig. 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. **Deep-Sea Res.** I 49(1):21-142.

Debrot, A.O. 1998. New cetacean records for Curaçao, Netherlands Antilles. **Caribb. J. Sci.** 34(1-2):168-169.

Delarue, J., R. Dziak, D. Mellinger, J. Lawson, H. Moors-Murphy, Y. Simard, and K. Stafford. 2014. Western and central North Atlantic fin whale (*Balaenoptera physalus*) stock structure assessed using geographic song variations. **J. Acoust. Soc. Am.** 135(4):2240.

Deng, Z.D., B.L. Southall, T.J. Carlson, J. Xu, J.J. Martinez, M.A. Weiland, and J.M. Ingraham. 2014. 200 kHz commercial sonar systems generate lower frequency side lobes audible to some marine mammals. **PLoS ONE** 9(4): e95315. doi:10.1371/journal.pone.0095315.

Di Iorio, L. and C.W. Clark. 2010. Exposure to seismic survey alters blue whale acoustic communication. **Biol. Lett.** 6(1):51-54.

Diebold, J.B., M. Tolstoy, L. Doermann, S.L. Nooner, S.C. Webb, and T.J. Crone. 2010. R/V Marcus G. Langseth seismic source: modeling and calibration. **Geochem. Geophys. Geosyst.** 11(12), Q12012, doi:10.1029/2010GC003126. 20 p.

Doksæter, L., E. Olsen, L. Nøttestad, and A. Fernö. 2008. Distribution and feeding ecology of dolphins along the Mid-Atlantic Ridge between Iceland and the Azores. Deep Sea Res. II 55(1-2):243-253.

Dolar, M.L.L. 2018. Fraser's dolphin *Lagenodelphis hosei*. p. 392-395 *In*: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Dolman, S.J. and M. Jasny. 2015. Evolution of marine noise pollution management. **Aquat. Mammal**. 41(4):357-374.

DoN (Department of the Navy). 2005. Marine resource assessment for the Northeast Operating Areas: Atlantic City, Narragansett Bay, and Boston. Rep. from GeoMarine Inc., Newport News, VA, for Naval Facilities Engineering Command, Atlantic; Norfolk, VA. Contract No. N62470-02-D-9997, Task Order No. 0018. 556 p.

DoN (Department of the Navy). 2008a. Marine resources assessment update for the Virginia Capes Operating Area. Department of the Navy, U.S. Fleet Forces Command, Norfolk, VA. Contract #N62470-02-D-9997, CTO 0056. Prepared by GeoMarine, Inc., Hampton, Virginia. 711 p.

DoN (Department of the Navy). 2008b. Marine resources assessment update for the Cherry Point Operating Area. Department of the Navy, U.S. Fleet Forces Command, Norfolk, VA. Contract #N62470-02-D-9997, CTO 0056. Prepared by GeoMarine, Inc., Hampton, Virginia. 643 p.

DoN (Department of the Navy). 2008c. Marine resources assessment update for the Charleston/Jacksonville Operating Area. Department of the Navy, U.S. Fleet Forces Command, Norfolk, VA. Contract #N62470-02-D-9997, CTO 0056. Prepared by GeoMarine, Inc., Hampton, Virginia. 663 p.

DoN. 2018. Atlantic Fleet Training and Testing Final Environmental Impact Statement/Overseas Environmental Impact Statement. 689 p. Available at: https://www.nepa.navy.mil/AFTT-Phase-III/.

DoN. 2022. Marine Species Monitoring for the U.S. Navy's Atlantic Fleet Training and Testing (AFTT)-2021 Annual Report. U.S. Fleet Forces Command, Norfolk, Virginia.

Donovan, C.R., C.M. Harris, L. Milazzo, J. Harwood, L. Marshall, and R. Williams. 2017. A simulation approach to assessing environmental risk of sound exposure to marine mammals. **Ecol. Evol.** 7:2101-2111.

Donovan, G.P. 1991. A review of IWC stock boundaries. **Rep. Int. Whal. Comm. Spec. Iss**. 13:39-63.

Duffield, D.A., S.H. Ridgway, and L.H. Cornell. 1983. Hematology distinguishes coastal and offshore forms of dolphins (*Tursiops*). **Can. J. Zool**. 61(4):930-933.

Dunlop, R. 2018. The communication space of humpback whale social sounds in vessel noise. **Proc. Meet. Acoust.** 35(1):010001.

Dunlop, R.A. 2015. The effect of vessel noise on humpback whale, *Megaptera novaeangliae*, communication behaviour. **Animal Behav.** 111:13-21.

Dunlop, R.A., J. Braithwaite, L.O. Mortensen, and C.M. Harris. 2021. Assessing population-level effects of anthropogenic disturbance on a marine mammal population. **Front. Mar. Sci.** 8:624981.

Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2016a. Response of humpback whales (*Megaptera novaeangliae*) to ramp-up of a small experimental air gun array. **Mar. Poll. Bull.** 103:72-83.

Dunlop, R.A., M.J. Noad, and D.H. Cato. 2016b. A spatially explicit model of the movement of humpback whales relative to a source. **Proc. Meet. Acoust.** 4ENAL 27(1):010026.

Dunlop, R., M.J. Noad, R. McCauley, and D. Cato. 2016c. The behavioral response of humpback whales to seismic air gun noise. **J. Acoust. Soc. Am**. 140(4):3412.

Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, D. Paton, and D.H. Cato. 2015. The behavioural response of humpback whales (*Megaptera novaeangliae*) to a 20 cubic inch air gun. **Aquatic Mamm.** 41(4):412-433.

Dunlop, R.A., M.J. Noad, R.D. McCauley, L. Scott-Hayward, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2017a. Determining the behavioural dose–response relationship of marine mammals to air gun noise and source proximity. **J. Exp. Biol.** 220:2878-2886.

Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2017b. The behavioural response of migrating humpback whales to a full seismic airgun array. **Proc. R. Soc.** B 284:20171901.

Dunlop, R.A., R.D. McCauley, and M.J. Noad. 2020. Ships and air guns reduce social interactions in humpback whales at greater ranges than other behavioral impacts. **Mar. Poll. Bull.** 154:111072.

Dunlop, R.A., J. Braithwaite, L.O. Mortensen, and C.M. Harris. 2021. Assessing population-level effects of anthropogenic disturbance on a marine mammal population. **Front. Mar. Sci.** 8:624981.

Dyndo, M., D.M. Wisniewska, L. Rojano-Doñate, and P.T. Madsen. 2015. Harbour porpoises react to low levels of high frequency vessel noise. **Sci. Rep.** 5:11083.

Edwards, E.F., C. Hall, T.J. Moore, C. Sheredy, and J.V. Redfern. 2015. Global distribution of fin whales *Balaenoptera physalus* in the post-whaling era (1980–2012). **Mamm. Rev.** 45(4):197-214.

Ellison, W.T., B.L. Southall, C.W. Clark, and A.S. Frankel. 2012. A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. **Conserv. Biol.** 26(1):21-28.

Ellison, W.T., R. Racca, C.W. Clark, B. Streever, A.S. Frankel, E. Fleishman, R. Angliss, J. Berger, D. Ketten, M. Guerra, M. Leu, M. McKenna, T. Sformo, B. Southall, R. Suydam, and L. Thomas. 2016. Modeling the aggregated exposure and responses of bowhead whales Balaena mysticetus to multiple sources of anthropogenic underwater sound. **Endang. Species Res.** 30:95-108.

Ellison, W.T., B.L. Southall, A.S. Frankel, K. Vigness-Raposa, and C.W. Clark. 2018. An acoustic scene perspective on spatial, temporal, and spectral aspects of marine mammal behavioral responses to noise. **Aquat. Mamm.** 44(3):239-243.

Engel, M.H., M.C.C. Marcondes, C.C.A. Martins, F.O. Luna, R.P. Lima, and A. Campos. 2004. Are seismic surveys responsible for cetacean strandings? An unusual mortality of adult humpback whales in Abrolhos Bank, northeastern coast of Brazil. Working Pap. SC/56/E28, **Int. Whal. Comm**., Cambridge, U.K.

Environment News Service. 2013. U.S. east coast dolphin die-off triggers investigation. Accessed on 17 September 2013 at http://ens-newswire.com/2013/08/08/u-s-east-coast-dolphin-die-off-triggers-investigation.

Erbe, C. 2012. The effects of underwater noise on marine mammals. p. 17-22 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Erbe, C., C. Reichmuth, K. Cunningham, K. Lucke, and R. Dooling. 2016. Communication masking in marine mammals: a review and research strategy. **Mar. Poll. Bull.** 103:15-38.

Evans, P.G.H. 1987. The natural history of whales and dolphins. Christopher Helm, Bromley, Kent. 343 p.

Evans, P.G.H. 1992. Status review of cetaceans in British and Irish waters. U.K. Mammal Society Cetacean Group Report, University of Oxford. 100 p.

Evans, W.E. 1994. Common dolphin, white-bellied porpoise *Delphinus delphis* Linnaeus, 1758. Handbook of marine mammals, 5, pp.191-224.

Farmer, N., K. Baker, D. Zeddies, M. Zykov, D. Noren, L. Garrison, E. Fougeres, and A. Machernis. 2017. Population consequences of disturbance for endangered sperm whales (Physeter macrocephalus) exposed to seismic surveys in the Gulf of Mexico, USA. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, Nova Scotia, Canada.

Fernandez-Betelu, O., I.M. Graham, K.L. Brookes, B.J. Cheney, T.R. Barton, and P.M. Thompson. 2021. Far-field effects of impulsive noise on coastal bottlenose dolphins. **Frontiers Mar. Sci.** 8:664230.

Fertl, D., T.A. Jefferson, I.B. Moreno, A.N. Zerbini, and K.D. Mullin. 2003. Distribution of the Clymene dolphin *Stenella clymene*. **Mammal Rev.** 33(3):253-271.

Finneran, J.J. 2012. Auditory effects of underwater noise in odontocetes. p. 197-202 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Finneran, J.J. 2015. Noise-induced hearing loss in marine mammals: a review of temporary threshold shift studies from 1996 to 2015. **J. Acoust. Soc. Am.** 138(3):1702-1726.

Finneran, J.J. 2020. Conditional attenuation of dolphin monaural and binaural auditory evoked potentials after preferential stimulation of one ear. **J. Acoust. Soc. Am.** 147(4):2302-2313.

Finneran, J.J. and B.K. Branstetter. 2013. Effects of noise on sound perception in marine mammals. p. 273-308 *In:* H. Brumm (ed.), Animal communication and noise. Springer Berlin, Heidelberg, Germany. 453 p.

Finneran, J.J. and C.E. Schlundt. 2010. Frequency-dependent and longitudinal changes in noise-induced hearing loss in a bottlenose dolphin (*Tursiops truncatus*) (L). **J. Acoust. Soc. Am.** 128(2):567-570.

Finneran, J.J. and C.E. Schlundt. 2011. Noise-induced temporary threshold shift in marine mammals. **J. Acoust. Soc. Am.** 129(4):2432. [supplemented by oral presentation at the ASA meeting, Seattle, WA, May 2011].

Finneran, J.J. and C.E. Schlundt. 2013. Effects of fatiguing tone frequency on temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 133(3):1819-1826.

Finneran, J.J., C.E. Schlundt, B.K. Branstetter, J.S. Trickey, V. Bowman, and K. Jenkins. 2015. Effects of multiple impulses from a seismic air gun on bottlenose dolphin hearing and behavior. **J. Acoust. Soc. Am.** 137(4):1634-1646.

Finneran, J.J., C.E. Schlundt, D.A. Carder, J.A. Clark, J.A. Young, J.B. Gaspin, and S.H. Ridgway. 2000. Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. **J. Acoust. Soc. Am.** 108(1):417-431.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder, and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. **J. Acoust. Soc. Am.** 111(6):2929-2940.

Finneran, J.J., D.A. Carder, C.E. Schlundt and R.L. Dear. 2010a. Growth and recovery of temporary threshold shift (TTS) at 3 kHz in bottlenose dolphins (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 127(5):3256-3266.

Finneran, J.J., D.A. Carder, C.E. Schlundt and R.L. Dear. 2010b. Temporary threshold shift in a bottlenose dolphin (*Tursiops truncatus*) exposed to intermittent tones. **J. Acoust. Soc. Am.** 127(5):3267-3272.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. **J. Acoust. Soc. Am.** 118(4):2696-2705.

Finneran, J.J., J.S. Trickey, B.K. Branstetter, C.E. Schlundt, and K. Jenkins. 2011. Auditory effects of multiple underwater impulses on bottlenose dolphins (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 130(4):2561.

Foley, H.J., K. Pacifici, R.W. Baird, D.L. Webster, Z.T. Swaim, and A.J. Read. 2021. Residency and movement patterns of Cuvier's beaked whales *Ziphius cavirostris* off Cape Hatteras, North Carolina, USA. **Mar. Ecol. Prog. Ser**. 660:203-216.

Ford, J.K.B. 2018. Killer whale *Orcinus orca*. p. 531-537 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.) Encyclopedia of Marine Mammals, 3rd ed. Academic Press/Elsevier, San Diego, CA. 1157 p.

Fornet, M.E.H., L.P. Matthews, C.M. Gabriele, S. Haver, D.K. Mellinger, and H. Klinck. 2018. Humpback whales *Megaptera novaeangliae* alter calling behavior in response to natural sounds and vessel noise. **Mar. Ecol. Prog. Ser.** 607:251-268.

Forney, K.A., B.L. Southall, E. Slooten, S. Dawson, A.J. Read, R.W. Baird, and R.L. Brownell, Jr. 2017. Nowhere to go: noise impact assessments for marine mammal populations with high site fidelity. **Endang. Species Res.** 32:391-413.

Gailey, G., B. Würsig, and T.L. McDonald. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, northeast Sakhalin Island, Russia. **Environ. Monit. Assessm.** 134(1-3):75-91.

Gailey, G., O. Sychenko, T. McDonald, R. Racca, A. Rutenko, and K. Bröker. 2016. Behavioural responses of western gray whales to a 4-D seismic survey off northeastern Sakhalin Island, Russia. **Endang. Species Res.** 30:53-71.

Gailey, G., O. Sychenko, A. Rutenko, and R. Racca. 2017. Western gray whale behavioral response to extensive seismic surveys conducted near their feeding grounds. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, NS, Canada.

Gailey, G., M. Zykov, O. Sychenko, A. Rutenko, A.L. Blanchard, L Aerts, and R.H. Melton. 2022a. Gray whale density during seismic surveys near their Sakhalin feeding ground. **Env. Monit. Assess.** 194 (Suppl. 1):739. https://doi.org/10.1007/s10661-022-10025-8.

Gailey, G., M. Zykov, O. Sychenko, A. Rutenko, A.L. Blanchard, L Aerts, and R.H. Melton. 2022b. Western gray whale behavioral response to seismic surveys during their foraging season. **Env. Monit. Assess.** 194 (Suppl. 1):740. https://doi.org/10.1007/s10661-022-10023-w.

Gallagher, C.A., V. Grimm, L.A. Kyhn, C.C. Kinze, and J. Nabe-Nielsen. 2021. Movement and seasonal energetics mediate vulnerability to disturbance in marine mammal populations. **Am. Nat.** 197(3):296-311.

Gambell, R. 1985. Fin whale *Balaenoptera physalus* (Linnaeus, 1758). p. 171-192 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, London, UK. 362 p.

Gannier, A. 2000. Distribution of cetaceans off the Society Islands (French Polynesia) as obtained from dedicated surveys. **Aquat. Mamm.** 26(2):111-126.

Gannier, A. and J. Epinat. 2008. Cuvier's beaked whale distribution in the Mediterranean Sea: results from small boat surveys 1996–2007. **J. Mar. Biol. Assoc. U.K.** 88(6):1245-1251.

Garrison, L.P. and P.E. Rosel. 2017. Partitioning short-finned and long-finned pilot whale bycatch estimates using habitat and genetic information. Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, 75 Virginia Beach Dr., Miami, FL 33140. PRBD Contribution # PRBD-2016-17. 24 p.

Gaskin, D.E. 1982. The ecology of whales and dolphins. Heineman Educational Books Ltd., London, U.K. 459 p.

Gaskin, D.E. 1984. The harbor porpoise *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. **Rep. Int. Whal. Comm.** 34:569-586.

Gaskin, D.E. 1987. Updated status of the right whale, *Eubalaena glacialis*, in Canada. **Can Field-Nat** 101:295-309.

Gaskin, D.E. 1992. The status of the harbour porpoise. **Can. Field Nat.** 106(1):36-54.

Gedamke, J. 2011. Ocean basin scale loss of whale communication space: potential impacts of a distant seismic survey. p. 105-106 *In*: Abstr. 19th Bienn. Conf. Biol. Mar. Mamm., Tampa, FL, 27 Nov.–2 Dec. 2011. 344 p.

Gedamke, J., N. Gales, and S. Frydman. 2011. Assessing risk of baleen whale hearing loss from seismic surveys: the effects of uncertainty and individual variation. **J. Acoust. Soc. Am.** 129(1):496-506.

Gervaise, C., N. Roy, Y. Simard, B. Kinda, and N. Menard. 2012. Shipping noise in whale habitat: characteristics, sources, budget, and impact on belugas in Saguenay-St. Lawrence Marine Park hub. **J. Acoust. Soc. Am.** 132(1):76-89.

Gomez, C., J.W. Lawson, A.J. Wright, A.D. Buren, D. Tollit, and V. Lesage. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. **Can. J. Zool.** 94(12):801-819.

Gong, Z., A.D. Jain, D. Tran, D.H. Yi, F. Wu, A. Zorn, P. Ratilal, and N.C. Makris. 2014. Ecosystem scale acoustic sensing reveals humpback whale behavior synchronous with herring spawning processes and re-evaluation finds no effect of sonar on humpback song occurrence in the Gulf of Maine in fall 2006. **PLoS ONE** 9(10):e104733.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift, and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. **Mar. Technol. Soc. J.** 37(4):16-34.

Gospić, N.R. and M. Picciulin. 2016. Changes in whistle structure of resident bottlenose dolphins in relation to underwater noise and boat traffic. **Mar. Poll. Bull.** 105:193-198.

Gray, H. and K. Van Waerebeek. 2011. Postural instability and akinesia in a pantropical spotted dolphin, *Stenella attenuata*, in proximity to operating airguns of a geophysical seismic vessel. **J. Nature Conserv.** 19(6):363-367.

Gregr, E.J. and A.W. Trites. 2001. Predictions of critical habitat of five whale species in the waters of coastal British Columbia. **Can. J. Fish. Aquat. Sci.** 58(7):1265-1285.

Gridley, T., S.H. Elwen, G. Rashley, A.B. Krakauer, and J. Heiler. 2016. Bottlenose dolphins change their whistling characteristics in relation to vessel presence, surface behavior and group composition. **Proc. Meet. Acoust.** 4ENAL 27(1):010030.

Guan, S., J.F. Vignola, J.A. Judge, D. Turo, and T.J. Ryan. 2015. Inter-pulse noise field during an arctic shallow-water seismic survey. **J. Acoust. Soc. Am.** 137(4):2212.

Guerra, M., A.M. Thode, S.B. Blackwell, and M. Macrander. 2011. Quantifying seismic survey reverberation off the Alaskan North Slope. **J. Acoust. Soc. Am.** 130(5):3046-3058.

Guerra, M., P.J. Dugan, D.W. Ponirakis, M. Popescu, Y. Shiu, and C.W. Clark. 2016. High-resolution analysis of seismic airgun impulses and their reverberant field as contributors to an acoustic environment. p. 371-379 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Hain, J.H.W., W.A.M. Hyman, R.D. Kenney, and H.E. Winn. 1985. The role of cetaceans in the shelf-edge region of the U.S. **Mar. Fish. Rev.** 47(1):13-17.

Halliday, W.D., S.J. Insley, R.C. Hilliard, T. de Jong, and M.K. Pine. 2017. Potential impacts of shipping noise on marine mammals in the western Canadian Arctic. **Mar. Poll. Bull.** 123:73–82.

Hamilton, P.K. and C.A. Mayo. 1990. Population characteristics of right whales (*Eubalaena glacialis*) observed in Cape Cod and Massachusetts Bays, 1978–86. **Rep. Int. Whal. Comm. Spec. Iss.** 12:203-208.

Hansen, L.J., K.D. Mullin, and C.L. Roden. 1994. Preliminary estimates of cetacean abundance in the U.S. Atlantic Exclusive Economic Zone from 1992 vessel surveys. Southeast Fisheries Science Center, Miami Laboratory. Contribution No. MIA-93/94-58.

Harris, C.M., L. Thomas, E.A. Falcone, J. Hildebrand, D. Houser, P.H. Kvadsheim, F.-P.A. Lam, P.J.O. Miller, D.J. Moretti, A.J. Read, H. Slabbekoorn, B.L. Southall, P.L. Tyack, D. Wartzok, and V.M. Janik. 2017. Marine mammals and sonar: dose–response studies, the risk-disturbance hypothesis and the role of exposure context. **J. Appl. Ecol**. 55(1):396-404.

Hartman, K.L. 2018. Risso's dolphin *Grampus griseus*. p. 824-827 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Harwood, J., S. King, C. Booth, C. Donovan, R.S. Schick, L. Thomas, and L. New. 2016. Understanding the population consequences of acoustic disturbance for marine mammals. **Adv. Exp. Med. Biol.** 875:417-243.

Hastie, G.D., C. Donovan, T. Götz, and V.M. Janik. 2014. Behavioral responses of grey seals (*Halichoerus grypus*) to high frequency sonar. **Mar. Poll. Bull.** 79:205-210.

Hastie, G., N.D. Merchant, T. Götz, D.J. Russell, P. Thompson, and V.M. Janik. 2019. Effects of impulsive noise on marine mammals: investigating range-dependent risk. **Ecol. Appl.** 15:e01906.

Hastie, G.D., P. Lepper, J.C. McKnight, R. Milne, D.J. Russell, and D. Thompson. 2021. Acoustic risk balancing by marine mammals: anthropogenic noise can influence the foraging decisions by seals. **J. Appl. Ecol.** 58(9):1854-1863.

Hatch, L.T., C.W. Clark, S.M. Van Parijs, A.S. Frankel, and D.W. Ponirakis. 2012. **Conserv. Biol.** 26(6):983-994.

Hayes, S.A, E. Josephson, K. Maze-Foley, P.E. Rosel, and J. Wallace (eds). 2022. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments 2021. 380 p.

Hayes, S.A., E. Josephson, K. Maze-Foley, and P.E. Rosel. 2019. U.S. Atlantic and Gulf of Mexico Marine mammal stock assessments - 2018. NOAA Tech. Memo NMFS-NE-258.

Hayes, S.A., E. Josephson, K. Maze-Foley, and P.E. Rosel. 2020. U.S. Atlantic and Gulf of Mexico Marine mammal stock assessments - 2019. NOAA Tech. Memo NMFS-NE-264.

Heide-Jørgensen, M.P., R.G. Hansen, S. Fossette, N.J. Nielsen, M.V. Jensen, and P. Hegelund. 2013a. Monitoring abundance and hunting of narwhals in Melville Bay during seismic surveys. Preliminary report from the Greenland Institute of Natural Resources. 59 p.

Heide-Jørgensen, M.P., R.G. Hansen, K. Westdal, R.R. Reeves, and A. Mosbech. 2013b. Narwhals and seismic exploration: is seismic noise increasing the risk of ice entrapments? **Biol. Conserv.** 158:50-54.

Heide-Jørgensen, M.P., S.B. Blackwell, O.M. Tervo, A.L. Samson, E. Garde, R.G. Hansen, M.C. Ngô, A.S. Conrad, P. Trinhammer, H.C. Schmidt, M.-H.S. Sinding, T.M. Williams, and S. Ditlevsen. 2021. Behavioral response study on seismic airgun and vessel exposures in narwhals. **Front. Mar. Sci.** 8:658173.

Heiler, J., S.H. Elwen, H.J. Kriesell, and T. Gridley. 2016. Changes in bottlenose dolphin whistle parameters related to vessel presence, surface behaviour and group composition. **Animal Behav.** 117:167-177.

Hermannsen, L., J. Tougaard, K. Beedholm, J. Nabe-Nielsen, and P.T. Madsen. 2014. High frequency components of ship noise in shallow water with a discussion of implications for harbor porpoises (*Phocoena phocoena*). **J. Acoust. Soc. Am.** 136(4):1640-1653.

Hermannsen, L., K. Beedholm, J. Tougaard, and P.T. Madsen. 2015. Characteristics and propagation of airgun pulses in shallow water with implications for effects on small marine mammals. **PLoS ONE** 10(7):e0133436.

Heyning, J.E. 1989. Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. p. 289-308 *In:* S.H. Ridgway and R. Harrison (eds.) Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 444 p.

Heyning, J.E. and M.E. Dahlheim. 1988. *Orcinus orca*. **Mammal. Spec.** 304:1-9.

Hodge, K., C. Muirhead, J. Morano, C. Clark, and A. Rice. 2015. North Atlantic right whale occurrence near wind energy areas along the mid-Atlantic US coast: Implications for management. **Endang. Species Res.** 28:225-234

Hogarth, W.T. 2002. Declaration of William T. Hogarth in opposition to plaintiff's motion for temporary restraining order, 23 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Div.

Holt, M.M., D.P. Noren, R.C. Dunkin, and T.M. Williams. 2015. Vocal performance affects metabolic rate in dolphins: implications for animals communicating in noisy environments. **J. Exp. Biol.** 218(11):1647-1654.

Horwood, J. 1987. The sei whale: population biology, ecology, and management. Croom Helm, Beckenham, Kent, UK. 375 p.

Horwood, J. 2018. Sei whale *Balaenoptera borealis*. p. 845-848 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Houghton, J., M.M. Holt, D.A. Giles, M.B. Hanson, C.K. Emmons, J.T. Hogan, T.A. Branch, and G.R. VanBlaricom. 2015. The relationship between vessel traffic and noise levels received by killer whales (*Orcinus orca*). **PLoS ONE** 10(12): e0140119.

Houser, D.S. 2021. When is temporary threshold shift injurious to marine mammals? **J. Mar. Sci. Eng.** 9(7):757.

Houser, D.S., C.D. Champagne, D.E. Crocker. N.M. Kellar, J. Cockrem, T. Romano, R.K. Booth, and S.K. Wasser. 2016. Natural variation in stress hormones, comparisons across matrices, and impacts resulting from induced stress in the bottlenose dolphin. p. 467-471 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Houser, D.S., W. Yost, R. Burkhard, J.J. Finneran, C. Reichmuth, and J. Mulsow. 2017. A review of the history, development and application of auditory weighting functions in humans and marine mammals. **J. Acoust. Soc. Am.** 41(3):1371-1413.

Huijser, L.A., M. Bérubé, A.A. Cabrera, R. Prieto, M.A. Silva, J. Robbins, N. Kanda, L.A. Pastene, M. Goto, H. Yoshida, and G.A. Víkingsson. 2018. Population structure of North Atlantic and North Pacific seis whales (*Balaenoptera borealis*) inferred from mitochondrial control region DNA sequences and microsatellite genotypes. **Conserv. Genet.** 19:1007-1024.

Hückstädt, L.A., L.K. Schwarz, A.S. Friedlaender, B.R. Mate, A.N. Zerbini, A. Kennedy, J. Robbins, N.J. Gales, and D.P. Costa. 2020. A dynamic approach to estimate the probability of exposure of marine predators to oil exploration seismic surveys over continental shelf waters. **End. Spec. Res. 42**:185-199.

IUCN. 2022. IUCN Red list of threatened species. Version 2022.1. Accessed on 5 September 2022 at http://www.iucnredlist.org.

IWC. 2007. Report of the standing working group on environmental concerns. Annex K to Report of the Scientific Committee. **J. Cetac. Res. Manage**. 9(Suppl.):227-260.

IWC. 2013. Whale population estimates: population table. Last updated 09/01/09. Accessed on 9 September 2013 at http://iwc.int/estimate.htm.

Jackson, J.A., D.J. Steel, P. Beerli, B.C. Congdon, C. Olavarría, M.S. Leslie, C. Pomilla, H. Rosenbaum, and C.S. Baker. 2014. Global diversity and oceanic divergence of humpback whales (*Megaptera novaeangliae*). **Proc. R. Soc.** B 281:20133222.

Jaquet, N. 1996. How spatial and temporal scales influence understanding of sperm whale distribution: a review. **Mamm. Rev.** 26:51-65.

Jaquet, N. and D. Gendron. 2002. Distribution and relative abundance of sperm whales in relation to key environmental features, squid landings and the distribution of other cetacean species in the Gulf of California, Mexico. **Mar. Biol.** 141(3):591-601.

Jaquet, N. and H. Whitehead. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. **Mar. Ecol. Prog. Ser.** 135(1-3):1-9.

Jefferson, T.A., C.R. Weir, R.C. Anderson, L.T. Balance, R.D. Kenney, and J.J. Kiszka. 2014. Global distribution of Risso's dolphin *Grampus griseus*: a review and critical evaluation. **Mamm. Rev.** 44:56-68.

Jefferson, T.A., D. Fertl, J. Bolanos-Jimenez and A.N. Zerbini. 2009. Distribution of common dolphins (*Delphinus* spp.) in the western North Atlantic: A critical re-examination. **Mar. Biol.** 156:1109-1124.

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2008. Marine mammals of the world: a comprehensive guide to their identification. Elsevier, London, U.K. 573 p.

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2015. Marine mammals of the world: a comprehensive guide to their identification, 2nd edit. Academic Press, London, U.K. 608 p.

Jensen, F.H., L. Bejder, M. Wahlberg, N. Aguilar Soto, M. Johnson, and P.T. Madsen. 2009. Vessel noise effects on delphinid communication. **Mar. Ecol. Prog. Ser**. 395:161-175.

Johnson, H., D. Morrison, and C. Taggart. 2021. WhaleMap: a tool to collate and display whale survey results in near real-time. **J. Open Source Software** 6(62):3094. https://joss.theoj.org/papers/10.21105/joss.03094

Johnson, S.R., W.J. Richardson, S.B. Yazvenko, S.A. Blokhin, G. Gailey, M.R. Jenkerson, S.K. Meier, H.R. Melton, M.W. Newcomer, A.S. Perlov, S.A. Rutenko, B. Würsig, C.R. Martin, and D.E. Egging. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. **Environ. Monit. Assessm.** 134(1-3):1-19.

Jones, E.L., G.D. Hastie, S. Smout, J. Onoufriou, N.D. Merchant, K.L. Brookes, and D. Thompson. 2017. Seals and shipping: quantifying population risk and individual exposure to vessel noise. **J. Appl. Ecol.** 54(6):1930-1940.

Kastak, D. and C. Reichmuth. 2007. Onset, growth, and recovery of in-air temporary threshold shift in a California sea lion (*Zalophus californianus*). **J. Acoust. Soc. Am.** 122(5):2916-2924.

Kastak, D., B.L. Southall, R.J. Schusterman, and C. Reichmuth. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. **J. Acoust. Soc. Am.** 118(5):3154-3163.

Kastak, D., J. Mulsow, A. Ghoul, and C. Reichmuth. 2008. Noise-induced permanent threshold shift in a harbor seal. **J. Acoust. Soc. Am.** 123(5):2986.

Kastak, D., R.L. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinnipeds. **J. Acoust. Soc. Am.** 106(2):1142-1148.

Kastelein, R., R. Gransier, L. Hoek, and J. Olthuis. 2012a. Temporary threshold shifts and recovery in a harbor porpoise (*Phocoena phocoena*) after octave-band noise at 4 kHz. **J. Acoust. Soc. Am.** 132(5):3525-3537.

Kastelein, R.A., R. Gransier, L. Hoek, A. Macleod, and J.M. Terhune. 2012b. Hearing threshold shifts and recovery in harbor seals (*Phoca vitulina*) after octave-band noise exposure at 4 kHz. **J. Acoust. Soc. Am.** 132(4):2745-2761.

Kastelein, R.A., R. Gransier, L. Hoek, and C.A.F. de Jong. 2012c. The hearing threshold of a harbor porpoise (*Phocoena phocoena*) for impulsive sounds (L). **J. Acoust. Soc. Am.** 132(2):607-610.

Kastelein, R.A., R. Gransier, and L. Hoek, and M. Rambags. 2013a. Hearing frequency thresholds of a harbour porpoise (*Phocoena phocoena*) temporarily affected by a continuous 1.5-kHz tone. **J. Acoust. Soc. Am.** 134(3):2286-2292.

Kastelein, R., R. Gransier, and L. Hoek. 2013b. Comparative temporary threshold shifts in a harbour porpoise and harbour seal, and severe shift in a seal (L). **J. Acoust. Soc. Am.** 134(1):13-16.

Kastelein, R., R. Gransier, and L. Hoek. 2013c. Comparative temporary threshold shifts in a harbour porpoise and harbour seal, and severe shift in a seal. **J. Acoust. Soc. Am.** 134(1):13-16.

Kastelein, R.A., L. Hoek, R. Gransier, M. Rambags, and N. Clayes. 2014. Effect of level, duration, and inter-pulse interval of 1–2 kHz sonar signal exposures on harbor porpoise hearing. **J. Acoust. Soc. Am.** 136:412-422.

Kastelein, R.A., R. Gransier, J. Schop, and L. Hoek. 2015a. Effects of exposure to intermittent and continuous 6-7 kHz sonar sweeps on harbor porpoise (*Phocoena phocoena*) hearing. **J. Acoust. Soc. Am.** 137(4):1623-1633.

Kastelein, R.A., R. Gransier, M.A.T. Marijt, and L. Hoek. 2015b. Hearing frequency thresholds of harbor porpoises (*Phocoena phocoena*) temporarily affected by played back offshore pile driving sounds. **J. Acoust. Soc. Am.** 137(2):556-564.

Kastelein, R.A., R. Gransier, and L. Hoek. 2016a. Cumulative effects of exposure to continuous and intermittent sounds on temporary hearing threshold shifts induced in a harbor porpoise (*Phocoena phocoena*). p. 523-528 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Kastelein, R.A., L. Helder-Hoek, J. Covi, and R. Gransier. 2016b. Pile driving playback sounds and temporary threshold shift in harbor porpoises (*Phocoena phocoena*): effect of exposure duration. **J. Acoust. Soc. Am.** 139(5):2842-2851.

Kastelein, R.A., L. Helder-Hoek, S. Van de Voorde, A.M. von Benda-Beckmann, F.P.A. Lam, E. Jansen, C.A.F. de Jong, and M.A. Ainslie. 2017. Temporary hearing threshold shift in a harbor porpoise (*Phocoena phocoena*) after exposure to multiple airgun sounds. **J. Acoust. Soc. Am.** 142(4):2430-2442.

Kastelein, R.A., L. Helder-Hoek, and J.M. Terhune. 2018. Hearing thresholds, for underwater sounds, of harbor seals (*Phoca vitulina*) at the water surface. **J. Acoust. Soc. Am.** 143:2554-2563.

Kastelein, R.A., L. Helder-Hoek, and R. Gransier. 2019a. Frequency of greatest temporary hearing threshold shift in harbor seals (*Phoca vitulina*) depends on fatiguing sound level. **J. Acoust. Soc. Am.** 145(3):1353-1362.

Kastelein, R.A., L. Helder-Hoek, R. van Kester, R. Huisman, and R. Gransier. 2019b. Temporary threshold shift in harbor porpoises (*Phocoena phocoena*) due to one-sixth octave noise band at 16 kHz. **Aquatic Mamm.** 45(3):280-292.

Kastelein, R.A., L. Helder-Hoek, R. van Kester, R. Huisman, and R. Gransier. 2019c. Temporary threshold shift in harbor porpoises (*Phocoena phocoena*) due to one-sixth octave noise band at 16 kHz. **Aquatic Mamm.** 45(3):280-292.

Kastelein, R.A., L. Helder-Hoek, S. Cornelisse, L.A.E. Huijser, and Gransier. 2019d. Temporary threshold shift in harbor porpoises (*Phocoena phocoena*) due to one-sixth octave noise band at 32 kHz. **Aquatic Mamm.** 45(5):549-562.

Kastelein, R.A., L. Helder-Hoek, S.A. Cornelisse, L.A.E. Huijser, and J.M. Terhune. 2020a. Temporary hearing threshold shift in harbor seals (*Phoca vitulina*) due to a one-sixth-octave noise band centered at 32 kHz. **J. Acoust. Soc. Am.** 147(3):1885-1896.

Kastelein, R.A., C. Parlog., L. Helder-Hoek, S.A. Cornelisse, L.A.E. Huijser, and J.M. Terhune. 2020b. Temporary hearing threshold shift in harbor seals (*Phoca vitulina*) due to a one-sixth-octave noise band centered at 40 kHz. **J. Acoust. Soc. Am.** 147(3):1966-1976.

Kastelein, R.A., L. Helder-Hoek, S.A. Cornelisse, L.N. Defillet, L.A.E. Huijser, and J.M. Terhune. 2020c. Temporary hearing threshold shift in harbor seals (*Phoca vitulina*) due to a one-sixth-octave noise bands centered at 0.5, 1, and 2 kHz. **J. Acoust. Soc. Am.** 148(6):3873-3885.

Kastelein, R.A., L. Helder-Hoek, S.A. Cornelisse, L.N. Defillet, L.A.E. Huijser, and J.M. Terhune. 2020d. Temporary hearing threshold shift in harbor porpoises (*Phocoena phocoena*) due to one-sixth-octave noise bands centered at 63 kHz. **Aquatic Mamm.** 46(2):167-182.

Kastelein, R.A., L. Helder-Hoek, S.A. Cornelisse, L.A.E. Huijser, and J.M. Terhune. 2020e. Temporary hearing threshold shift at ecologically relevant frequencies in a harbor porpoise (*Phocoena phocoena*) due to exposure to a noise band centered at 88.4 kHz. **Aquatic Mamm.** 46(5):444-453.

Kastelein, R.A., L. Helder-Hoek, S.A. Cornelisse, L.N. Defillet, and L.A. Huijser. 2020f. Temporary hearing threshold shift in a second harbor porpoise (*Phocoena phocoena*) after exposure to a one-sixth-octave noise band at 1.5 kHz and 6.5 kHz continuous wave. **Aquatic Mamm.** 46(5):431-443.

Kastelein, R.A., L. Helder-Hoek, S.A. Cornelisse, A.M. von Benda-Beckmann, F.P.A. Lam, C.A.F. de Jong, and D.R. Ketten. 2020g. Lack of reproducibility of temporary hearing threshold shifts in a harbor porpoise after exposure to repeated airgun sounds. **J. Acoust. Soc. Am.** 148:556-565.

Kastelein, R.A., L. Helder-Hoek, L.N. Defillet, L.A. Huijser, J.M. Terhune, and R. Gransier. 2021a. Temporary hearing threshold shift in a harbor porpoise (*Phocoena phocoena*) due to exposure to a continuous one-sixth-octave noise band centered at 0.5 kHz. **Aquatic Mamm.** 47(2):135-145.

Kastelein, R.A., L. Helder-Hoek, L.N. Defillet, L.A. Huijser, J.M. Terhune, and R. Gransier. 2021b. Temporary hearing threshold shift in California sea lions (*Zalophus californianus*) due to one-sixth-octave noise bands centered at 2 and 4 kHz: effect of duty cycle and testing the equal-energy hypothesis. **Aquatic Mamm.** 47(4):394-418.

Kastelein, R.A., L. Helder-Hoek, L.N. Defillet, L.A. Huijser, J.M. Terhune, and R. Gransier. 2022. Temporary hearing threshold shift in California sea lions (*Zalophus californianus*) due to one-sixth-octave noise bands centered at 8 and 16 kHz: effect of duty cycle and testing the equal-energy hypothesis. **Aquatic Mamm.** 48(1):36-58.

Kato, H. and W.F. Perrin. 2018. Bryde's whale *Balaenoptera edeni*. p. 143-145 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.) Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Katona, S.K. and J.A. Beard. 1990. Population size, migrations and feeding aggregations of the humpback whale (*Megaptera novaeangliae*) in the western North Atlantic Ocean. **Rep. Int. Whal. Comm.** (Spec. Iss. 12): 295-306.

Katona, S.K., J.A. Beard, P.E. Girton, and F. Wenzel. 1988. Killer whales (*Orcinus orca*) from the Bay of Fundy to the Equator, including the Gulf of Mexico. **Rit Fiskideildar** 11:205-224.

Kavanagh, A.S., M. Nykänen, W. Hunt, N. Richardson, and M.J. Jessopp. 2019. Seismic surveys reduce cetacean sightings across a large marine ecosystem. **Sci. Rep.** 9:19164.

Kenney, R.D. and H.E. Winn. 1987. Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. **Continent. Shelf Res.** 7:107-114.

Kenney, R.D., C.A. Mayo, and H.E. Winn. 2001. Migration and foraging strategies at varying spatial scales in western North Atlantic right whales: a review of hypotheses. **J. Cetac. Res. Manage**. **Spec. Iss.** 2:251-260.

Kenney, R.D., H.E. Winn, and M.C. Macaulay. 1995. Cetaceans in the Great South Channel, 1979–1989: right whale (*Eubalaena glacialis*). **Cont. Shelf Res.** 15:385-414.

Ketten, D.R. 2012. Marine mammal auditory system noise impacts: evidence and incidence. p. 207-212 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York. 695 p.

Ketten, D.R., J. O'Malley, P.W.B. Moore, S. Ridgway, and C. Merigo. 2001. Aging, injury, disease, and noise in marine mammal ears. **J. Acoust. Soc. Am.** 110(5, Pt. 2):2721.

King, S.L., R.S. Schick, C. Donovan, C.G. Booth, M. Burgman, L. Thomas, and J. Harwood. 2015. An interim framework for assessing the population consequences of disturbance. **Meth. Ecol. Evol.** 6(1):1150-1158.

Klatsky, L.J. 2004. Movement and dive behavior of bottlenose dolphins (*Tursiops truncatus*) near the Bermuda Pedestal. MSc thesis, San Diego State University.

Klinck, H., S.L. Nieukirk, D.K. Mellinger, K. Klinck, H. Matsumoto, and R.P. Dziak. 2012. Seasonal presence of cetaceans and ambient noise levels in polar waters of the North Atlantic. **J. Acoust. Soc. Am.** 132(3): EL176-EL181.

Knowlton, A.R., J. Sigurjónsson, J.N. Ciano, and S.D. Kraus. 1992. Long-distance movements of North Atlantic right whales (*Eubalaena glacialis*). **Mar. Mamm. Sci.** 8(4):397-405.

Knowlton, A.R., J.B. Ring, and B. Russell. 2002. Right whale sightings and survey effort in the mid-Atlantic region: migratory corridor, time frame, and proximity to port entrances. Final Rep. to National Marine Fisheries Ship Strike Working Group. 25 p.

Kok, A.C.M., J.P. Engelberts, R.A. Kastelein, L. Helder-Hoek, S. Van de Voorde, F. Visser, and H. Slabbekoorn. 2017. Spatial avoidance to experimental increase of intermittent and continuous sound in two captive harbour porpoises. **Env. Poll.** 233:1024-1036.

Kowarski, K.A., S.B. Martin, E.E. Maxner, C.B. Lawrence, J.J.Y. Delarue, and J.L. Miksis-Olds. 2022. Cetacean acoustic occurrence on the US Atlantic Outer Continental Shelf from 2017 to 2020. **Mar. Mamm. Sci.** doi: 10.1111/mms.12962

Kraus, S.D., J.H. Prescott, A.R. Knowlton, and G.S. Stone. 1986. Migration and calving of right whales (*Eubalaena glacialis*) in the western North Atlantic. **Rep. Int. Whal. Comm. Spec. Iss.** 10:139-144.

Krieger, K.J. and B.L. Wing. 1984. Hydroacoustic surveys and identification of humpback whale forage in Glacier Bay, Stephens Passage, and Frederick Sound, southeastern Alaska, summer 1983. NOAA Tech. Memo. NMFS F/NWC-66. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 60 p. NTIS PB85-183887.

Krieger, K.J. and B.L. Wing. 1986. Hydroacoustic monitoring of prey to determine humpback whale movements. NOAA Tech. Memo. NMFS F/NWC-98. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 63 p. NTIS PB86-204054.

Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin Grampus griseus (G. Cuvier, 1812). p. 183-212 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Kujawa, S.G. and M.C. Liberman. 2009. Adding insult to injury: cochlear nerve degeneration after "temporary" noise-induced hearing loss. **J. Neurosci.** 29(45):14077-14085.

Kunc, H.P., K.E. McLaughlin, and R. Schmidt. 2016. Aquatic noise pollution: implications for individuals, populations, and ecosystems. **Proc. R. Soc.** B 283:20160839.

Kyhn, L.A., D.M. Wisniewska, K. Beedholm, J. Tougaard, M. Simon, A. Mosbech, and P.T. Madsen. 2019. Basin-wide contributions to the underwater soundscape by multiple seismic surveys with implications for marine mammals in Baffin Bay, Greenland. **Mar. Poll. Bull.** 138:474-490.

Lalas, C. and H. McConnell. 2015. Effects of seismic surveys on New Zealand fur seals during daylight hours: do fur seals respond to obstacles rather than airgun noise? **Mar. Mamm. Sci.** 32(2):643-663.

Laws, R. 2012. Cetacean hearing-damage zones around a seismic source. p. 473-476 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Le Prell, C.G. 2012. Noise-induced hearing loss: from animal models to human trials. p. 191-195 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Leatherwood, S., D.K. Caldwell, and H.E. Winn. 1976. Whales, dolphins, and porpoises of the western North Atlantic. A guide to their identification. NOAA Tech. Rep. NMFS Circ. 396. U.S. Dep. Comm., Washington, DC. 176 p.

Lesage, V., A. Omrane, T. Doniol-Valccroze, and A. Mosnier. 2017. Increased proximity of vessels reduces feeding opportunities of blue whales in St. Lawrence Estuary, Canada. **Endang. Species Res**. 32:351–361.

LGL (LGL Limited). 2014. Environmental assessment of a marine geophysical survey by the R/V *Marcus G. Langseth* in the Atlantic Ocean, September–October 2014. LGL Report TA8350-1 prepared by LGL Limited, King City, ON, for Lamont-Doherty Earth Observatory, Palisades, NY, and National Science Foundation, Arlington, VA. 104 p.

Liberman, M.C., M.J. Epstein, S.S. Cleveland, H. Wang, and S.F. Maison. 2016. Toward a differential diagnosis of hidden hearing loss in humans. **PLoS ONE** 11(9):e0162726.

Lien J., R. Sears, G.B. Stenson, P.W. Jones, and I-Hsun Ni. 1989. Right whale, (*Eubalaena glacialis*), sightings in waters off Newfoundland and Labrador and the Gulf of St. Lawrence, 1978–1987. **Can. Field-Nat.** 103:91-93.

Lockyer, C.H. and S.G. Brown. 1981. The migration of whales. p. 105-137 In: D.J. Aidley (ed.), Animal migration. Soc. Exp. Biol. Sem. Ser. 13, Cambridge University Press, London, U.K.

Lucke, K., U. Siebert, P.A. Lepper, and M.-A. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. **J. Acoust. Soc. Am.** 125(6):4060-4070.

Lucke, K., S.B. Martin, and R. Racca. 2020. Evaluating the predictive strength of underwater noise exposure criteria for marine mammals. **J. Acoust. Soc. Am.** 147:3985. doi:10.1121/10.0001412.

Luís, A.R., M.N. Couchinho, and M.E. Dos Santos. 2014. Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. **Mar. Mamm. Sci.** 30(4):1417-1426

Lurton, X. 2016. Modelling of the sound field radiated by multibeam echosounders for acoustical impact assessment. **Appl. Acoust.** 101:201-216.

Lusseau, D. and L. Bejder. 2007. The long-term consequences of short-term responses to disturbance experience from whalewatching impact assessment. **Int. J. Comp. Psych.** 20(2-3):228-236.

Lyamin, O.I., S.M. Korneva, V.V. Rozhnov, and L.M. Mukhametov. 2016. Cardiorespiratory responses to acoustic noise in belugas. p. 665-672 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

MacGillivray, A.O., R. Racca, and Z. Li. 2014. Marine mammal audibility of selected shallow-water survey sources. **J. Acoust. Soc. Am.** 135(1): EL35-EL40.

MacLeod, C.D., Perrin, W.F., Pitman, R., Barlow, J., Ballance, L., D Amico, A.N.G.E.L.A., Gerrodette, T., Joyce, G., Mullin, K.D., Palka, D.L. and Waring, G.T., 2005. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). Journal of Cetacean Research and Management, 7(3), p.271.

MacLeod, C.D., W.F. Perrin, R. Pitman, J. Barlow, L.T. Ballance, A. D'Amico, T. Gerrodette, G. Joyce, K.D. Mullin, D. Palka, and G.T. Waring. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). **J. Cetac. Res. Manage.** 7(3):271-286.

MAFMC (Mid-Atlantic Fishery Management Council) and NMFS (National Marine Fisheries Service). 2008. Amendment 1 to the tilefish fishery management plan, Vol. 1. Mid-Atlantic Fishery Management Council in cooperation with the National Marine Fisheries Service. A publication of the Mid-Atlantic Fishery Management Council pursuant to National Oceanic and Atmospheric Administration Award No. NA57FC0002. Accessed in October 2013 at https://googledrive.com/host/0B7aKVuJOPoZVYm90STFRTTZFLU0/Tilefish_Amend_1_Vol_1.pdf.

Malakoff, D. 2002. Suit ties whale deaths to research cruise. **Science** 298(5594):722–723.

Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280 *In:* G.D. Greene, F.R. Engelhard, and R.J. Paterson (eds.), Proc. Workshop on Effects of Explosives Use in the Marine Environment, Jan. 1985, Halifax, NS. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Ont. 398 p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 5586. Rep. from Bolt Beranek & Newman Inc., Cambridge, MA, for MMS, Alaska OCS Region, Anchorage, AK. NTIS PB86-218377.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark, and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. BBN Rep. 5851; OCS Study MMS 85-0019. Rep. from BBN Labs Inc., Cambridge, MA, for MMS, Anchorage, AK. NTIS PB86-218385.

Mannocci, L., J.J. Roberts, D.L. Miller, and P.N. Halpin. 2017. Extrapolating cetacean densities to quantitatively assess human impacts on populations in the high seas. **Conserv. Biol.** 31(3):601–614. Models for all species available at: http://seamap.env.duke.edu/models/AFTT-2015/.

Martin, S.B., K. Lucke, and D.R. Barclay. 2020. Techniques for distinguishing between impulsive and non-impulsive sound in the context of regulating sound exposure for marine mammals. **J. Acoust. Soc. Am.** 147(4):2159-2176.

Martins, D.T.L., M.R. Rossi-Santos, and F.J. De Lima Silva. 2016. Effects of anthropogenic noise on the acoustic behaviour of *Sotalia guianensis* (Van Bénéden, 1864) in Pipa, North-eastern Brazil. **J. Mar. Biol. Assoc. U.K.** 2016:1-8.

Matos, F. 2015. Distribution of cetaceans in Vestfjorden, Norway, and possible impacts of seismic surveys. MSc. Thesis, University of Nordland, Norway. 45 p.

Matthews, L. 2017. Harbor seal (*Phoca vitulina*) reproductive advertisement behavior and the effects of vessel noise. Ph.D. Thesis, Syracuse University. 139 p.

Matthews, L.P. and S.E. Parks. 2021. An overview of North Atlantic right whale acoustic behavior, hearing capabilities, and responses to sound. **Mar. Poll. Bull.** 173:113043.

Maze-Foley, K. and K.D. Mullin. 2006. Cetaceans of the oceanic northern Gulf of Mexico: Distributions, group sizes and interspecific associations. **J. Cetacean Res. Manage.** 8(2):203-213.

McAlpine, D.F. 2018. Pygmy and dwarf sperm whales. p. 786-788 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd ed. Academic Press/Elsevier, San Diego, CA. 1157 p.

McCarthy, E., D. Moretti, L. Thomas, N. DiMarzio, R. Morrissey, S. Jarvis, J. Ward, A. Izzi, and A. Dilley. 2011. Changes in spatial and temporal distribution and vocal behavior of Blainville's beaked whales (*Mesoplodon densirostris*) during multiship exercises with mid-frequency sonar. **Mar. Mamm. Sci.** 27(3):E206-E226.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: Analysis of airgun signals; and effects of air gun

exposure on humpback whales, sea turtles, fishes, and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, Western Australia, for Australian Petrol. Produc. & Explor. Association, Sydney, NSW. 188 p.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe, and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. **APPEA J.** 38:692-707.

McDonald, T.L., W.J. Richardson, K.H. Kim, and S.B. Blackwell. 2010. Distribution of calling bowhead whales exposed to underwater sounds from Northstar and distant seismic surveys, 2009. p. 6-1 to 6-38 *In*: W.J. Richardson (ed.), Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil development, Alaskan Beaufort Sea: Comprehensive report for 2005–2009. LGL Rep. P1133-6. Rep. from LGL Alaska Res. Assoc. Inc. (Anchorage, AK), Greeneridge Sciences Inc. (Santa Barbara, CA), WEST Inc. (Cheyenne, WY) and Applied Sociocult. Res. (Anchorage, AK) for BP Explor. (Alaska) Inc., Anchorage, AK. 265 p.

McDonald, T.L., W.J. Richardson, K.H. Kim, S.B. Blackwell, and B. Streever. 2011. Distribution of calling bowhead whales exposed to multiple anthropogenic sound sources and comments on analytical methods. p. 199 *In*: Abstr. 19th Bienn. Conf. Biol. Mar. Mamm., Tampa, FL, 27 Nov.–2 Dec. 2011. 344 p.

McGeady, R., B.J. McMahon, and S. Berrow. 2016. The effects of surveying and environmental variables on deep diving odontocete stranding rates along Ireland's coast. **Proc. Meet. Acoust.** 4ENAL 27(1):040006.

McHuron, E.A., L. Aerts, G. Gailey, O. Sychenko, D.P. Costa, M. Mangel, and L.K. Schwartz. 2021. Predicting the population consequences of acoustic disturbance, with application to an endangered gray whale population. **Ecol. Appl.** 31(8): p.e02440.

McKenna, M.F., J. Calambokidis, E.M. Oleson, D.W. Laist, and J.A. Goldbogen. 2015. Simultaneous tracking of blue whales and large ships demonstrate limited behavioral responses for avoiding collision. **Endang. Species. Res.** 27:219-232.

Mead, J.G. 1986. Twentieth-century records of right whales (*Eubalaena glacialis*) in the northwest Atlantic Ocean. **Rep. Int. Whal. Comm. Spec. Iss.** 10:109-120.

Mead, J.G. 1989. Beaked whales of the genus *Mesoplodon*. p. 349-430 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 442 p.

Mead, J.G. and C.W. Potter. 1995. Recognizing two populations of the bottlenose dolphins (*Tursiops truncatus*) off the Atlantic coast of North America: morphological and ecological considerations. IBI Reports 5:31-44.

Meier, S.K., S.B. Yazvenko, S.A. Blokhin, P. Wainwright, M.K. Maminov, Y.M. Yakovlev, and M.W. Newcomer. 2007. Distribution and abundance of western gray whales off northeastern Sakhalin Island, Russia, 2001-2003. **Environ. Monit. Assess.** 134(1-3):107-136.

Melcón, M.L., A.J. Cummins, S.M. Kerosky, L.K. Roche, S.M. Wiggins, and J.A. Hildebrand. 2012. Blue whales response to anthropogenic noise. **PLoS ONE** 7(2): e32681. doi:10.1371/journal.pone.0032681.

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton, and W.J. Richardson. 1999. Whales. p. 5-1 to 5-109 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray, and D. Hannay. 2005. Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001–2002. p. 511-542 *In:* S.L. Armsworthy, P.J. Cranford, and K. Lee (eds.), Offshore Oil and Gas Environmental Effects Monitoring/Approaches and Technologies. Battelle Press, Columbus, OH.

Miller, P.J.O., M.P. Johnson, P.T. Madsen, N. Biassoni, M. Quero, and P.L. Tyack. 2009. Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. **Deep-Sea Res. I** 56(7):1168-1181.

Miller, P.J., S. Isojunno, E. Siegal, F.P.A. Lam, P.H. Kvadsheim, and C. Curé. 2022. Behavioral responses to predatory sounds predict sensitivity of cetaceans to anthropogenic noise within a soundscape of fear. **Proc. Nat. Acad. Sci.** 119(13):e2114932119.

Mitchell, E. and D.G. Chapman. 1977. Preliminary assessment of stocks of northwest Atlantic sei whales (*Balaenoptera borealis*). **Rep. Int. Whal. Comm. Spec. Iss.** 1:117-120.

Mitchell, E.D. 1975. Report on the meeting on small cetaceans, Montreal, April 1-11. **J. Fish. Res. Board Canada** 32:914-916.

Miyazaki, N. and W.F. Perrin. 1994. Rough-toothed dolphin *Steno bredanensis* (Lesson, 1828). p. 1-21 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Monaco, C., J.M. Ibáñez, F. Carrión, and L.M. Tringali. 2016. Cetacean behavioural responses to noise exposure generated by seismic surveys: how to mitigate better? **Ann. Geophys.** 59(4): S0436. doi:10.4401/ag-7089.

Moore, M.J., B. Rubinstein, S.A. Norman, and T. Lipscomb. 2004. A note on the most northerly record of Gervais' beaked whale from the western North Atlantic Ocean. **J. Cetac. Res. Manage.** 6(3):279-281.

Morano, J.L., A.N. Rice, J.T. Tielens, B.J. Estabrook, A. Murray, B.L. Roberts, and C.W. Clark. 2012. Acoustically detected year - round presence of right whales in an urbanized migration corridor. **Conserv. Biol.** 26(4):698-707.

Morell, M., A. Brownlow, B. McGovern, S.A. Raverty, R.E. Shadwick, and M. André. 2017. Implementation of a method to visualize noise-induced hearing loss in mass stranded cetaceans. **Sci. Rep.** 7:41848.

Mortensen, L.O., M.E. Chudzinska, H. Slabbekoorn, and F. Thomsen. 2021. Agent-based models to investigate sound impact on marine animals: bridging the gap between effects on individual behaviour and population level consequences. **Oikos** 130(7):1074-1086

Moulton, V.D. and M. Holst. 2010. Effects of seismic survey sound on cetaceans in the Northwest Atlantic. Environ. Stud. Res. Funds Rep. 182. St. John's, Nfld. 28 p. Available at http://www.esrfunds.org/pdf/182.pdf.

Muir, J.E., L. Ainsworth, R. Joy, R. Racca, Y. Bychkov, G. Gailey, V. Vladimirov, S. Starodymov, and K. Bröker. 2015. Distance from shore as an indicator of disturbance of gray whales during a seismic survey off Sakhalin Island, Russia. **Endang. Species. Res.** 29:161-178.

Muir, J.E., L. Ainsworth, R. Racca, Y. Bychkov, G. Gailey, V. Vladimirov, S. Starodymov, and K. Bröker. 2016. Gray whale densities during a seismic survey off Sakhalin Island, Russia. **Endang. Species Res.** 29(2):211-227.

Mulsow, J., C.E. Schlundt, L. Brandt, and J.J. Finneran. 2015. Equal latency contours for bottlenose dolphins (Tursiops truncatus) and California sea lions (*Zalophus californianus*). **J. Acoust. Soc. Am.** 138(5): 2678-2691.

Mussoline, S.E., D. Risch, L.T. Hatch, M.T. Weinrich, D.N. Wiley, M.A. Thompson, P.J. Corkeron, and S.M. Van Parijs. 2012. Seasonal and diel variation in North Atlantic right whale up-calls: implications for management and conservation in the northwestern Atlantic Ocean. **Endang. Species Res.** 17(1):17-26.

Nachtigall, P.E. and A.Y. Supin. 2013. Hearing sensation changes when a warning predicts a loud sound in the false killer whale. Abstr. 3rd Int. Conf. Effects of Noise on Aquatic Life, Budapest, Hungary, August 2013.

Nachtigall, P.E. and A.Y. Supin. 2014. Conditioned hearing sensitivity reduction in the bottlenose dolphin (*Tursiops truncatus*). **J. Exp. Biol.** 217(15): 2806-2813.

Nachtigall, P.E. and A.Y. Supin. 2015. Conditioned frequency-dependent hearing sensitivity reduction in the bottlenose dolphin (*Tursiops truncatus*). **J. Exp. Biol.** 218(7): 999-1005.

Nachtigall, P.E. and A.Y. Supin. 2016. Hearing sensation changes when a warning predict a loud sound in the false killer whale (*Pseurorca crassidens*). p. 743-746 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Nachtigall, P.E., A.Y. Supin, A.F. Pacini, and R.A. Kastelein. 2018. Four odontocete species change hearing levels when warned of impending loud sound. **Integr. Zool.** 13(2):160-165.

NAMMCO (North Atlantic Marine Mammal Commission). 2022. Fin Whale. Accessed August 2022 at https://nammco.no/fin-whale/#1475843214679-e49183cc-36fc.

National Academies of Sciences, Engineering, and Medicine. 2017. Approaches to understanding the cumulative effects of stressors on marine mammals. The National Academies Press. Washington, DC. 134 p.

NEFSC and SEFSC. 2021. Annual report of a comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the Western North Atlantic Ocean – AMAPPS III.

New, L.F., J. Harwood, L. Thomas, C. Donovan, J.S. Clark, G. Hastie, P.M. Thompson, B. Cheney, L. Scott-Hayward, and D. Lusseau. 2013a. Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. **Function. Ecol.** 27:314-322.

New, L.F., D. Moretti, S.K. Hooker, D.P. Costa, and S.E. Simmons. 2013b. Using energetic models to investigate the survival and reproduction of beaked whales (family Ziphiidae). **PLoS ONE** 8(7): e68725.

Nieukirk, S.L., D.K. Mellinger, S.E. Moore, K. Klinck, R.P. Dziak and J. Goslin. 2012. Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999–2009. **J. Acoust. Soc. Am.** 131(2):1102-1112.

NMFS (National Marine Fisheries Service). 2001. Small takes of marine mammals incidental to specified activities: oil and gas exploration drilling activities in the Beaufort Sea/Notice of issuance of an incidental harassment authorization. **Fed. Reg.** 66(26, 7 Feb.):9291-9298.

NMFS. 2013. Effects of oil and gas activities in the Arctic Ocean: supplemental draft environmental impact statement. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources. Accessed in October 2021 at https://www.fisheries.noaa.gov/national/marine-mammal-protection/environmental-impact-statement-eis-effects-oil-and-gas-activities.

NMFS. 2016a. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: underwater acoustic thresholds for onset of permanent and temporary threshold shifts. U.S. Depart. Commerce, National Oceanic and Atmospheric Administration. 178 p.

NMFS. 2016b. Endangered and threatened species; critical habitat for endangered north Atlantic right whale. Doc. Citation 81 FR 4837, 50 CFR 226. National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 38 p. Available at: https://www.federalregister.gov/documents/2016/01/27/2016-01633/endangered-and-threatened-species-critical-habitat-for-endangered-north-atlantic-right-whale.

NMFS. 2016c. Endangered and threatened species; identification of 14 distinct population segments of the humpback whale (*Megaptera novaeangliae*) and revision of species-wide listing. Final Rule. **Fed. Reg.** 81(174, 8 Sept.):62260-62320.

NMFS. 2018. 2018 revision to: technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (version 2.0). Underwater thresholds for onset of permanent and temporary threshold shifts. Office of Protected Resources Nat. Mar. Fish. Serv., Silver Spring, MD. 167 p.

NMFS. 2019a. Takes of marine mammals incidental to specified activities; taking marine mammals incidental to a marine geophysical survey in the Gulf of Alaska. **Fed. Reg.** 84(113, 12 June):27246-27270.

NMFS. 2019b. Takes of marine mammals incidental to specified activities; taking marine mammals incidental to a marine geophysical survey in the Northeast Pacific Ocean. **Fed. Reg.** 84(140, 22 July):35073-35099.

NMFS. 2022. Amendments to the North Atlantic right whale vessel strike reduction rule. Proposed rule. **Fed. Reg.** 87(146, 1 August):46922-46936.

NOAA. 2022a. 2017-2022 North Atlantic Right Whale Unusual Mortality Event. Accessed on 16 November 2022 at https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2022-north-atlantic-right-whale-unusual-mortality-event.

NOAA. 2022b. North Atlantic right whale calving season 2022. NOAA Fisheries, U.S. Department of Commerce. Available at: https://www.fisheries.noaa.gov/national/endangered-species-conservation/north-atlantic-right-whale-calving-season-2022.

NOAA. 2022c. NOAA right whale sighting advisory system. NOAA Fisheries, U.S. Department of Commerce. Available at: https://apps-nefsc.fisheries.noaa.gov/psb/surveys/MapperiframeWithText.html.

NOAA. 2022d. Reducing vessel strikes to north Atlantic right whales. NOAA Fisheries, U.S. Department of Commerce. Available at: https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales.

NOAA. 2022e. 2016-2022 Humpback Whale Unusual Mortality Event along the Atlantic Coast. Accessed on 16 November 2022 at https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2022-humpback-whale-unusual-mortality-event-along-atlantic-coast.

NOAA. 2022f. 2017-2022 Minke Whale Unusual Mortality Event along the Atlantic Coast. Accessed on 16 November 2022 at https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2022-minke-whale-unusual-mortality-event-along-atlantic-coast.

NOAA. 2022g. Active and Closed Unusual Mortality Events. Accessed on 16 November 2022 at https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events.

Nowacek, D.P., A.I. Vedenev, B.L. Southall, and R. Racca. 2012. Development and implementation of criteria for exposure of western gray whales to oil and gas industry noise. p. 523-528 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Nowacek, D.P., C.W. Clark, P. Mann, P.J.O. Miller, H.C. Rosenbaum, J.S. Golden, M. Jasny, J. Kraska, and B.L. Southall. 2015. Marine seismic surveys and ocean noise: time for coordinated and prudent planning. **Front. Ecol. Environ.** 13(7):378-386.

Nowacek, D.P., K. Bröker, G. Donovan, G. Gailey, R. Racca, R.R. Reeves, A.I. Vedenev, D.W. Weller, and B.L. Southall. 2013a. Responsible practices for minimizing and monitoring environmental impacts of marine seismic surveys with an emphasis on marine mammals. **Aquatic Mamm.** 39(4):356-377.

Nowacek, D.P., K. Bröker, G. Donovan, G. Gailey, R. Racca, R.R. Reeves, A.I. Vedenev, D.W. Weller, and B.L. Southall. 2013b. Environmental impacts of marine seismic surveys with an emphasis on marine mammals. **Aquatic Mamm.** 39(4):356-377.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. **Mamm. Rev.** 37(2):81-115.

NRC (National Research Council). 2005. Marine mammal populations and ocean noise/Determining when noise causes biologically significant effects. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on characterizing biologically significant marine mammal behavior (Wartzok, D.W., J. Altmann, W. Au, K. Ralls, A. Starfield, and P.L. Tyack). Nat. Acad. Press, Washington, DC. 126 p.

NSF (National Science Foundation). 2012. Record of Decision for marine seismic research funded by the National Science Foundation. June 2012. 41 p. Accessed at http://www.nsf.gov/geo/oce/envcomp/rod-marine-seismic-research-june2012.pdf on 23 September 2013.

NSF and USGS (National Science Foundation and U.S. Geological Survey). 2011. Final Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey. Available at http://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/nsf-usgs-final-eis-oeis-with-appendices.pdf.

O'Brien, J.M., S. Beck, S.D. Berrow, M. André, M. van der Schaar, I. O'Connor, and E.P. McKeown. 2016. The use of deep water berths and the effect of noise on bottlenose dolphins in the Shannon Estuary cSAC. p. 775-783 In: The effects of noise on aquatic life II, Springer, New York, NY. 1292 p.

Oakley, J.A., A.T. Williams, and T. Thomas. 2017. Reactions of harbour porpoise (*Phocoena phocoena*) to vessel traffic in the coastal waters of South Wales, UK. **Ocean Coastal Manage.** 138:158-169.

OBIS (Ocean Biogeographic Information System). 2022. Data from the Ocean Biogeographic Information System. Intergovernmental Oceanographic Commission of UNESCO. Accessed July 2022 at http://www.iobis.org.

Odell, D.K. and K.M. McClune. 1999. False killer whale *Pseudorca crassidens* (Owen, 1846). p. 213-243 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Olson, P.A. 2018. Pilot whales *Globicephala melas* and *G. macrorhynchus*. p. 701-705 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Palka, D. 2020. Cetacean abundance in the US Northwestern Atlantic Ocean Summer 2016. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 20-05. 60 p. Available from: https://www.fisheries.noaa.gov/new-england-mid-atlantic/northeast-center-reference-document-series.

Palka, D.L., S. Chavez-Rosales, E. Josephson, D. Cholewiak, H.L. Haas, L. Garrison, M. Jones, D. Sigourney, G. Waring (retired), M. Jech, E. Broughton, M. Soldevilla, G. Davis. A. DeAngelis, C.R. Sasso, M.W. Winton, R.J. Smolowitz, G. Fay, E. LaBrecque, J.B. Leiness, M. Warden, K. Murray, and C. Orphanides. 2017. Atlantic Marine Assessment Program for Protected Species: 2010-2014. US Dept. of the Interior, Bureau of Ocean Energy Management, Atlantic OCS Region, Washington, DC. OCS Study BOEM 2017-071. 211 p.

Palka, D., L.A. Dias, E. Broughton, S. Chavez-Rosales, D. Cholewiak, G. Davis, A. DeAngelis, L. Garrison, H. Haas, J. Hatch, K. Hyde, M. Jech, E. Josephson, L. Mueller-Brennan, C. Orphanides, N. Pegg, C. Sasso, D. Sigourney, M. Soldevilla, and H. Walsh. 2021. Atlantic Marine Assessment Program for Protected Species: FY15 – FY19. Washington DC: US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-051.

Palsbøll, P.J., J. Allen, T.H. Anderson, M. Berube, P.J. Clapham, T.P. Feddersen, N.A. Friday, P.S. Hammond, H. Jorgensen, S.K. Katona, F. Larsen, J. Lien, D.K. Mattila, F.B. Nygaard, J. Robbins, R. Sponer, R. Sears, J. Sigurjonsson, T.G. Smith, P.T. Stevick, G.A. Vikingsson, and N. Oien. 2001. Stock structure and composition of the North Atlantic humpback whale, *Megaptera novaeangliae*. Working Pap. SC/53/NAH11. Int. Whal. Comm., Cambridge, U.K.

Papale, E., M. Gamba, M. Perez-Gil, V.M. Martin, and C. Giacoma. 2015. Dolphins adjust species-specific frequency parameters to compensate for increasing background noise. **PLoS ONE** 10(4): e0121711.

Parks, S.E., D.A. Cusano, A. Bocconcelli, and A.S. Friedlaender. 2016b. Noise impacts on social sound production by foraging humpback whales. Abstr. 4th Int. Conf. Effects of Noise on Aquatic Life, July 2016, Dublin, Ireland.

Parks, S.E., K. Groch, P. Flores, R. Sousa-Lima, and I.R. Urazghildiiev. 2016a. Humans, fish, and whales: how right whales modify calling behavior in response to shifting background noise conditions. p. 809-813 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Parks, S.E., M. Johnson, D. Nowacek, and P.L. Tyack. 2011. Individual right whales call louder in increased environmental noise. **Biol. Lett.** 7(1):33-35.

Parks, S.E., M.P. Johnson, D.P. Nowacek, and P.L. Tyack. 2012. Changes in vocal behaviour of North Atlantic right whales in increased noise. p. 317-320 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Patrician, M.R., I.S. Biedron, H.C. Esch, F.W. Wenzel, L.A. Cooper, P.K. Hamilton, A.H. Glass, and M.F. Baumgartner. 2009. Evidence of a North Atlantic right whale calf (*Eubalaena glacialis*) born in northeastern U.S. waters. **Mar. Mamm. Sci.** 25(2):462-477.

Payne, P.M., L.A. Selzer and A.R. Knowlton. 1984. Distribution and density of cetaceans, marine turtles and seabirds in the shelf waters of the northeast U.S., June 1980 - Dec. 1983, based on shipboard observations. National Marine Fisheries Service, Woods Hole. NA81FAC00023: 245.

Payne, R. 1978. Behavior and vocalizations of humpback whales (*Megaptera* sp.). *In*: K.S Norris and R.R. Reeves (eds.), Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. MCC-77/03. Rep. from Sea Life Inc., Makapuu Pt., HI, for U.S. Mar. Mamm. Comm., Washington, DC.

Payne, R. S. and S. McVay. 1971. Songs of humpback whales. **Science** 173(3997):585-597.

Perrin, W.F. 2018a. Pantropical spotted dolphin *Stenella attenuata*. p. 676-678 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd ed. Academic Press/Elsevier, San Diego, CA. 1157 p.

Perrin, W.F. 2018b. Spinner dolphin *Stenella longirostris*. p. 925-928 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd ed. Academic Press/Elsevier, San Diego, CA. 1157 p.

Perrin, W.F., D.K. Caldwell, and M.C. Caldwell. 1994a. Atlantic spotted dolphin *Stenella frontalis* (G. Cuvier, 1829). p. 173-190 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Perrin, W.F., S. Leatherwood, and A. Collet. 1994b. Fraser's dolphin *Lagenodelphis hosei* Fraser, 1956. p. 225-240 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, London, U.K. 416 p.

Perryman, W.L. and K. Danil. 2018. Melon-headed whale *Peponocephala electra*. p. 593-595 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Perryman, W.L., D.W.K. Au, S. Leatherwood, and T.A. Jefferson. 1994. Melon-headed whale *Peponocephala electra* Gray, 1846. p. 363-386 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, London, U.K. 416 p.

Pierson, M.O., J.P. Wagner, V. Langford, P. Birnie, and M.L. Tasker. 1998. Protection from, and mitigation of, the potential effects of seismic exploration on marine mammals. Chapter 7 *In*: M.L. Tasker and C. Weir (eds.), Proc. Seismic Mar. Mamm. Worksh., London, U.K., 23–25 June 1998.

Pike, C., V. Crook, and M. Gollock. 2020. *Anguilla*. The IUCN Red List of Threatened Species. 2020: e.T60344A152845178. Available at: https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T60344A152845178.en.

Pirotta, E., K.L. Brookdes, I.M. Graham, and P.M. Thompson. 2014. Variation in harbour porpoise activity in response to seismic survey noise. **Biol. Lett.** 10:20131090.

Pirotta, E., M. Mangel, D.P. Costa, B. Mate, J.A. Goldbogen, D.M. Palacios, L.A. Hückstädt, E.A. McHuron, L. Schwartz, and L. New. 2018. A dynamic state model of migratory behavior and physiology to assess the consequence of environmental variation and anthropogenic disturbance on marine vertebrates. **Am. Nat.** 191(2): E000-E000.

Pirotta, E., N.D. Merchant, P.M. Thompson, T.R. Barton, and D. Lusseau. 2015. Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. **Biol. Conserv.** 181:82-98.

Pirotta, E., R. Milor, N. Quick, D. Moretti, N. Di Marzio, P. Tyack, I. Boyd, and G. Hastie. 2012. Vessel noise affects beaked whale behavior: results of a dedicated acoustic response study. **PLoS ONE** 7(8):e42535. doi:10.1371/journal.pone.0042535.

Pitman, R. 2018. Mesoplodon beaked whales *Mesoploldon* spp. p. 595-602 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Popov, V., A. Supin, D. Nechaev, E.V. Sysueva, and V. Rozhnov. 2016. Temporary threshold shifts in naïve and experienced belugas: Can dampening of the effects of fatiguing sounds be learned? p. 853-859 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Popov, V.V., A.Y. Supin, D. Wang, K. Wang, L. Dong, and S. Wang. 2011. Noise-induced temporary threshold shift and recovery in Yangtze finless porpoises *Neophocaena phocaenoides asiaeorientalis*. **J. Acoust. Soc. Am.** 130(1):574-584.

Popov, V.V., A.Y. Supin, V.V. Rozhnov, D.I. Nechaev, E.V. Sysuyeva, V.O. Klishin, M.G. Pletenko, and M.B. Tarakanov. 2013. Hearing threshold shifts and recovery after noise exposure in beluga whales, *Delphinapterus leucas*. **J. Exper. Biol.** 216:1587-1596.

Popov, V.V., D.I. Nechaev, E.V. Sysueva, V.V. Rozhnov, and A.Y. Supin. 2015. Spectrum pattern resolution after noise exposure in a beluga whale: evoked potential study. **J. Acoust. Soc. Am.** 138(1):377-388.

Popov, V.V., A.Y. Supin, A.P. Gvozdeva, D.I. Nechaev, M.B. Tarakanov, and E.V. Sysueva. 2020. Spatial release from masking in a bottlenose dolphin *Tursiops truncatus*. **J. Acoust. Soc. Am.** 147(3):1719-1726.A

Putland, R.L., N.D. Merchant, A. Farcas, and C.A. Radford. 2017. Vessel noise cuts down communication space for vocalizing fish and marine mammals. **Glob. Change Biol.** 24(4):1708-1721.

Quick, N., L. Scott-Hayward, D. Sadykova, D. Nowacek, and A.J. Read. 2017. Effects of a scientific echo sounder on the behavior of short-finned pilot whales (*Globicephala macrorhynchus*). **Can. J. Fish. Aquat. Sci.** 74:716-726.

Redfern, J.V., M.F. McKenna, T.J. Moore, J. Calambokidis, M.L. Deangelis, E.A. Becker, J. Barlow, K.A. Forney, P.C. Fiedler, and S.J. Chivers. 2013. Assessing the risk of ships striking large whales in marine spatial planning. **Conserv. Biol.** 27(2):292-302.

Reeves, R.R. 2001. Overview of catch history, historic abundance and distribution of right whales in the western North Atlantic and in Cintra Bay, West Africa. **J. Cetac. Res. Manage.** Spec. Iss. 2:187-192.

Reeves, R.R. and E. Mitchell. 1986. American pelagic whaling for right whales in the North Atlantic. **Rep. Int. Whal. Comm**. Spec. Iss. 10:221-254.

Reeves, R.R., B.S. Stewart, P.J. Clapham, and J.A. Powell. 2002. Guide to marine mammals of the world. Chanticleer Press, New York, NY. 525 p.

Reichmuth, C., A. Ghoul, A. Rouse, J. Sills, and B. Southall. 2016. Low-frequency temporary threshold shift not measured in spotted or ringed seals exposed to single airgun impulses. **J. Acoust. Soc. Am.** 140(4): 2646-2658.

Reilly, S.B. and V.G. Thayer. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. **Mar. Mamm. Sci.** 6(4):265–277.

Rice, A.N., J.T. Tielens, B.J. Estabrook, C.A. Muirhead, A. Rahaman, M. Guerra, and C.W. Clark. 2014. Variation of ocean acoustic environments along the western North Atlantic coast: a case study in context of the right whale migration route. **Ecol. Inform.** 21:89-99.

Rice, D.W. 1998. Marine mammals of the world, systematics and distribution. Spec. Publ. 4. Soc. Mar. Mammal., Allen Press, Lawrence, KS. 231 p.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego. 576 p.

Richardson, W.J., G.W. Miller, and C.R. Greene, Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. **J. Acoust. Soc. Am.** 106(4, Pt. 2):2281 (Abstract).

Risch, D., P.J. Corkeron, W.T. Ellison, and S.M. Van Parijs. 2012. Changes in humpback whale song occurrence in response to an acoustic source 200 km away. **PLoS One** 7: e29741.

Risch, D., P.J. Corkeron, W.T. Ellison, and S.M. Van Parijs. 2014. Formal comment to Gong et al.: Ecosystem scale acoustic sensing reveals humpback whale behavior synchronous with herring spawning processes and re-evaluation finds no effect of sonar on humpback song occurrence in the Gulf of Maine in fall 2006. **PLoS One** 9(10): e109225.

Roberts, J.J., B.D. Best, L. Mannocci, E. Fujioka, P.N. Halpin, D.L. Palka, L.P. Garrison, K.D. Mullin, T.V. Cole, C.B. Khan, and W.A. McLellan. 2016. Habitat-based cetacean density models for the US Atlantic and Gulf of Mexico. **Sci. Rep.** 6(1):22615. Densities last updsated on 20 June 2022 at https://seamap.env.duke.edu/models/Duke/EC/

Robertson, F.C., W.R. Koski, T.A. Thomas, W.J. Richardson, B. Würsig, and A.W. Trites. 2013. Seismic operations have variable effects on dive-cycle behavior of bowhead whales in the Beaufort Sea. **Endang. Species Res.** 21:143-160.

Rolland, R.M., S.E. Parks, K.E. Hunt, M. Castellote, P.J. Corkeron, D.P. Nowacek, S.K. Water, and S.D. Kraus. 2012. Evidence that ship noise increases stress in right whales. **Proc. R. Soc. B** 279:2363-2368.

RPS. 2014a. Final Environmental Assessment for Seismic Reflection Scientific Research Surveys During 2014 and 2015 in Support of Mapping the US Atlantic Seaboard Extended Continental Margin and Investigating Tsunami Hazards. Report prepared by RPS Evan – Hamilton Inc. (EHI), for USGS.

RPS. 2014b. Draft protected species mitigation and monitoring report: U.S. Geological Survey 2-D seismic reflection scientific research survey program: mapping the U.S. Atlantic seaboard extended continental margin and investigating tsunami hazards, in the northwest Atlantic Ocean, Phase 1, 20 August 2014–13 September 2014, R/V *Marcus G. Langseth*. Rep. from RPS, Houston, TX, for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY.

RPS. 2015. Protected Species Mitigation and Monitoring Report: East North American Margin (ENAM) 2-D Seismic Survey in the Atlantic Ocean off the coast of Cape Hatteras, North Carolina. 16 September – 18 October 2014. Report by RPS, Houston, TX, for Lamont-Doherty Earth Observatory, Palisades, NY.

Ruppel, C.D., T.C. Weber, E.R. Staaterman, S.J. Labak, and P.E. Hart. 2022. Categorizing active marine acoustic sources based on their potential to affect marine animals. **J. Mar. Sci. Eng.** 10:1278.

Rutenko, A.N., M.M. Zykov, V.A. Gritsenko, M.Y. Fershalov, M.R. Jenkerson, R. Racca, and V.E. Nechayuk 2022. Real-time acoustic monitoring with telemetry to mitigate potential effects of seismic survey sounds on marine mammals: a case study offshore Sakhalin Island. **Env. Monit. Assess.** 194 (Suppl. 1):745. https://doi.org/10.1007/s10661-022-10019-6.

Sairanen, E.E. 2014. Weather and ship induced sounds and the effect of shipping on harbor porpoise (*Phocoena phocoena*) activity. M.Sc. Thesis, University of Helsinki. 67 p.

Salden, D.R. 1993. Effects of research boat approaches on humpback whale behavior off Maui, Hawaii, 1989–1993. p. 94 *In*: Abstr. 10th Bienn. Conf. Biol. Mar. Mamm., Galveston, TX, Nov. 1993. 130 p.

Savage, K. 2017. Alaska and British Columbia Large Whale Unusual Mortality Event Summary Report. NOAA Fisheries, Juneau, AK. 42 p.

Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2016. Temporary shift in masking hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. p. 987-991 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Scholik-Schlomer, A. 2015. Where the decibels hit the water: perspectives on the application of science to real-world underwater noise and marine protected species issues. **Acoustics Today** 11(3):36-44.

Schwarz, L., E. McHuron, M. Mangel, G. Gailey, and O. Synchenko. 2022. Gray whale habitat use and reproductive success during seismic surveys near their feeding grounds: comparing state-dependent life history models and field data. **Env. Monit. Assess.** 194 (Suppl. 1):733. https://doi.org/10.1007/s10661-022-10024-9.

Sciacca, V., S. Viola, S. Pulvirenti, G. Riccobene, F. Caruso, E. De Domenico, and G. Pavan. 2016. Shipping noise and seismic airgun surveys in the Ionian Sea: potential impact on Mediterranean fin whale. **Proc. Meet. Acoust.** 4ENAL 27(1):040010.

Selzer, L.A. and P.M. Payne. 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. **Mar. Mamm. Sci.** 4:141-153.

Sergeant, D.E. 1977. Stocks of fin whales *Balaenoptera physalus* L. in the North Atlantic Ocean. Rep. Int. Whal. Comm. 27:460-473.

Shearer, J.M., N.J. Quick, W.R. Cioffi, R.W. Baird, D.L. Webster, H.J. Foley, Z.T. Swaim, D.M. Waples, J.T. Bell, and A.J. Read. 2019. Diving behaviour of Cuvier's beaked whales (*Ziphius cavirostris*) off Cape Hatteras, North Carolina. **Roy. Soc. Open Sci**. 6(2):181728.

Sidorovskaia, N., B. Ma, A.S. Ackleh, C. Tiemann, G.E. Ioup, and J.W. Ioup. 2014. Acoustic studies of the effects of environmental stresses on marine mammals in large ocean basins. p. 1155 *In:* AGU Fall Meeting Abstracts, Vol. 1.

Sills, J.M., B. Ruscher, R. Nichols, B.L. Southall, and C. Reichmuth. 2020. Evaluating temporary threshold shift onset levels for impulsive noise in seals. **J. Acoust. Soc. Am.** 148(5):2973-2986.

Sills, J.M., B.L. Southall, and C. Reichmuth. 2017. The influence of temporally varying noise from seismic air guns on the detection of underwater sounds by seals. **J. Acoust. Soc. Am.** 141(2):996-1008.

Simard, Y., F. Samaran, and N. Roy. 2005. Measurement of whale and seismic sounds in the Scotian Gully and adjacent canyons in July 2003. p. 97-115 *In*: K. Lee, H. Bain, and C.V. Hurley (eds.), Acoustic monitoring and marine mammal surveys in The Gully and outer Scotian Shelf before and during active seismic surveys. Environ. Stud. Res. Funds Rep. 151. 154 p. (Published 2007).

Simmonds, M.P., S.J. Dolman, M. Jasny, E.C.M. Parsons, L. Weilgart, A.J. Wright, and R. Leaper. 2014. Marine noise pollution – Increasing recognition but need for more practical action. **J. Ocean Tech.** 9:71-90.

Sivle, L.D., P.H., Kvadsheim, and M.A. Ainslie. 2014. Potential for population-level disturbance by active sonar in herring. **ICES J. Mar. Sci.** 72:558-567.

Smith, T.D., J. Allen, P.J. Clapham, P.S. Hammond, S. Katona, F. Larsen, J. Lien, D. Mattila, P. Palsbøll, J. Sigur-jónsson, P.T. Stevick and N. Øien. 1999. An ocean-basin-wide mark-recapture study of the North Atlantic humpback whale (*Megaptera novaeangliae*). **Mar. Mamm. Sci.** 15(1):1-32.

Solé, M., M. Lenoir, M. Durfort, M. López-Bejar, A. Lombarte, M. van der Schaaer, and M. André. 2013a. Does exposure to noise from human activities compromise sensory information from cephalopod statocysts? **Deep-Sea Res. II** 95:160-181.

Solé, M., M. Lenoir, M. Durfort, M. López-Bejar, A. Lombarte, and M. André. 2013b. Ultrastructural damage of *Loligo vulgaris* and *Illex coindetii* statocysts after low frequency sound exposure. **PLoS One** 8(10):e78825.

Solé, M., P. Sigray, M. Lenoir, M. van der Schaar, E. Lalander, and M. André. 2017. Offshore exposure experiments on cuttlefish indicate received sound pressure and particle motion levels associated with acoustic trauma. **Sci. Rep.** 7:45899.

Southall, B.L. 2021. Evolutions in marine mammal noise exposure criteria. **Acoustics Today** 17(2):52-60.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. **Aquat. Mamm.** 33(4):411-522.

Southall, B.L., T. Rowles, F. Gulland, R.W. Baird, and P.D. Jepson. 2013. Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon-headed whales (*Peponocephala electra*) in Antsohihy, Madagascar. Available at http://iwc.int/2008-mass-stranding-in-madagascar.

Southall, B.L., D.P. Nowacek, P.J.O. Miller, and P.L. Tyack. 2016. Experimental field studies to measure behavioral responses of cetaceans to sonar. **Endang. Species Res.** 31:293-315.

Southall, B.L., D.P. Nowacek, A.E. Bowles, V. Senigaglia, L. Bejder, and P.L. Tyack. 2021. Marine mammal noise exposure criteria: assessing the severity of marine mammal behavioral responses to human noise. **Aquatic**

Stanistreet, J.E., D.P. Nowacek, J.T. Bell, D.M. Cholewiak, J.A. Hildebrand, L.E.W. Hodge, S.M. Van Parijs, and A.J. Read. 2018. Spatial and seasonal patterns in acoustic detections of sperm whales *Physeter macrocephalus* along the continental slope in the western North Atlantic Ocean. Endang. **Spec. Res.** 35:1– 13.

Stanistreet, J.E., D.P. Nowacek, S. Baumann-Pickering, J.T. Bell, D.M. Cholewiak, J.A. Hildebrand, L.E. Hodge, H.B. Moors-Murphy, S.M. Van Parijs, and A.J. Read. 2017. Using passive acoustic monitoring to document the distribution of beaked whale species in the western North Atlantic Ocean. **Can. J. Fish. Aqua. Sci**. 74(12):2098-2109.

Stevick, P.T., J. Allen, P.J. Clapham, N. Friday, S.K. Katona, F. Larsen, J. Lien, D.K. Mattila, P.J. Palsbøll, J. Sigurjónsson, T.D. Smith, N. Øien, and P.S. Hammond. 2003. North Atlantic humpback whale abundance and rate of increase four decades after protection from whaling. **Mar. Ecol. Prog. Ser.** 258:263-272.

Stewart, B.S. and S. Leatherwood. 1985. Minke whale *Balaenoptera acutorostrata* Lacépède, 1804. p. 91-136 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, London, UK. 362 p.

Stone, C.J. 2015. Marine mammal observations during seismic surveys from 1994–2010. JNCC Rep. No. 463a. 64 p.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in U.K. waters. **J. Cetac. Res. Manage.** 8(3):255-263.

Supin, A., V. Popov, D. Nechaev, E.V. Sysueva, and V. Rozhnov. 2016. Is sound exposure level a convenient metric to characterize fatiguing sounds? A study in beluga whales. p. 1123-1129 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Sychenko, O., G. Gailey, R. Racca, A. Rutenko, L. Aerts, and R. Melton. 2017. Gray whale abundance and distribution relative to three seismic surveys near their feeding habitat in 2015. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22-27 October, Halifax, Nova Scotia, Canada.

Teilmann, J., D.M. Wisniewska, M. Johnson, L.A. Miller, U. Siebert, R. Dietz, S. Sveegaard, A. Galatius, and P.T. Madsen. 2015. Acoustic tags on wild harbour porpoises reveal context-specific reactions to ship noise. *In*: 18. Danske Havforskermøde 2015, 28-30 January 2015.

Tenessen, J.B. and S.E. Parks. 2016. Acoustic propagation modeling indicates vocal compensation in noise improves communication range for North Atlantic right whales. **Endang. Species Res.** 30:225-237.

Terhune, J.M. and T. Bosker. 2016. Harp seals do not increase their call frequencies when it gets noisier. p. 1149-1153 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Tervo, O.M., S.B. Blackwell, S. Ditlevsen, A.S. Conrad, A.L. Samson, E. Garde, R.G. Hansen, and M.P. Heide-Jørgensen. 2021. Narwhals react to ship noise and airgun pulses embedded in background noise. **Biol. Lett.** 17(11): 20210220.

Thode, A.M., K.H. Kim, S.B. Blackwell, C.R. Greene, Jr., C.S. Nations, T.L. McDonald, and A.M. Macrander. 2012. Automated detection and localization of bowhead whale sounds in the presence of seismic airgun surveys. **J. Acoust. Soc. Am.** 131(5):3726-3747.

Thode, A.M., S.B. Blackwell, A.S. Conrad, K.H. Kim, T. Marques, L. Thomas, C.S. Oedekoven, D. Harris, and K. Bröker. 2020. Roaring and repetition: How bowhead whales adjust their call density and source level (Lombard effect) in the presence of natural and seismic airgun survey noise. **J. Acoust. Soc. Am.** 147(3):2061-2080.

Thompson, D., M. Sjöberg, E.B. Bryant, P. Lovell, and A. Bjørge. 1998. Behavioural and physiological responses of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals to seismic surveys. Abstr. World Mar. Mamm. Sci. Conf., Monaco.

Thompson, P.M., K.L. Brookes, I.M. Graham, T.R. Barton, K. Needham, G. Bradbury, and N.D. Merchant. 2013. Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. **Proc. Royal Soc. B** 280:20132001.

Torres, L.G., P.E. Rosel, C. D'Agrosa and A.J. Read. 2003. Improving managment of overlapping bottlenose dolphin ecotypes through spatial analysis and genetics. **Mar. Mamm. Sci.** 19:502-514.Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohenstiehl, T.J. Crone, and R.C. Holmes. 2009. Broad¬band calibration of R/V Marcus G. Langseth four-string seismic sources. Geochem. Geophys. Geosyst. 10:Q08011. https//doi.org/10.1029/2009GC002451.

Tougaard, J., A.J. Wright, and P.T. Madsen. 2015. Cetacean noise criteria revisited in light of proposed exposure limits for harbour porpoises. **Mar. Poll. Bull.** 90(1-2):196-208.

Tougaard, J., A.J. Wright, and P.T. Madsen. 2016. Noise exposure criteria for harbor porpoises. p. 1167-1173 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Tougaard, J., K. Beedholm, and P.T. Madsen. 2022. Thresholds for noise induced hearing loss in harbor porpoises and phocid seals. **J. Acoust. Soc. Am.** 151:4252-4263.

Tyack, P.L. and L. Thomas. 2019. Using dose-response functions to improve calculations of the impact of anthropogenic noise. **Aquatic Conserv. Mar. Freshw. Ecosyst.** 29(S1):242-253.

Tyack, P.L. and V.M. Janik. 2013. Effects of noise on acoustic signal production in marine mammals. p. 251-271 In: H. Brumm (ed.), Animal communication and noise. Springer, Berlin, Heidelberg, Germany. 453 p.

van Beest, F.M., J. Teilmann, L. Hermannsen, A. Galatius, L. Mikkelsen, S. Sveegaard, J.D. Balle, R. Dietz, and J. Nabe-Nielsen. 2018. Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. **R. Soc. Open Sci.** 5:170110.

Varghese, H.K., K. Lowell, J. Miksis-Olds, N. DiMarzio, D. Moretti, and L. Mayer. 2021. Spatial analysis of beaked whale foraging during two 12 kHz multibeam echosounder surveys. **Front. Mar. Sci.** 8:654184.

Vigness-Raposa, K.J., R.D. Kenney, M.L. Gonzalez, and P.V. August. 2010. Spatial patterns of humpback whale (*Megaptera novaeangliae*) sightings and survey effort: insight into North Atlantic population structure. **Mar. Mamm. Sci.** 26(1):161-175.

Víkingsson, G.A., T. Gunnlaugsson, and C. Pampoulie. 2010. A proposal to initiate a pre-implementation assessment of sei whales in the Central North Atlantic. Working Pap. SC/62/RMP2. Int. Whal. Comm., Cambridge, U.K. 27 p.

Vilela, R., U. Pena, R. Esteban, and R. Koemans. 2016. Bayesian spatial modeling of cetacean sightings during a seismic acquisition survey. **Mar. Poll. Bull.** 109(1):512-520.

Wade, P.R. and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. Rep. Int. Whal. Comm. 43:477-493.

Walker, J.L., C.W. Potter, and S.A. Macko. 1999. The diets of modern and historic bottlenose dolphin populations reflected through stable isotopes. **Mar. Mamm. Sci.** 15(2):335-350.

Waring, G.T., C.P. Fairfield, C.M. Ruhsam, and M. Sano. 1992. Cetaceans associated with Gulf Stream features off the Northeastern U.S.A. shelf. **ICES C.M.** 1992/N:12.

Waring, G.T., T. Hamazaki, D. Sheehan, G. Wood, and S. Baker. 2001. Characterization of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocephalus*) summer habitat in shelf-edge and deeper waters off the northeast U.S. **Mar. Mamm. Sci.** 17(4):703-717.

Wartzok, D., A.N. Popper, J. Gordon, and J. Merrill. 2004. Factors affecting the responses of marine mammals to acoustic disturbance. **Mar. Technol. Soc. J.** 37(4):6-15.

Weilgart, L. 2017. Din of the deep: noise in the ocean and its impacts on cetaceans. p. 111-124 *In:* A. Butterworth (ed.) Marine mammal welfare human induced change in the marine environment and its impacts on marine mammal welfare. Springer.

Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. **Int. J. Comp. Psychol.** 20:159-168.

Weilgart, L.S. 2014. Are we mitigating underwater noise-producing activities adequately? A comparison of Level A and Level B cetacean takes. Working pap. SC/65b/E07. Int. Whal. Comm., Cambridge, UK. 17 p.

Weinrich, M.T., R.D. Kenney, and P.K. Hamilton. 2000. Right whales (*Eubalaena glacialis*) on Jeffreys Ledge: a habitat of unrecognized importance? **Mar. Mamm. Sci.** 16:326-337.

Weir, C.R. and S.J. Dolman. 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. **J. Int. Wildl. Law Policy** 10(1):1-27.

Weller, D.W., S.H. Rickards, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2006a. The influence of 1997 seismic surveys on the behavior of western gray whales off Sakhalin Island, Russia. Paper SC/58/E4 presented to the IWC Scient. Commit., IWC Annu. Meet., 1-13 June, St. Kitts.

Weller, D.W., G.A. Tsidulko, Y.V. Ivashchenko, A.M. Burdin, and R.L. Brownell, Jr. 2006b. A re-evaluation of the influence of 2001 seismic surveys on western gray whales off Sakhalin Island, Russia. Paper SC/58/E5 presented to the IWC Scient. Commit., IWC Annu. Meet., 1-13 June, St. Kitts.

Weller, D.W., Y.V. Ivashchenko, G.A. Tsidulko, A.M. Burdin, and R.L. Brownell, Jr. 2002. Influence of seismic surveys on western gray whales off Sakhalin Island, Russia in 2001. Paper SC/54/BRG14, IWC, Western Gray Whale Working Group Meet., 22-25 Oct., Ulsan, South Korea. 12 p.

Wells, R.S. and M.D. Scott. 2018. Bottlenose dolphin, *Tursiops truncatus*, common bottlenose dolphin. p. 118-124 In: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd ed. Academic Press/Elsevier, San Diego, CA. 1157 p.

Wensveen, P.J., A.M. von Benda-Beckmann, M.A. Ainslie, F.P.A. Lam, P.H. Kvadsheim, P.L. Tyack, and P.J.O. Miller. 2015. How effectively do horizontal and vertical response strategies of long-finned pilot whales reduce sound exposure from naval sonar? **Mar. Environ. Res.** 106:68-81.

Wensveen, P.J., L.A.E. Huijser, L. Hoek, and R.A. Kastelein. 2014. Equal latency contours and auditory weighting functions for the harbour porpoise (*Phocoena phocoena*). **J. Exp. Biol.** 217(3):359-369.

Wenzel, F., D.K. Mattila, and P.J. Clapham. 1988. *Balaenoptera musculus* in the Gulf of Maine. **Mar. Mamm. Sci.** 4(2):172-175.

Wenzel, F.W., J. Allen, S. Berrow, C.J. Hazevoet, B. Jann, R. E. Seton, L. Steiner, P. Stevick, P. López Suárez, and P. Whooley. 2009. Current knowledge on the distribution and relative abundance of humpback whales (*Megaptera novaeangliae*) off the Cape Verde Islands, eastern North Atlantic. **Aquatic Mamm.** 35(4):502-510.

Westgate, A.J., A.J. Read, T.M. Cox, T.D. Schofield, B.R. Whitaker, and K.E. Anderson. 1998. Monitoring a rehabilitated harbor porpoise using satellite telemetry. **Mar. Mamm. Sci.** 14(3):599-604.

Whitehead, H. 2018. Sperm whale *Physeter macrocephalus*. p. 919-925 *In:* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3rd Edition. Academic Press/Elsevier, San Diego, CA. 1157 p.

Whitt, A.D., K. Dudzinski, and J.R. Laliberté. 2013. North Atlantic right whale distribution and seasonal occurrence in nearshore waters off New Jersey, U.S.A., and implications for management. **Endang. Species Res.** 20:59-69.

Wiley, D.N., C.A. Mayo, E.M. Maloney, and M.J. Moore. 2016. Vessel strike mitigation lessons from direct observations involving two collisions between noncommercial vessels and North Atlantic right whales (*Eubaleana glacialis*). **Mar. Mammal Sci.** 32(4):1501-1509.

Williams, R., E. Ashe, L. Yruretagoyena, N. Mastick, M. Siple, J. Wood, R. Joy, R. Langrock, S. Mews, and E. Finne. 2021. Reducing vessel noise increases foraging in endangered killer whales. **Mar. Poll. Bull.** 173:112976.

Williams, T.M, W.A. Friedl, M.L. Fong, R.M. Yamada, P. Sideivy, and J.E. Haun. 1992. Travel at low energetic cost by swimming and wave-riding bottlenose dolphins. **Nature** 355(6363):821-823.

Williams, T.M., S.B. Blackwell, O. Tervo, E. Garde, M.H.S. Sinding, B. Richter, and M.P. Heide-Jørgensen. 2022. Physiological responses of narwhals to anthropogenic noise: a case study with seismic airguns and vessel traffic in the Arctic. **Funct. Ecol.** 36:2251-2266.

Willis, K.L., J. Christensen-Dalsgaard, D.R. Ketten, and C.E. Carr. 2013. Middle ear cavity morphology is consistent with an aquatic origin for testudines. **PLoS One** 8(1):e54086.

Winn, H.E. and N.E. Reichley. 1985. Humpback whale Megaptera novaeangliae (Borowski, 1781). p. 241-273 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, London, UK. 362 p.

Winn, H.E., C.A. Price, and P.W. Sorensen. 1986. The distributional biology of the right whale (*Eubalaena glacialis*) in the western North Atlantic. **Rep. Int. Whal. Comm. Spec. Iss.** 10:129-138.

Winsor, M.H., L.M. Irvine, and B.R. Mate. 2017. Analysis of the spatial distribution of satellite-tagged sperm whales (*Physeter macrocephalus*) in close proximity to seismic surveys in the Gulf of Mexico. **Aquatic Mamm.** 43(4):439-446.

Wisniewska, D.M., M. Johnson, J. Teilmann, U. Siebert, A. Galatius, R. Dietz, and P.T. Madsen. 2018. High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). **Proc. R. Soc. B** 285:20172314.

Wittekind, D., J. Tougaard, P. Stilz, M. Dähne, K. Lucke, C.W. Clark, S. von Benda-Beckmann, M. Ainslie, and U. Siebert. 2016. Development of a model to assess masking potential for marine mammals by the use of airguns in Antarctic waters. p. 1243-1249 *In:* A.N. Popper and A. Hawkins (eds.) The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Wole, O.G. and E.F. Myade. 2014. Effect of seismic operations on cetacean sightings off-shore Akwa Ibom State, south-south, Nigeria. **Int. J. Biol. Chem. Sci.** 8(4):1570-1580.

Wright, A.J. 2014. Reducing impacts of human ocean noise on cetaceans: knowledge gap analysis and recommendations. 98 p. World Wildlife Fund Global Arctic Programme, Ottawa, ON.

Wright, A.J. and A.M. Consentino. 2015. JNCC guidelines for minimizing the risk of injury and disturbance to marine mammals from seismic surveys: we can do better. **Mar. Poll. Bull.** 100(1):231-239.

Wright, A.J., T. Deak, and E.C.M. Parsons. 2011. Size matters: management of stress responses and chronic stress in beaked whales and other marine mammals may require larger exclusion zones. **Mar. Poll. Bull.** 63(1-4):5-9.

Würsig, B. 2017. Marine mammals of the Gulf of Mexico. Chapter 13 *In:* C.H. Ward (ed.) Habitats and Biota of the Gulf of Mexico: Before the Deepwater Horizon Oil Spill. Volume 2: Fish Resources, Fisheries, Sea Turtles, Avian Resources, Marine Mammals, Diseases and Mortalities. Springer Nature, New York.

Würsig, B., S.K. Lynn, T.A. Jefferson, and K.D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. **Aquatic Mamm.** 24(1):41-50.

Würsig, B., T.A. Jefferson, and D.J. Schmidly. 2000. The marine mammals of the Gulf of Mexico. Texas A&M University Press, College Station, TX. 232 p.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L. Bradford, S.A. Blokhin, and R.L. Brownell, Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July–October 1997. A joint U.S.-Russian scientific investigation. Final Report. Rep. from Texas A&M Univ., College Station, TX, and Kamchatka Inst. Ecol. & Nature Manage., Russian Acad. Sci., Kamchatka, Russia, for Sakhalin Energy Investment Co. Ltd. and Exxon Neftegaz Ltd., Yuzhno-Sakhalinsk, Russia. 101 p.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov, and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. **Environ. Monit. Assessm.** 134(1-3):45-73.

Yazvenko, S. B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, H.R. Melton, and M.W. Newcomer. 2007b. Feeding activity of western gray whales during a seismic survey near Sakhalin Island, Russia. **Environ. Monit. Assessm.** 134(1-3):93-106

Yochem, P.K. and S. Leatherwood. 1985. Blue whale. p. 193-240 In: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, New York, NY. 362 p.

Yoder, J.A. 2002. Declaration of James A. Yoder in opposition to plaintiff's motion for temporary restraining order, 28 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Division.

Zerbini, A.N., A. Andriolo, M.-P. Heide-Jørgensen, S.C. Moreira, J.L. Pizzorno, Y.G. Maia, G.R. VanBlaricom, and D.P. DeMaster. 2011. Migration and summer destinations of humpback whale (*Megaptera novaeangliae*) in the western South Atlantic Ocean. **J. Cetac. Res. Manage.** (Spec. Iss.) 3:113-118.

LIST OF APPENDICES

APPENDIX A: **DETERMINATION OF MITIGATION ZONES**

APPENDIX B: **MARINE MAMMAL TAKE CALCULATIONS**

APPENDIX C: **ENSONIFIED AREAS CALCULATIONS**

APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for Level A and Level B (160 dB re 1µPa$_{rms}$) thresholds. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the 36-airgun array, two 45/105 in^3 GI airguns, and for a single 1900LL 40-in^3 airgun. Models for the 36-airgun array and 40-in^3 airgun used a 12-m tow depth, whereas the model for the two GI airguns used a 3-m tow depth. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

Typically, for deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those GoM sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth for marine mammals of ~2000 m (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep and slope sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model— constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant. The results are summarized below.

In deep and intermediate-water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results for the same array tow depth are in good agreement (Fig. 12 and 14 in Appendix H of the PEIS). Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent (Fig. 11, 12, and 16 in Appendix H of the PEIS). Aside from local topography effects, the region around the critical distance (~5 km in Fig. 11 and 12, and ~4 km in Fig. 16 in Appendix H of the PEIS) is where the observed levels rise closest to the mitigation model curve. However, the observed sound levels are found to fall almost entirely below the mitigation model curve (Fig. 11, 12, and 16 in Appendix H of the PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the GoM calibration survey was appropriate to sample the maximum sound level in the water column, and the field measurements reported in Table 1 of Tolstoy et al. (2009) for the 36-airgun array at a tow depth of 6 m can be used to derive mitigation radii.

The proposed surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m for the 36-airgun array (Fig. A-1). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5,

such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS. No effort would occur in shallow water during the proposed surveys.

Table A-1 shows the distances at which the 160-dB and 175-dB re 1μPa$_{rms}$ sound levels are expected to be received for the 36-airgun array. The 160-dB level is the behavioral disturbance criteria (Level B) that is used by NMFS to estimate anticipated takes for marine mammal. The 175-dB level is used by NMFS, based on data from the DoN (2017), to determine behavioral disturbance for turtles. A recent retrospective analysis of acoustic propagation of R/V *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for R/V *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[3] have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL$_{cum}$ and SPL$_{flat}$, respectively. The new guidance incorporates marine mammal auditory weighting functions (Fig. A-2) and dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). The largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate takes and Level A threshold distances. The dual criteria for sea turtles (DoN 2017) were also used here. The new NMFS guidance did not alter the current threshold, 160 dB re 1μPa$_{rms}$, for Level B harassment (behavior). It should be recognized that there are a number of limitations and uncertainties associated with these injury criteria (Southall et al. 2007). Lucke et al. (2020) caution that some current thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise. Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 2018), but include all marine mammals (including sirenians), and a re-classification of hearing groups.

---

[3] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).
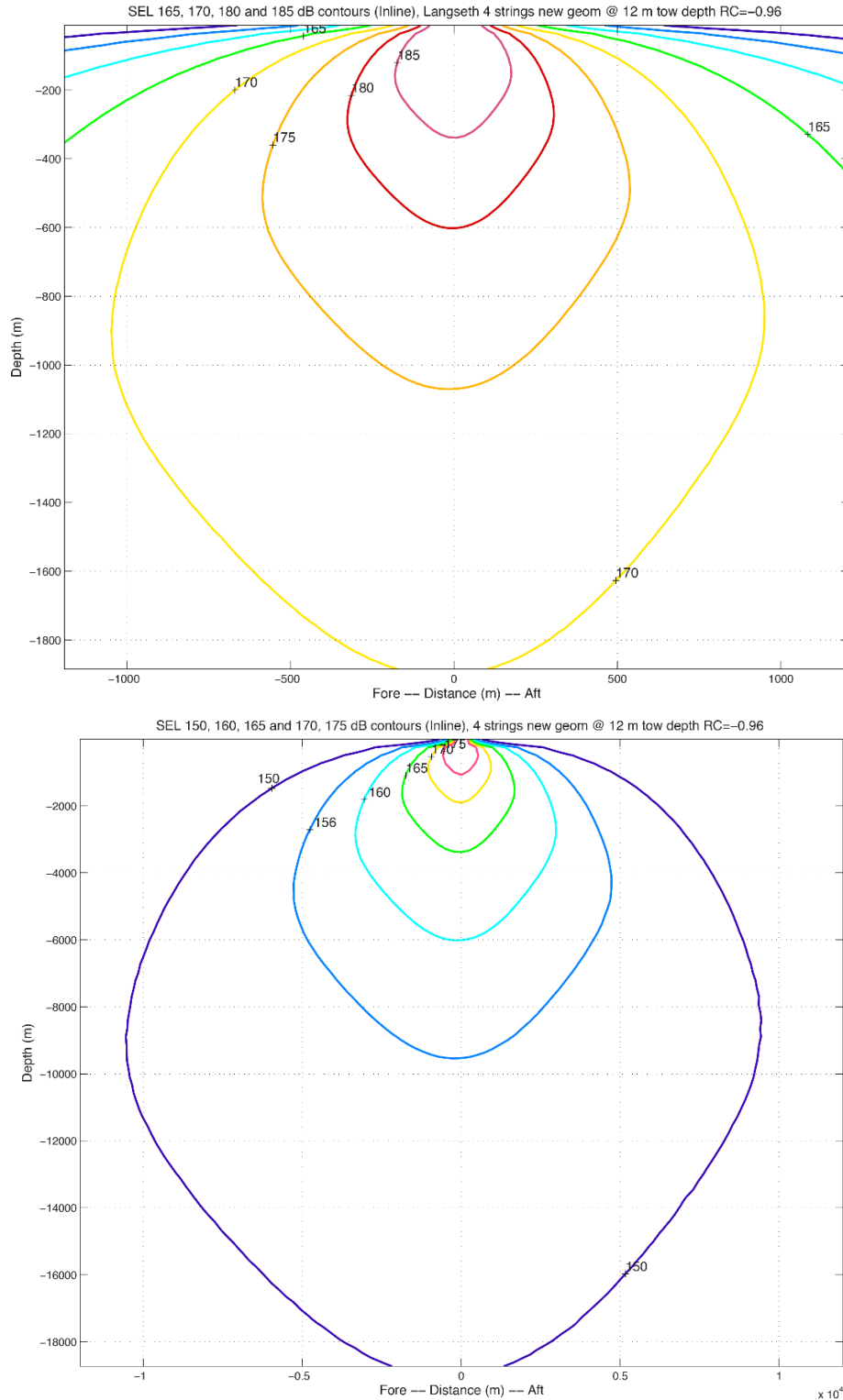
FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed surveys. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

TABLE A-1. Predicted distances to behavioral disturbance sound levels ≥160-dB re 1 µPa_{rms} and ≥175-dB re 1 µPa_{rms} that could be received during the proposed surveys on the Blake Plateau off the southeastern U.S. The 160-dB criterion applies to all hearing groups of marine mammals (Level B harassment), and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth[1] (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
4 strings, 36 airguns, 6600 in³	12	>1000 m	6,733[2]	1,864[2]
		100–1000 m	10,100[3]	2,796[3]

[1] Maximum tow depth was used for conservative distances. [2] Distance is based on L-DEO model results. [3] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.
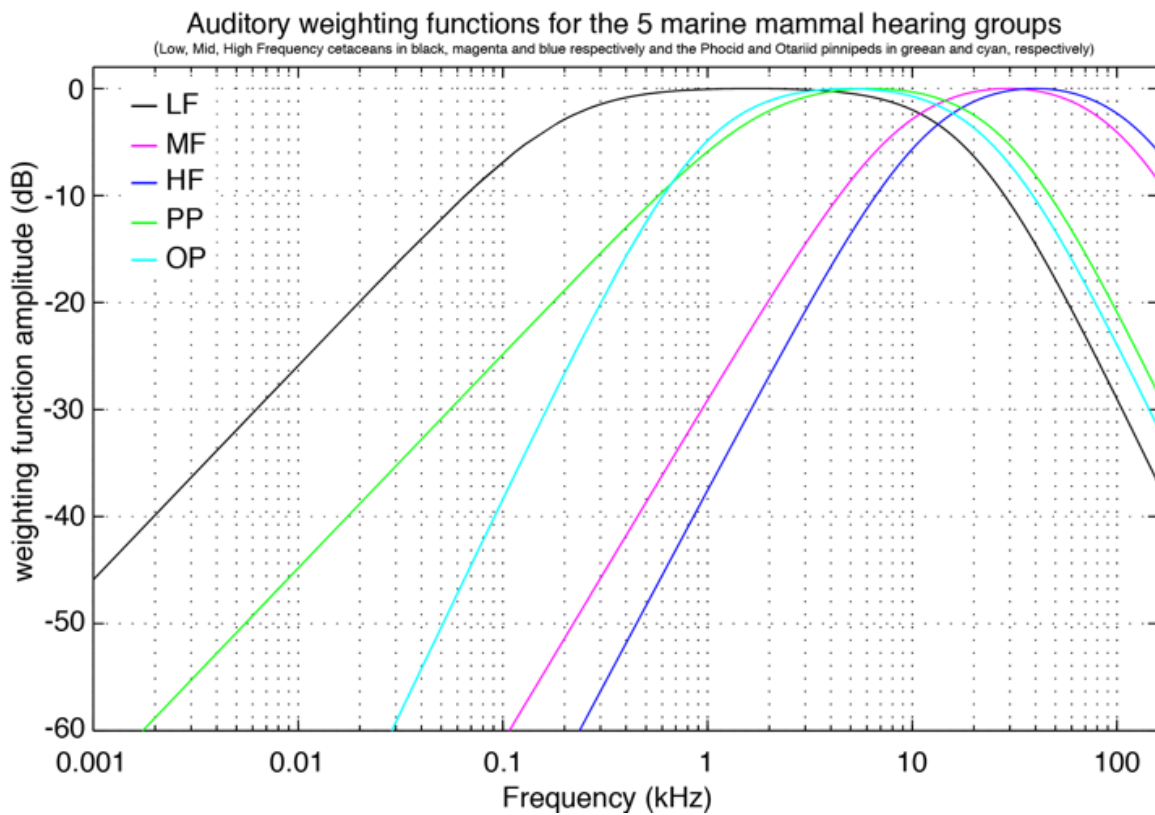

FIGURE A-2. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

The SEL$_{cum}$ for R/V *Langseth* array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature.

The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the farfield signature is not an appropriate measure of the sound source level for large arrays.

To estimate SEL$_{cum}$ and Peak SPL, we used the acoustic modeling developed at L-DEO (same as used for Level B takes) with a small grid step in both the inline and depth directions. The propagation modeling takes into account all airgun interactions at short distances from the source including interactions between subarrays which we do using the NUCLEUS software to estimate the notional signature and the MATLAB software to calculate the pressure signal at each mesh point of a grid.

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL$_{cum}$ isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). A source velocity of 2.16067 m/s and a 1/Repetition rate of 23.1 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL$_{cum}$ PTS thresholds (Level A) for the 36-airgun array.

For the LF cetaceans during operations with the 36-airgun array, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL$_{cum}$ isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor of -12.91 dB assuming a propagation of $20\log_{10}$(Radial distance) (Table A-2).

However, for MF and HF cetaceans, and OW and PW pinnipeds, the modeling for a single shot with the weighted function applied leads to 0-m isopleths; the adjustment factors thus cannot be derived the same way as for LF cetaceans. Hence, for MF and HF cetaceans, and OW and PW pinnipeds, the difference between weighted and unweighted spectral source levels at each frequency up to 3 kHz was integrated to actually calculate these adjustment factors in dB. These calculations also account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014).

TABLE A-2. Results for modified farfield SEL source level modeling for the 36-airgun array with and without applying weighting functions to various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL$_{cum}$ threshold is the largest. A propagation of 20 log$_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL$_{cum}$ Threshold	183	185	155	185	203	204*
Radial Distance (m) (no weighting function)	315.5691	246.4678	8033.2	246.4678	28.4413	25.1030
Modified Farfield SEL	232.9819	232.8352	233.0978	232.8352	232.0790	231.9945
Radial Distance (m) (with weighting function)	71.3752	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.91	N.A.	N.A.	N.A.	N.A.	N.A.

* Sea turtles. N.A. means not applicable or not available.

For the 36-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SEL$_{cum}$, and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-3 shows the impact of weighting functions by hearing group. Figures A-4–A-7 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-8 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.
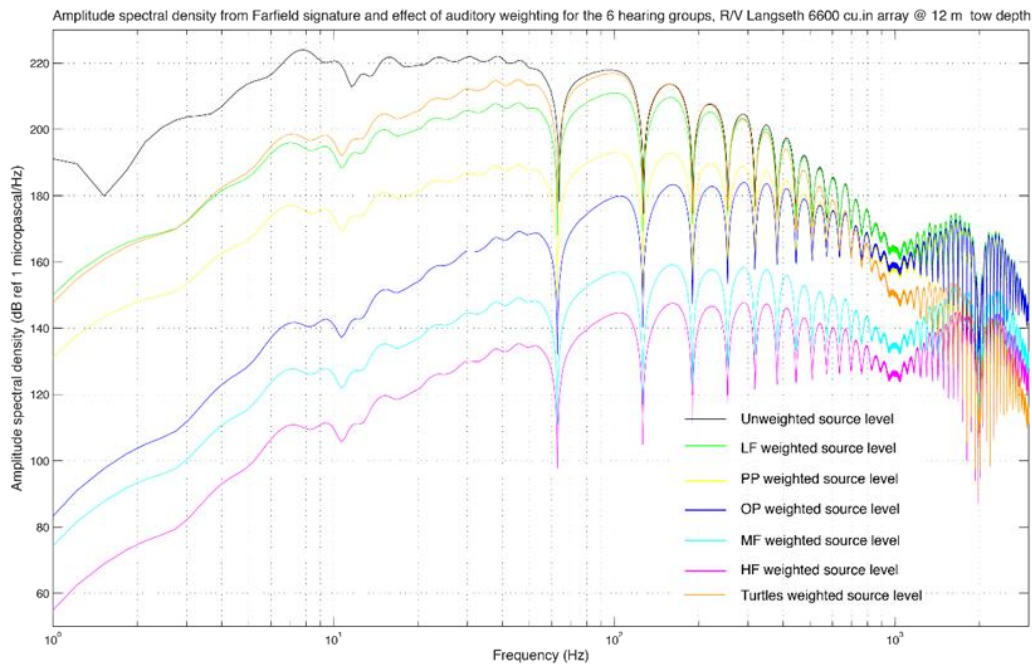
FIGURE A-3. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-3. Results for single shot SEL source level modeling for the 36-airgun array with weighting function calculations for the SEL_cum criteria, as well as resulting isopleths to thresholds for various hearing groups, for the MCS surveys.

STEP 1: GENERAL PROJECT INFORMATION						
PROJECT TITLE						
PROJECT/SOURCE INFORMATION	source: 4 string 36 element 6600 cuin of the R/V Langseth at a 12m towed depth. Shot interval of 50 m. Source velocity of 4.2 knots					
Please include any assumptions						
PROJECT CONTACT						

STEP 2: WEIGHTING FACTOR ADJUSTMENT	Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value					
Weighting Factor Adjustment (kHz)ᵛ	NA					
ᵛ Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab	Override WFA: Using LDEO modeling					
	† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.					

* BROADBAND Source: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)

STEP 3: SOURCE-SPECIFIC INFORMATION
NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in stage boxes for both)   NOTE: LDEO modeling relies on Method F2
F2: ALTERNATIVE METHOD† TO CALCULATE PK and SEL_cum (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)
SEL_cum

Source Velocity (meters/second)	2.16067	4.2 knots
1/Repetition rate^ (seconds)	23.14097016	50m/2.16067

†Methodology assumes propagation of 20 log R; Activity duration (time) independent
^ Time between onset of successive pulses.

Modified farfield SEL	232.9819	232.8352	233.0978	232.8352	232.079	231.9945
Source Factor	8.58635E+21	8.30115E+21	8.81858E+21	8.30115E+21	6.97459E+21	6.84019E+21

RESULTANT ISOPLETHS*   *Impulsive sounds have dual metric thresholds (SEL cum & PK). Metric producing largest isopleth should be used.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters	Sea Turtles
SEL_cum Threshold	183	185	155	185	203	204
PTS SEL_cum Isopleth to threshold (meters)	320.2	0.0	1.0	10.4	0.0	15.4

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters	Sea Turtles
a	1	1.6	1.8	1	2	1.4
b	2	2	2	2	2	2
f₁	0.2	8.8	12	1.9	0.94	0.077
f₂	19	110	140	30	25	0.44
C	0.13	1.2	1.36	0.75	0.64	2.35
Adjustment (dB)†	-12.91	-56.70	-66.07	-25.65	-32.62	-4.11	OVERRIDE Using LDEO Modeling

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log₁₀ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-3).

TABLE A-4. Results for single shot SEL source level modeling for the 36-airgun array with weighting function calculations for the SEL_cum criteria, as well as resulting isopleths to thresholds for various hearing groups, for the OBS surveys.

F: MOBILE SOURCE: Impulsive, Intermittent (SAFE DISTANCE METHODOLOGY)

VERSION 1.1: Aug-16

KEY
	Action Proponent Provided Information
	NMFS Provided Information (Acoustic Guidance)
	Resultant Isopleth

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION Please include any assumptions	source : 4 string 36 element 6600 cu.in of the R/V Langseth at a 12m towed depth. Shot inteval of 200 m. Source velocity of 5.0 knots
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT — Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

Weighting Factor Adjustment (kHz)¥	NA	Override WFA: Using LDEO modeling

¥ Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

* BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both)   NOTE: LDEO modeling relies on Method F2

F2: ALTERNATIVE METHOD† TO CALCULATE PK and SEL_cum (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)

SEL_cum

Source Velocity (meters/second)	2.572	5 knots
1/Repetition rate^ (seconds)	77.76049767	200 m/2.572

†Methodology assumes propagation of 20 log R; Activity duration (time) independent
^Time between onset of successive pulses.

	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters	Sea Turtles
Modified farfield SEL	232.9819	232.8352	233.0978	232.8352	232.079	231.9945
Source Factor	2.55524E+21	2.47036E+21	2.62435E+21	2.47036E+21	2.07559E+21	2.03559E+21

RESULTANT ISOPLETHS*   *Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters	Sea Turtles
SEL_cum Threshold	183	185	155	185	203	204
PTS SEL_cum Isopleth to threshold (meters)	80.0	0.0	0.3	2.6	0.0	3.8

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters	Sea Turtles	
a	1	1.6	1.8	1	2	1.4	
b	2	2	2	2	2	2	
f₁	0.2	8.8	12	1.9	0.94	0.077	
f₂	19	110	140	30	25	0.44	
c	0.13	1.2	1.36	0.75	0.64	2.35	
Adjustment (dB)†	-12.91	-56.70	-66.07	-25.65	-32.62	-4.11	**OVERIDE Using LDEO Modeling**

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log₁₀ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-3).

FIGURE A-4. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial distance).

FIGURE A-5. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).
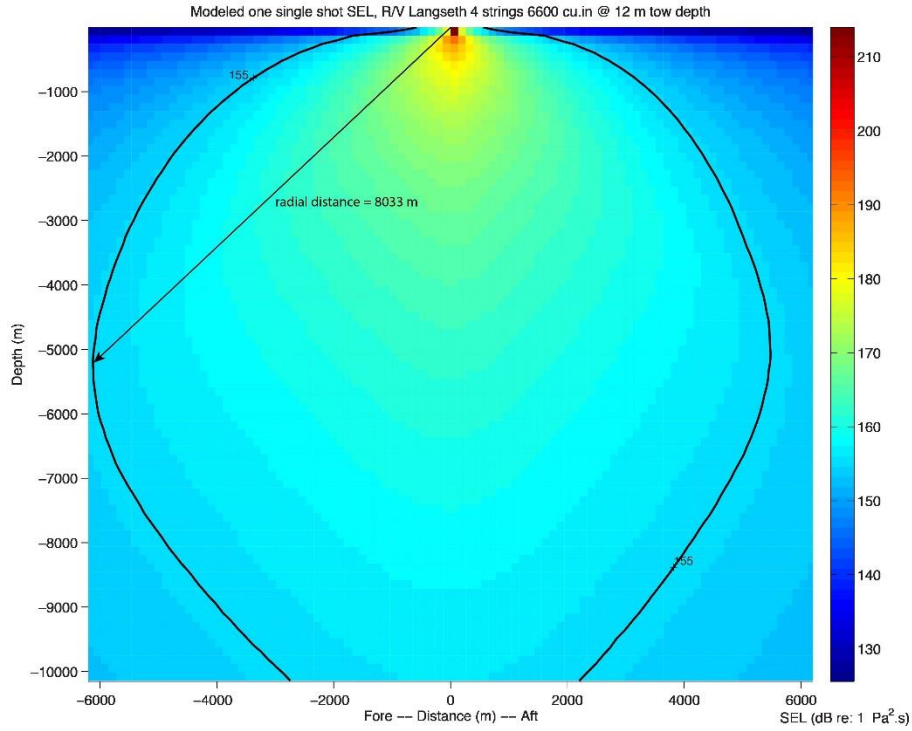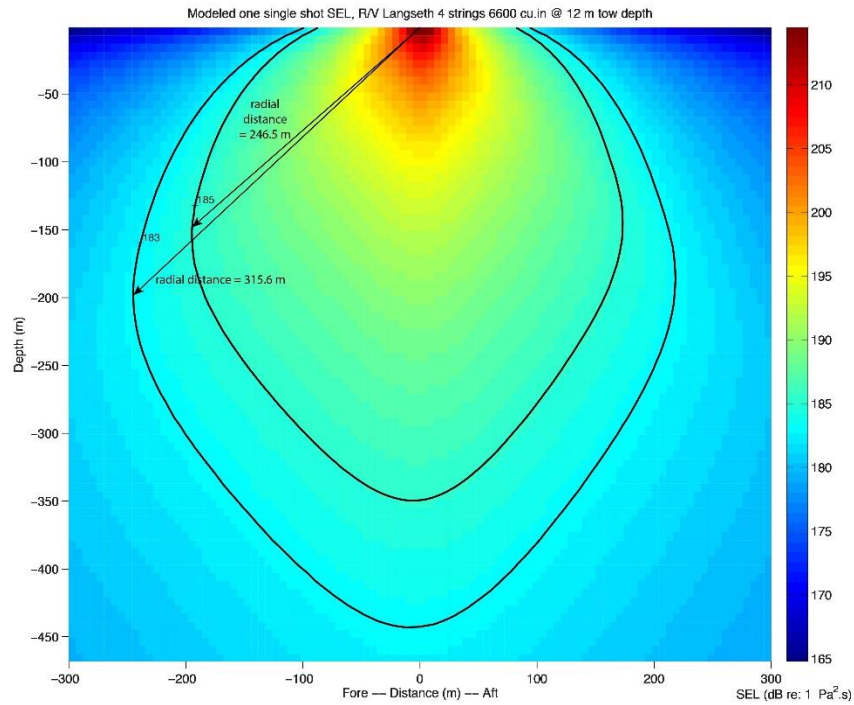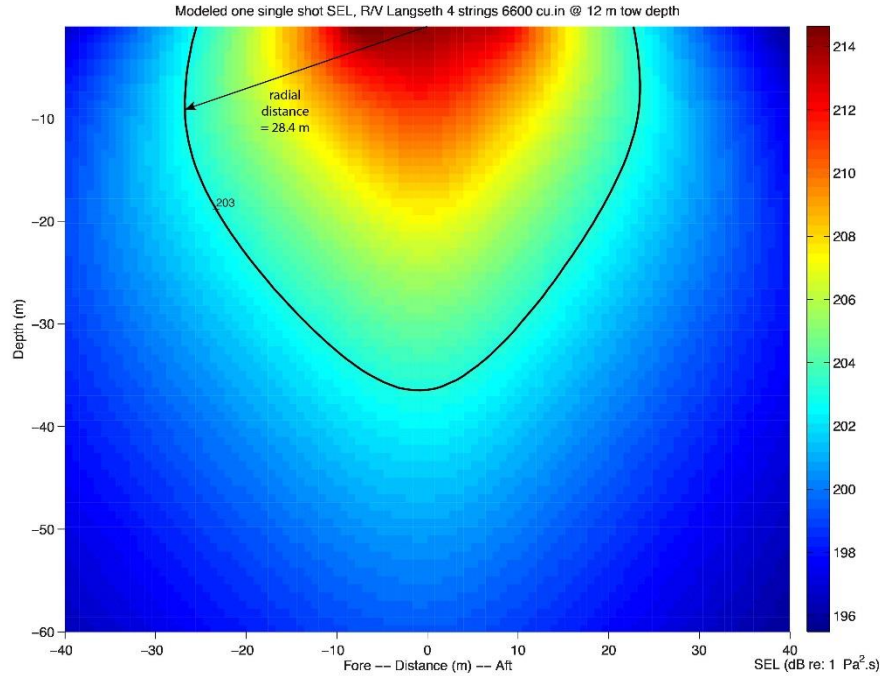
FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth (28.4 m).
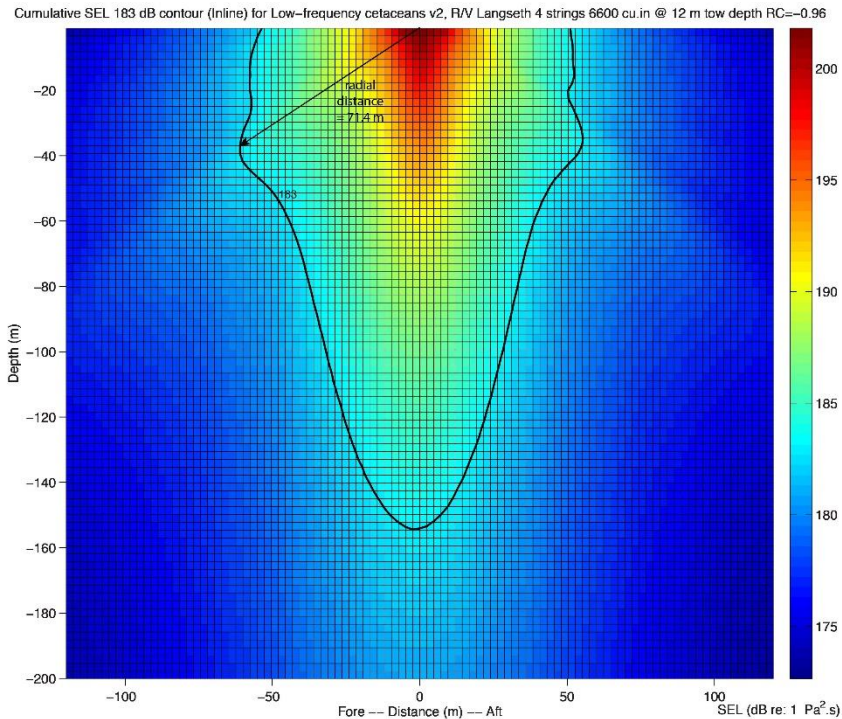
FIGURE A-7. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-5 and this figure (71.4 m) allows us to estimate the adjustment in dB.

The thresholds for Peak SPL$_{flat}$ for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-5. Figures A-8–A-10 show the modeled received sound levels to the Peak SPL$_{flat}$ thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-6.

TABLE A-5. NMFS Level A acoustic thresholds (Peak SPL$_{flat}$) for impulsive sources for marine mammals and sea turtles and predicted distances to Level A thresholds for various hearing groups that could be received from the 36-airgun array during the proposed surveys.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/ Sea Turtles
Peak Threshold	219	230	202	218	232
Radial Distance to Threshold (m)	45.00	13.57	364.67	51.59	10.62
Modified Farfield Peak SPL	252.06	252.65	253.24	252.25	252.52
PTS Peak Isopleth (Radius) to Threshold (m)	38.9	13.6	268.3	43.7	10.6

N.A. means not applicable or not available.

TABLE A-6. Level A threshold distances for different marine mammal hearing groups and sea turtles for the 36-airgun array. Following the guidance by NMFS (2016, 2018), the largest distance (in bold) of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
MCS Surveys						
PTS SEL$_{cum}$	**320.2**	0	1.0	10.4	0	**15.4**
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**	10.6
OBS Surveys						
PTS SEL$_{cum}$	**80.0**	0	0.3	2.6	0	3.8
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**	**10.6**

FIGURE A-8. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

FIGURE A-9. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.
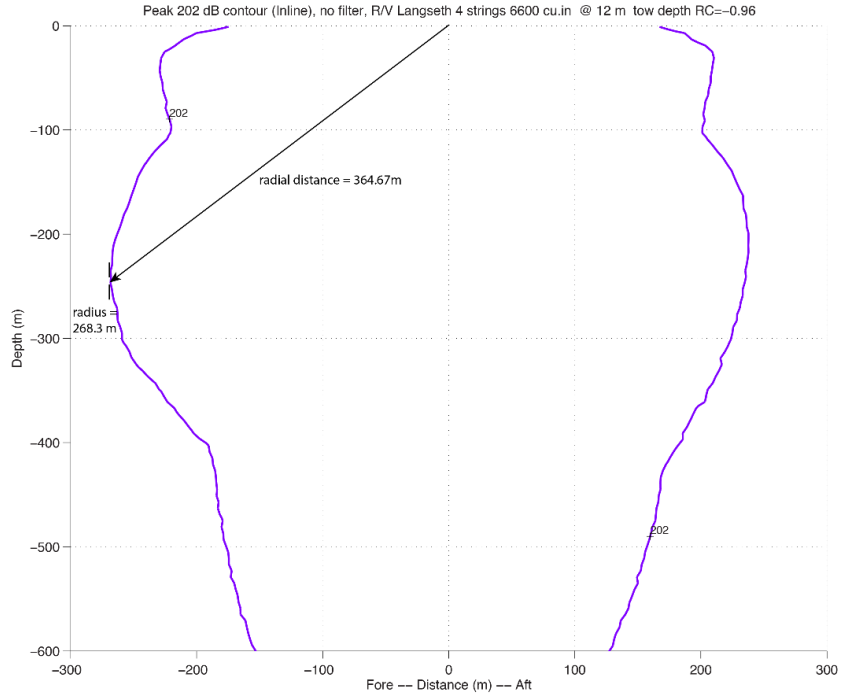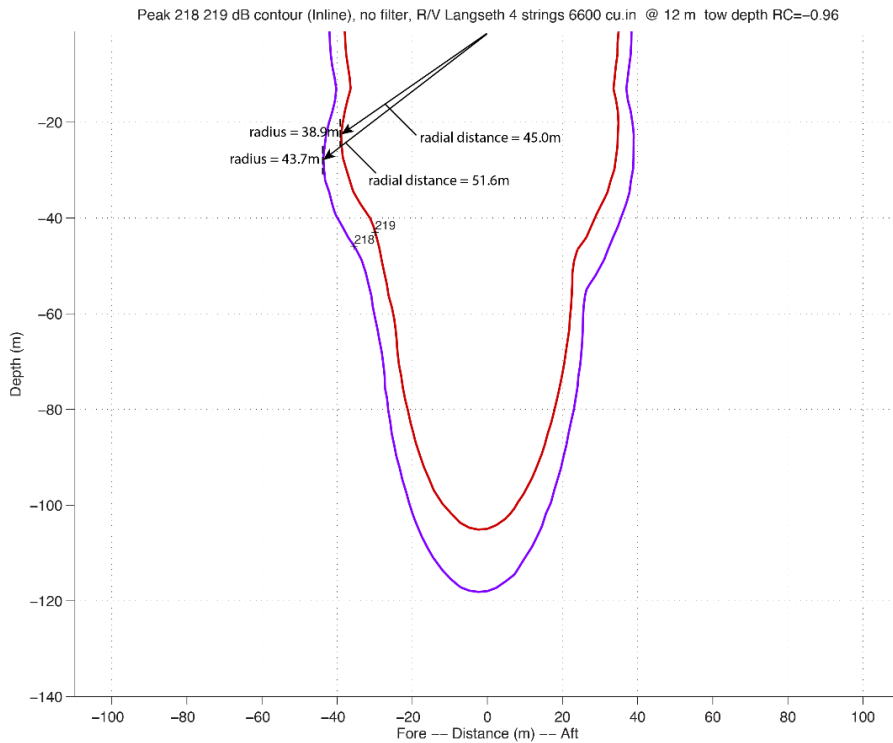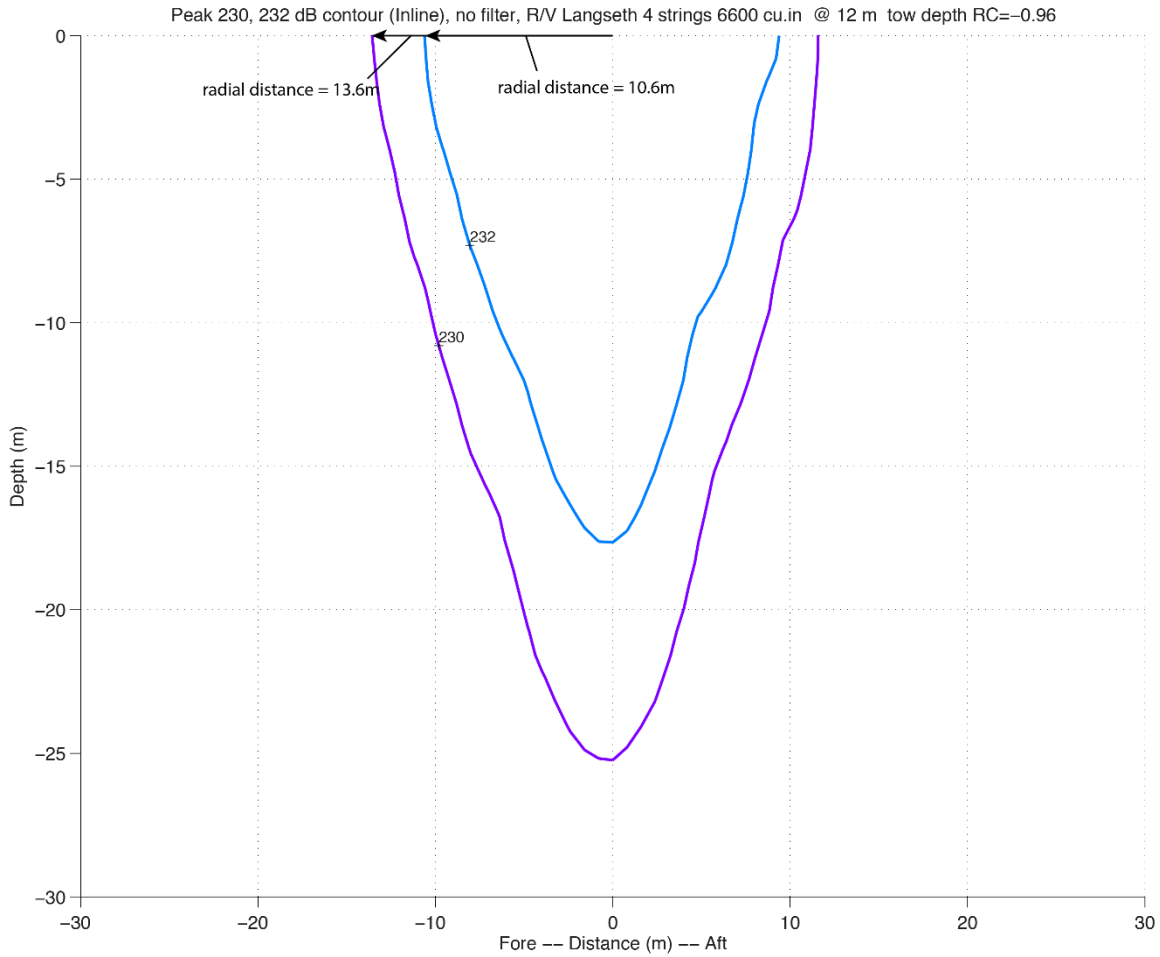
FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

Literature Cited

Barton, P., J. Diebold, and S. Gulick. 2006. Balancing mitigation against impact: a case study from the 2005 Chicxulub seismic survey. **Eos Trans. Amer. Geophys. Union** 87(36), Joint Assembly Suppl., Abstr. OS41A-04. 23–26 May, Balitmore, MD.

Costa, D.P. and T.M. Williams. 1999. Marine mammal energetics. p. 176-217 *In:* J.E. Reynolds III and S.A. Rommel (eds.), Biology of marine mammals. Smithsonian Institution Press, Washington. 578 p.

Crone, T.J., M. Tolstoy, and H. Carton. 2014. Estimating shallow water sound power levels and mitigation radii for the R/V *Marcus G. Langseth* using an 8 km long MCS streamer. **Geochem., Geophys., Geosyst.** 15(10):3793-3807.

Crone, T.J., M. Tolstoy, and H. Carton. 2017. Utilizing the R/V *Marcus G. Langseth*'s streamer to measure the acoustic radiation of its seismic source in the shallow waters of New Jersey's continental shelf. **PloS ONE** 12(8):e0183096. http://doi.org/10.1371/journal.pone.0183096.

Diebold, J.B., M. Tolstoy, P.J. Barton, and S.P. Gulick. 2006. Propagation of exploration seismic sources in shallow water. **Eos Trans. Amer. Geophys. Union** 87(36), Joint Assembly Suppl., Abstr. OS41A-03. 23–26 May, Baltimore, MD.

Diebold, J.B., M. Tolstoy, L. Doermann, S.L. Nooner, S.C. Webb, and T.J. Crone. 2010. R/V *Marcus G. Langseth* seismic source: modeling and calibration. **Geochem. Geophys. Geosyst.** 11(12):Q12012. http://doi.org/10.1029/2010GC003126. 20 p.

DoN (U.S. Department of the Navy). 2017. Criteria and thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical Report prepared by the U.S. Navy.

Lucke, K., S.B. Martin, and R. Racca. 2020. Evaluating the predictive strength of underwater noise exposure criteria for marine mammals. **J. Acoust. Soc. Am.** 147:3985. doi:10.1121/10.0001412.

NMFS. 2016. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: underwater acoustic thresholds for onset of permanent and temporary threshold shifts. U.S. Dept. of Commer., NOAA. 178 p.

NMFS. 2018. 2018 revision to: technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (version 2.0). Underwater thresholds for onset of permanent and temporary threshold shifts. Office of Protected Resources Nat. Mar. Fish. Serv., Silver Spring, MD. 167 p.

Sivle, L.D., P.H., Kvadsheim, and M.A. Ainslie. 2014. Potential for population-level disturbance by active sonar in herring. **ICES J. Mar. Sci.** 72:558-567.

Southall, B.L., J.J. Finneran, C. Reichmuth, P.E. Nachtigall, D.R. Ketten, A.E. Bowles, W.T. Ellison, D.P. Nowacek, and P.L. Tyack. 2019. Marine mammal noise exposure criteria: updated scientific recommendations for residual hearing effects. **Aquatic Mamm.** 45(4):411-522.

Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohenstiehl, T.J. Crone, and R.C. Holmes. 2009. Broadband calibration of R/V *Marcus G. Langseth* four-string seismic sources. **Geochem. Geophys. Geosyst.** 10:Q08011. https//doi.org/10.1029/2009GC002451.

APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

Level A and Level B takes were determined for the seismic surveys; the detailed take calculations are shown in Table B-1. The ensonified areas that were used to calculate Level A and B takes are provided in Appendix C.

TABLE B-1. Take estimates for the proposed surveys at the Blake Plateau, Northwest Atlantic Ocean.

Species	Estimated Density (#/km²) Intermediate 100-1000 m	Deep >1000 m	Population Size North Atlantic[1]	Hearing Group	Level B Ensonified Area (km²) Intermediate 100-1000 m	Deep >1000 m	Level A Ensonified Area (km²)	Level B Takes Intermediate 100-1000 m	Deep >1000 m	Only Level B Takes minus Level A	Level A Takes	% of NA Pop. (Total Takes)	Requested Level A+B Take Authorization[2]
LF Cetaceans													
Night Atlantic right whale	0.0000006	0.0000002	368	LF	111,169	62,693	7,621	0	0	0	0	0	0
Bryde's whale	N.A.	N.A.	N.A.	LF	111,169	62,693	7,621	N.A.	N.A.	N.A.	N.A.	N.A.	**2**
Humpback whale	0.0000009	0.0000002	1,396	LF	111,169	62,693	7,621	0	0	0	0	0.21	**3**
Minke whale	0.0000965	0.0001776	21,968	LF	111,169	62,693	7,621	11	11	21	1	0.10	22
Fin whale	0.0000266	0.0000271	6,802	LF	111,169	62,693	7,621	3	2	5	0	0.07	5
Sei whale	0.0001681	0.0001753	6,292	LF	111,169	62,693	7,621	19	11	29	1	0.47	30
Blue whale	0.0000115	0.0000124	402	LF	111,169	62,693	7,621	1	1	2	0	0.51	2
MF Cetaceans													
Sperm whale	0.0013001	0.0090562	4,349	MF	111,169	62,693	549	145	568	707	5	16.38	712
Cuvier's beaked whale	0.0000953	0.0056729	5,744	MF	111,169	62,693	549	11	356	363	3	6.38	366
Beaked whales	0.0001318	0.0022294	10,107	MF	111,169	62,693	549	15	140	153	1	1.53	154
Blaineville's beaked whale	N.A.	N.A.	N.A.	MF	111,169	62,693	549	N.A.	N.A.	51	0	N.A.	51
Gervais' beaked whale	N.A.	N.A.	N.A.	MF	111,169	62,693	549	N.A.	N.A.	51	1	N.A.	52
True's beaked whale	N.A.	N.A.	N.A.	MF	111,169	62,693	549	N.A.	N.A.	51	0	N.A.	51
Risso's dolphin	0.0109262	0.0010384	35,215	MF	111,169	62,693	549	1,215	65	1,279	1	3.63	1,280
Rough-toothed dolphin	0.0016741	0.0018725	N.A.	MF	111,169	62,693	549	186	117	302	1	N.A.	303
Bottenose dolphin	0.0328258	0.0128819	62,851	MF	111,169	62,693	549	3,649	808	4,450	7	7.09	4,457
Pantropical spotted dolphin	0.0023233	0.0026089	6,593	MF	111,169	62,693	549	258	164	421	1	6.40	422
Atlantic spotted dolphin	0.0072551	0.0154221	39,921	MF	111,169	62,693	549	807	967	1,765	8	4.44	1,773
Spinner dolphin	0.0008544	0.0008658	4,102	MF	111,169	62,693	549	95	54	149	0	3.64	149
Striped dolphin	9.580E-10	4.200E-08	67,036	MF	111,169	62,693	549	0	0	0	0	0.09	**60**
Clymene dolphin	3.270E-08	1.430E-09	4,237	MF	111,169	62,693	549	0	0	0	0	1.04	**44**
Fraser's dolphin	0.0013009	0.0013183	N.A.	MF	111,169	62,693	549	145	83	226	1	N.A.	227
Common dolphin	0.0008332	0.0014130	172,974	MF	111,169	62,693	549	93	89	180	1	0.10	181
Pilot whales	0.0089973	0.0069079	28,924	MF	111,169	62,693	549	1,000	433	1,429	4	4.96	1,433
Short-finned pilot whales	N.A.	N.A.	N.A.	MF	111,169	62,693	549	N.A.	N.A.	1,143	4	N.A.	1,147
Long-finned pilot whales	N.A.	N.A.	N.A.	MF	111,169	62,693	549	N.A.	N.A.	286	0	N.A.	286
Killer whale	0.0000315	0.0000319	N.A.	MF	111,169	62,693	549	4	2	6	0	N.A.	**7**
False killer whale	0.0000233	0.0000236	1,791	MF	111,169	62,693	549	3	1	4	0	0.67	**12**
Pgymy killer whale	0.0001168	0.0001183	N.A.	MF	111,169	62,693	549	13	7	20	0	N.A.	20
Melon-headed whale	0.0012219	0.0012382	N.A.	MF	111,169	62,693	549	136	78	212	1	N.A.	213
HF Cetaceans													
Kogia spp.	0.0008602	0.0088538	7,750	HF	111,169	62,693	10,862	96	555	555	96	8.40	651
Dwarf sperm whale	N.A.	N.A.	N.A.	HF	111,169	62,693	10,862	N.A.	N.A.	277	48	N.A.	325
Pygmy sperm whale	N.A.	N.A.	N.A.	HF	111,169	62,693	10,862	N.A.	N.A.	278	48	N.A.	326
Harbor porpoise	0.0000002	0.0000001	95,543	HF	111,169	62,693	10,862	0.0221	0.0071	0	0	0	**2**

N.A. means not available or not applicable. [1] Most population sizes from Hayes et al. (2022); for a detailed list of sources, see Table 5. [2] Requested take authorization is Level A plus Level B calculated takes unless indicated in bold. Bold takes have been increased to mean group size from Palka (2020); when group size was not available from Palka (2020), takes in bold and italics were increased to mean group size from Maze-Foley and Mullin (2006).

APPENDIX C: ENSONIFIED AREA CALCULATIONS

APPENDIX C: ENSONIFIED AREA CALCULATIONS

The ensonified areas that were used to calculate Level A and B takes for the proposed surveys at Blake Plateau, Northwest Atlantic Ocean.

TABLE C-1. Areas expected to ensonified during the proposed surveys.

	Survey Zone	Criterion	Daily Ensonified Area (km²)	Total Survey Days	25% Increase	Total Ensonified Area (km²)	Relevant Isopleth (m)
Marine Mammals							
MCS	Int 100-1000 m	160 dB	2296.3	32	1.25	91852.1	10,100
MCS	Deep >1000 m	160 dB	1097.5	32	1.25	43900.8	6,733
OBS	Int 100-1000 m	160 dB	1931.7	8	1.25	19316.9	10,100
OBS	Deep >1000 m	160 dB	1879.2	8	1.25	18792.2	6,733
	Overall	**160 dB**	**7204.7**	**40**	**1.25**	**173862.0**	
Sea Turtles							
MCS	Int 100-1000 m	175 dB	604.0	32	1.25	24158.1	2,796
MCS	Deep >1000 m	175 dB	289.5	32	1.25	11578.3	1,864
OBS	Int 100-1000 m	175 dB	503.0	8	1.25	5030.2	2,796
OBS	Deep >1000 m	175 dB	505.9	8	1.25	5058.7	1,864
	Overall	**160 dB**	**893.4**	**40**	**1.25**	**45825.2**	
Hearing Groups							
MCS	All zones	LF Cetacean	116.9	40	1.25	5843.7	320.2
MCS	All zones	MF Cetacean	5.0	40	1.25	247.5	13.6
MCS	All zones	HF Cetacean	97.9	40	1.25	4894.4	268.3
MCS	All zones	Sea Turtle	5.6	40	1.25	280.3	15.4
OBS	All zones	LF Cetacean	35.5	40	1.25	1777.0	80.0
OBS	All zones	MF Cetacean	6.0	40	1.25	301.9	13.6
OBS	All zones	HF Cetacean	119.4	40	1.25	5967.6	268.3
OBS	All zones	Sea Turtle	4.7	40	1.25	235.3	10.6

Note: Ensonified areas are adjusted for overlap and include endcaps.